AIC 2012 TAIPEI
Color & Environment
In Color We Live

Can you imagine a world without colors? The physical and psychological effects of colors contribute to a satisfying and joyful way of life, far beyond aesthetic pleasure, in both natural and man-made environments. Color as an interface connects us with our surrounding environment, and color differentiates the things we need not only to survive, but to indulge in life and to appreciate it.
The aim of the conference is to explore how colors interact with our daily life, to approach the conscious and unconscious influence color may have on individual thought and perception, and how we can identify and apply colors from a healthier and more sustainable perspective. Seven fields of discussion have been selected for discussion: Color and Environment, Color Culture, Art and Design, Color Communication, Color Synesthesia and Visionary Projects, Color Science and Technology, Color Psychology, and Color Education.

"In Color We Live - Color and Enviroment" hopes to emphasize the importance of a colorful environment for a sustainable and healthy way of life, by addressing both individual and basic human needs, and by giving examples drawn from all aspects of life.

www.aic2012.org
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Color & Environment
In Color We Live

Conference Proceedings   AIC 2012   In Color We Live: Color and Environment

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In Color We Live: Color and Environment

In Color We Live: Color and Environment

Interim Meeting of the
International Colour Association (AIC)
22-25 September 2012 Taipei, Taiwan

Conference Proceedings

Editors: Tien- Rien LEE, James SHYU

中華色彩學會
Color Association of Taiwan

AIC
International Colour Association
Internationale Vereinigung für die Farbe
Association Internationale de la Couleur

AIC 2012 Interim Meeting of the International Colour Association (AIC)

In Color We Live: Color and Environment

Conference Proceedings

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PROCEEDINGS

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The Conference Proceedings contain the full papers of the technical program cited in the cover and title page of this volume. They reflect the author's opinions and are published as presented.

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AIC President's Message

It is with great pleasure that AIC is coming to Taipei, especially since it is the first time that Color Association of Taiwan is holding an AIC Meeting. It was three years ago we got your application to become a regular member and you have been a member since the end of 2009. Almost immediately after joining AIC, Color Association of Taiwan enthusiastically invited AIC to their country for a meeting in 2012. So this is really an occasion for celebrating.

This is the 39th AIC meeting since the first meeting was held, 43 years ago, in Stockholm. We can see an increased interest in the AIC meetings the last years and the number of delegates at this meeting is round 250! At this meeting we are also very proud to announce the winner of the AIC Logo Competition for the International Colour Day March 21st. We hope that all of you will have color activities in your country all over the world in the same colorful day.

Now we are looking forward to three coming days of this AIC meeting with the theme, "In Color We Live: Color and Environment" and it is about understanding the effects of colors in natural and man-made environments which contributes to create healthier living spheres through color applications. In this theme we will listen to the importance of color and commonly raised questions like: What effect does the color of a room have on the people in it? How are we affected by colors? Few things influence us as much as color and few things engage and interest people as much as color. Color plays an essential role in our environment.

I would like to thank especially Professor Tien-Rien Lee, the chair of Color Association of Taiwan and his team and the Chinese Culture University for the great organization of this meeting. I also would like to thank the members of the international scientific committee who reviewed 244 abstracts which has resulted in 45 oral presentations and 115 poster presentations..

After the very successful and memorable meeting in Zürich, Switzerland we are now working on the coming meetings. Next year's meeting will be the 12th AIC Congress which will take place in Newcastle, Great Britain, July 8-12. AIC Interim Meeting 2014 "Colors, Culture and Identity: Past, Present and Future" will be in Oaxaca, Mexico, October 29 – November 1. The AIC Midterm Meeting 2015 "Color and Image" will be in Tokyo, Japan in May. 2016 is still open. The 13th AIC Congress will be held in Jeju, Korea October 16-20, 2017.

I am sure that the members of the organizing committee have done their best to ensure that this meeting will work out under the best possible conditions, that the proceedings will be interesting and that it will be exciting to learn about the latest developments under the theme of , "In Color We Live: Color and Environment". I am sure there will be many memorable moments and fruitful meetings to remember in the coming years. In Taiwan - the beautiful island with towering mountains and beautiful coastal scenes.

Berit Bergström, AIC President
Stockholm, August 2012

AIC, International Colour Association

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AIC

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AIC 2012 Chair's Preface

Since the official hand-over of the AIC banner from the Swiss color organization pro/colore to the CAT delegation of Taiwan in Zurich 2011, an ambitious program under the conference theme 'In Color We Live – Color and Environment' has been created with a total of 244 abstracts submitted. The final program lists four keynote lectures, 45 oral papers, and 115 posters to be presented to an expected audience of more than 200 international color experts from 27 countries, offering participants the opportunity to discuss latest color trends and developments during the three conference days from Sep. 23-25, 2012. We have included many additional highlights for you like a Chinese music concert, dance performance, and a top-level banquet in one of the world's highest restaurants in the Taipei 101 tower.

I would like to thank the members of the AIC 2012 International Scientific Committee for reviewing the submissions: their professional commitment has been an indispensable contribution to the efforts of the AIC 2012 Organizing Committee, and helped shaping the program to become the solid foundation for the whole exciting conference.

The AIC 2012 venue is at Chinese Culture University, including a color market on site. The conference is going to be broadcasted by internet life streaming; and social media are used for delivering the message of the event to an even broader international audience via cell phone apps and a facebook presence, as well as by a range of colorful souvenirs. Besides, AIC 2012 offers pre-conference excursions to four different destinations around Taipei and along the north coast, covering visits to the Taipei Museum of Modern Arts and the National Palace Museum, and two after-conference trips to Yang-Ming-Shan and to Taroko Gorge National Park near the east coast city of Hua-lien.

I would like to extend my deep thankfulness to our sponsors, all experts and participants for their valuable contribution and commitment, which has made possible the AIC 2012 Interim Meeting to become a fascinating color event. We hope you will enjoy the warm hospitality of the people in Taiwan, the natural heritage and cultural peculiarities of this beautiful land - Formosa.

We are very grateful to have the chance of receiving you, and hope you will indulge in exploring our colorful world as much as possible!

I wish you all a most inspiring conference, and a most joyful stay in Taiwan!

Tien-Rein Lee

Prof. Dr. Tien-Rein LEE
AIC 2012 General Conference Chair

In Color We Live: Color and Environment

Conference Topics

Under the theme "In Color We Live: Color and Environment" AIC 2012, Taipei, provides a platform for experts from the research, business, and artistic color industries. The conference invites to engage in future-oriented exchange and to build and intensify networks in different fields of interest from both theoretical and practical points of view. By investigating terms and concepts related to color as an interface of perception, nature, and man-made environments, the AIC 2012 Interim Meeting offers to explore color in its individual perception, interior and exterior contexts, by different terminologies and methodologies, and last not least, in its applications for industrial and everyday products.
The AIC 2012 Interim Meeting aims to inspire and encourage the scientific dialogue, and to meet the challenges of future color research and development, by emphasizing the importance of the environment and our daily interactions with color.

Conference Topics and Sub-Topics

Submissions were accepted for consideration in any of the topics mentioned below.

A. Color and Environment:
Nature, lighting, interior architecture, exterior architecture, landscaping & horticulture, urban design & planning.

B. Color Culture, Art and Design:
Aesthetics, history, philosophy, transportation, food, medical & personal care, warning systems, fashion design, performance, painting, sculpture and installations, ceramics & glass, jewellery and metalwork, art conservation.

C. Color Communication:
Interpretations, color codes & symbols, semiotics, visual communication & design, color naming & language, color categorization, color order systems.

D. Color Synesthesia and Visionary Projects
visual models, color physics, color chemistry, image reproduction, color management system, high dynamic range imaging, multispectral imaging, computational photography, multimedia in color imaging, 3D color imaging, virtual reality (VR) and augmented reality (AR), display and printing, colorimetry, industry applications.

E. Color Psychology:
color perception, color preference, physiology & psychophysics, light & color interaction, color vision and aging, vision illusions and effects, defective color vision.

F. Color Science and Technology:
Visual models, color physics & color chemistry, image reproduction, color management system, high dynamic range imaging, multispectral imaging, computational photography, multimedia in color imaging, 3D color imaging, virtual reality (VR) and augmented reality (AR), display and printing, colorimetry, industry applications.

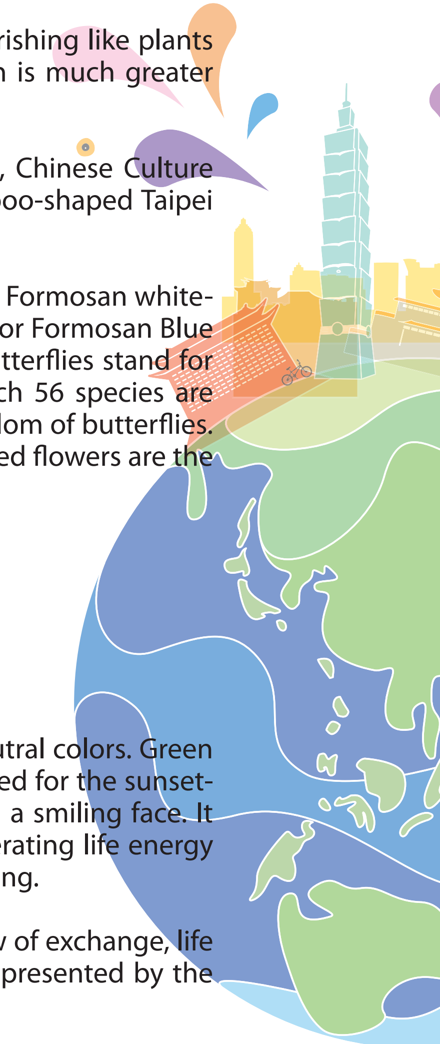
G. Color Education:
Pedagogy, terminology, methodology, electronic media applications, teaching aids.

AIC 2012 in Taipei – Welcome to our Colorful World

The conference topic "In Color We Live – Color and Environment" is represented by the many natural and cultural symbols of Taipei and Taiwan, embedded in the world of colors like the island is situated between the Eurasian Continent and the Pacific Ocean:

Earth is placed between the water and a multitude of colorful shapes flourishing like plants and towering like mountains, resembling the abundance of nature, which is much greater than all shapes that can be created by humans.

A closer look at the picture reveals the skyline of the venue of AIC 2012, Chinese Culture University, and the Grand Hotel nearby. Rising up high into the sky, bamboo-shaped Taipei 101 Tower reaches out like modern society for the future to come.



Taiwan's opulent fauna and flora is indicated by its endemic species like the Formosan white-throated black bear, the Formosan landlocked salmon, the Taiwan Magpie (or Formosan Blue Magpie), and the Formosan Sika deer. Besides, the Taipei Tree Frog and butterflies stand for the peculiarities of Taipei and Taiwan: with 377 recorded species, of which 56 species are reportedly endemic to the island, Taiwan is well-known as the world's kingdom of butterflies. A species of the Orchidaceae family is the Taiwan Pleione. Commonly beloved flowers are the Azalea and the Mexican Aster.

We warmly welcome to enjoy our colorful world: Welcome to Taipei!

The AIC 2012 Logo

The logo is composed of primary colors of the Component Theory, and neutral colors. Green and blue also stand for mountains and the sea, yellow for the sunrise and red for the sunset-natural colors of the environment. The shape resembles a hand-shake and a smiling face. It also stands for the Tai Chi symbol, rotating actively and continuously generating life energy ("Chi"). Its irregular shape is both harmonically balanced and endlessly moving.

The logo stands for the connected world we live in: through a constant flow of exchange, life comes into being, following the natural energies of creation and decay, represented by the two basic principles of the cosmic Tao - Yin and Yang in a colorful way.

"In Color We Live" stands for the colorful meanings of our lives – for our personal color preferences as well as for our daily living environment, the man-made as well as natural surroundings. The five colors of the Chinese Five-Elements-Theory – green-blue, red, yellow, white and black – accompany and guide us through the changes of day and night and the seasons for our entire lifespan long.

When East meets West we recognize each other by the similarities and differences that make everyone so special. Hands are shaken in a gesture of friendship and mutual collaboration, for the future research and well-being, and the prospering of color studies around the world.

Chinese Culture University (CCU)

Chinese Culture University (CCU) is one of the most reputable and the largest private universities in the Republic of China. Surrounded by the beautiful mountain nature resort of Yang-Ming-Shan and with a magnificent view over Taipei city, the main campus provides its students, faculty, and visitors with a peaceful and convenient environment for research and academic growth. CCU has a branch campus in Taipei city. Its School of Continuing Education (SCE), is the largest and the most successful in Taiwan, with branches throughout the island. Formerly known as Far-Eastern University, CCU is a private, comprehensive university fully accredited by the Ministry of Education of the Republic of China (ROC) since 1962. It was founded by Dr. Chang Chi-Yun, the former Minister of Education of ROC, and named by the late ROC President, Chiang, Kai-shek. Over five decades, CCU has grown to become one of the best and the largest universities in Taiwan, with more than 80 sister universities worldwide. Since its establishment, CCU carries the mission of preserving the essence of Chinese culture, language, philosophy, and values. Also, CCU places special emphasis on international learning, international exchanges, and foreign languages to prepare students for the increasing demands, challenges, and competition of the international market, ensuring their success in the era of globalization. CCU presently consists of 12 Colleges, with 59 undergraduate departments, 40 master and 11 doctorate institutes. SCE has 10 departments and 11 graduate institutes, offering various courses, professional trainings, and degree programs for students of all ages.

Hsiao Feng Library

The university's library - Hsiao Feng Library - was built in memory of the CCU founder, Dr. Chang Chi-Yun, alias Mr. Hsiao-Feng, and opened on March 1, 1999 in celebration of the university's 37th Anniversary. It is one of the best libraries in Taiwan, storing more than one million books, a rich collection of periodicals, video, tapes, CDs and special archives. It runs an automated electronic service system, and includes an exhibition area, study rooms, and a multi-media service center.

Hwa Kang Museum

Established in 1971, the University Museum (Hwa Kang Museum) was the first comprehensive museum of its kind in Taiwan. Its permanent collection covers Chinese ceramics made during different historical periods, more than 4,000 master pieces of Chinese calligraphic works and paintings, and a great variety of Chinese folk artifacts and woodblock prints. It maintains the Ou Hao-Nian Art Center, and a special room for displaying precious CCU historical documents and archives. The museum encourages artists in the neighboring community to interact with art works exhibitions.

Da-Xiao Arena

The newly completed CCU gymnasium is one of the most outstanding in Asia: The 14-floor building offers state-of-the-art facilities for all kinds of physical education including golf, baseball trainings, billiards, dance studio, table tennis, athletic recovery rooms, gymnastic training room, Taekwondo practice room, a swimming pool and Spas for men and for women. The building includes an administrative part and rooms for official events.

Color Association of Taiwan (CAT)
中華色彩學會

The National Taiwan Color Association was founded in 2001, and officially named "Color Association of Taiwan (CAT)" on 21 July 2001, during its annual General Assembly. Among the founders of CAT were the color research experts Tien-Rein Lee, Lu-Yin Juan, Shin-Chuan Yao, Ming-Ching Shyu, Chun-Yen Chen, Lin-Lin Chen, Wen-Guey Kuo, Chung-Yi Chang, Shing Sheng Guan, Tsao-hung Wei, and others.

The Color Association of Taiwan (CAT) aims to:

1. integrate color-related knowledge in Taiwan in order to cultivate the expertise and understanding of color in the fields of science and arts.

2. form study groups to explore new territories of color studies and applications to enrich color utilization and education.

3. link with the international color communities, to develop advanced collaborations and cross-cultural research.

CAT's activities cover a broad range of color-related fields, both industrial and academic, with a strong foothold in business. Since 2010, CAT has become a member of the International Color Association (AIC). This is a big milestone in the Association's history, marking its entry to the international stage. CAT has become one of the most active members, with our delegations attending the worldwide AIC conferences every year. We are very grateful for this opportunity to build up more intense networking and collaboration on an international scale.

In responding to the rapid changes of the Age of the Digital Sciences, CAT offers some of the few platforms promoting color science and related arts in Taiwan to become a more and more differentiated field of study; ranging from fine arts, design, ecology, architecture, optics, and printing up to psychology and more. To date, 12 congresses have taken place, introducing color research to a broader audience, and facilitating exchange between international color experts. CAT conducts its General Assembly and the International Scientific Color Symposium on Color Design and Application on an annual basis, including lectures and discussion forums, and publishing the Symposium proceedings. Besides, irregular meetings and workshops on special topics are organized with invited international color experts. Furthermore, CAT is involved in promoting color knowledge together with other Asian color organizations, forming a strong-tied Asian Color network, and strives to actively expand cooperation with global partners.

In 2012, CAT holds its 13th congress together with the AIC 2012 Interim Meeting in Taipei. We highly welcome this wonderful opportunity to make friends with many more color experts from all over the world! By shaping this international conference into a multifaceted platform, we hope and encourage the color research communities, artists and industries to engage in a most intense and fruitful exchange, and to inspire color studies through globalization, interdisciplinary collaboration, and the spirit of innovation.

In this Age of the Digital Sciences, CAT strives to evoke the attention from various fields of research, business and arts, to realize the importance of colors, and to collaborate for a better understanding of our commonly shared, colorful world.

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Haisong Xu	*China*
Pietro Zennaro	*Italy*
Peter Zolliker	*Switzerland*

Keynote lectures, Oral papers

in order of presentation

AIC 2012 TAIPEI

Prof. Steven SHEVELL

Steven Shevell is the E. H. Moore Distinguished Service Professor at the University of Chicago, in Psychology, Ophthalmology & Visual Science, and Computational Neuroscience. He received an undergraduate degree in psychology and an M.S. in engineering from Stanford University; and an M.A. in statistics and Ph.D. in mathematical psychology from the University of Michigan. He was the founding associate editor of the Journal of Vision, a former senior editor of Vision Research, and the editor of the Optical Society of America's most recent edition ofT he Science of Color. He is a past-president of the Vision Sciences Society, and currently serves on the board of directors of the International Colour Vision Society.

9/23 Sunday
9:40 -10:20

Principles of color vision revealed by spatial complexity

Prof. Steven K. SHEVELL
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Abstract

Chromatic background fields reveal fundamental aspects of color vision. Increment-detection thresholds as well as color appearance vary systematically with the wavelength of a uniform background. Quantitative modeling of these shifts has advanced color theory for more than a century. Uniform backgrounds, however, are rare in the natural world where, instead, the background typically is a mosaic of many different chromatic lights in view simultaneously. Recent studies show that chromatic variation within a background – spatial complexity – unveils basic neural processes of color vision that cannot be detected with a uniform background.

The spatial complexity of a background is an elementary property of a scene but often overlooked. The minimum number of different background colors required for spatial complexity is two, and experiments show that two different chromaticities within a patterned chromatic background are sufficient to cause large shifts in color appearance. Importantly, theses shifts are larger than those caused by a uniform background at either of the two chromaticities presented alone. Furthermore, the spatial frequency of the patterned chromatic background is a critical determinant of the background's effect on color, revealing a neural mechanism that depends on center-surround receptive-field organization. In addition, interocular transfer – that is, the color shift in a light presented to one eye caused by a spatially complex background seen by only the other eye – reveals that the color changes from spatial complexity are mediated by a cortical neural mechanism. A cortical mechanism is consistent also with the highly selective loss of chromatic sensitivity caused by a spatially complex background composed of colors restricted to a particular direction in color space (Webster et. al, Journal of Vision, 2002). Finally, chromatic spatial complexity also reveals that perception of three-dimensional shape can affect color appearance and, reciprocally, chromatic patterns within a scene can alter perceived three-dimensional shape. In sum, chromatic spatial complexity is a critical feature of a scene that contributes to both color perception and to the influence of chromatic neural signals on percepts other than color.

Prof. Tien-Rein LEE

Prof. Dr. Tien-Rein Lee was President of the Chinese Culture University (CCU) from 2003-2009. He was Chairman of the Department of Graphic Communications, Dean of the College of Journalism Communications, Dean of the Center for Information and Communications, and Dean of General Affairs at CCU. Prof. Dr. Lee is now teaching Visual Communication, Color Communication and Communication Technology at the Department of Information Communications of Chinese Culture University. One focus of his current research interest is color application in Chinese culture. Prof. Dr. Lee is now President of the Color Association of Taiwan (CAT), President of the Chinese Culture University's Alumni Association, and President of the Chinese Association for Life-long Learning (CALL).

9/23 Sunday
11:00 -11:40

Color in traditional Chinese culture - Practical applications based on the Five Elements Theory

Tien-Rein LEE
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Abstract

Color has played an important role in Chinese culture since its early beginnings, as can be traced by the Theory of the Five Elements (also called phases, essences or stages). This early and very influential doctrine of ancient China is deeply rooted in Chinese culture, based on the concept of the harmonious relations and interactions of the three spheres of heaven, earth and humans, and merging the wisdom and life experience of former generations with traditional color application in daily life.

The color concept builds on five basic colors, each one being associated with one of the five elements identified by Chinese philosophy: blue/green-wood, red-fire, yellow-earth, white-metal, and black-water. Every element connotes to certain life qualities and natural phenomena, such as the directions, the seasons, life factors and many more: wood–east, spring, birth; fire-south, summer, growth; earth-central, late summer, ripening; metal-west, fall, decay; and water-north, winter, death. By closely watching their environment, people associated natural phenomena and their colors with potential influences on their daily lives. Besides, the identified five elements were thought of as an interconnected and interdependent system driven by a core mechanism of mutual exchange explained as "the constructive and the destructive rules", determining the way of how people were to choose colors of favorable effects on their daily life. The Theory of the Five Elements and color representing the natural life forces became an indispensable part of a natural and dynamic concept that served for people's survival and constant improvement of their life standards, even becoming influential on a person's fate, similar to fortune-telling. This article introduces how the Chinese people used colors since ancient times. It explores how much color application based on the doctrine of the Five Elements is still alive, by presenting examples of practical use. Following an explanation of the underlying philosophical thought and key terms, Chinese daily color use is shown by selected fields of applications like nutrition, medicine, architecture, design, administration, and military. It is perfectly worth discussing if methods of modern sciences can prove this dynamic color theory, to re-assess the preserved insights, and maybe discover beneficial knowledge and rules for people's lives which might help to make our lives more comfortable and happier.

Prof. Axel VENN

Axel Venn studied at the famous Folkwangschule für Gestaltung in Essen, Germany, Design and Arts. Since 1983 Axel Venn has his own studio. He works all over Europe and partly world wide as a design strategy- and colour-consultant and research scientist. He works among design innovations for RAL, ICI, Beiersdorf, Du Pont, Dunlop, Lambert, Siemens, WMF, St. Gobain, GlaxoSmithKline, Hornbach, Brillux etc. and some international fairs. He is Kurator of the Deutsches Farbenzentrum e.V., Berlin, and member of the trend panel of Mood, Bruxelles, and other trend circles. He is Professor em. for Colour-Design and Trendscouting at the University of Applied Sciences and Arts, HAWK, Hildesheim, Germany. Axel Venn is well-known for the seminars and lectures, in NewYork, Atlanta, London, Vienna, Cologne, Bruxelles, Paris, Moscow, Prague, Beijing, Shanghai, Nice, Colorado Springs, Taipei etc. He published hundreds of articles and more than sixteen books, translated in twelve languages, about colour-science, design, trend and marketing. He lives and works in the city of Berlin.

Color and the Future – upcoming new color trends

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Abstract

Weariness about the current „Zeitgeist“ (spirit of the time) builds the foundations for new trends.The upcoming new is future-oriented and in all cultures more important than the old. Philosophy aims at tomorrow, psychology looks for the past. Trends always use archetypes of the past. The concurrent modern is therefore „genetically“ continuing the unmodern: trends follow a genealogically pre-determined trace. The talent to recognize future trends depends on endless curiosity, the seemingly endless ability to memorize experiences, and the subtle, perceptive skills of a Sherlock Holmes. Colors are the most articulate signals for upcoming new trends, and colors provide meaning and philosophy to things. Color trends add to the perception of a positive life style. There will be three main new trends for the next two years to come: the appeal for aesthetics, for design, and for emotions. These three appeals will influence the eight most important trend themes of the years 2013 and 2014, covering life-style, fashion, and products. There will be 6 main colors identified for each trend with three main colors and three additional colors for greater effects. Each trend will be introduced in its capacity of trend intensity and duration. Trend themes will mention classical and modern aspects of lifestyle, explain the importance of the play of light and shadow, and also relate to patterns and materials. A great influence of colors on personal comfort can be found in designs, like strict or flowery surroundings transferring messages of simplicity or freshness, and similar effects. Nature has its place within the upcoming favourite living worlds, carrying its abundant forms and flavours into people’s homes. Colors of nature combine with modern habits of pleasure and convenience, adding to individual life quality and personal well-being. The indications for the new trends on the horizon promise to bring surprising, exciting, and fascinating new color worlds.

Prof. Monica C. KUO

Prof. Monica Kuo is the Chair of the Digital Earth Research Center at Chinese Culture University (CCU), Taipei. She was the Dean of the College of Environmental Planning & Design of CCU and Member of the Urban Design Review Committee of the Taipei City Government, Taiwan, R.O.C., as well as a Member of the Urban Planning Commission and the Regional Planning Commission Ministry of Interior, Taiwan, R.O.C. Besides, she was President of the Chinese Landscape Architecture Society in Taiwan, Chair of the Department of Landscape Architecture at CCU, and Chair of the Environmental Committee at Zonta International. Prof. Kuo has presided as Chairman in international congresses concerned with landscape architecture, and has received several government awards for her commitment.

9/25 Tuesday
9:20 -10:00

Formosa Taiwan's natural color expression

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Abstract

Taiwan, situated in the north hemisphere and embraced by the Tropic of Cancer, exhibits a great diversity of geographical climates. From sea level to the highest mountain, Taiwan's topography reaches 4000 meters, giving home to a splendidly rich ecosystem in which landscapes such as tropical strand forest and temperate tundra prosper. Taiwan's ecological diversity also results in broad array of natural and cultural landscapes.

From the perspective of natural geography, this article presents Taiwan's landscape characteristics as viewed in different geographical climate zones. One major point will be addressing the quality of Taiwan's environmental color throughout four seasons. As Taiwan was traditionally called "Formosa," such a naming also displays its abundant biodiversity and landscapes.

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The Urban and Rural Environment – Scaling Outdoor Scenes

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ABSTRACT

Providing a rewarding and stimulating environment for residents and visitors is an aim of forward looking city councils. For this a specification of our sensory perceptions of the areas involved is essential. Interactions with a scene can be described in terms of perceptions of the scene physical properties, and the expectations and impacts produced. It will be possible to use imaging methods for quantification of many of the elements involved and it will also be possible to feed into the model physically measured variables, such as traffic speeds, population density and town lighting specifications.

INTRODUCTION

In many cities there has been a rise in civic pride through the wish to develop a sustainable environment. These may be characterised by economic and social growth according to nature's ability to sustain that growth ecologically. However, visitors are important to the life and advancement of many cities and development plans must consider them. The commercial case is simple. Visitors are attracted for one reason or another to the city. The money spent attracts businesses which pay local taxes to finance city infrastructure and improve visitor facilities. Hence, the scene as perceived by the viewer should be considered in planning designed to deliver on to the next generation an area in a better and a more appealing condition than we ourselves inherited. To do this a successful protocol for describing urban and rural scenes is essential.

In this paper we suggest a protocol for scaling the outdoor environment using standard methodology of total appearance. This follows on from the successful application of such principles to indoor environments (Hutchings 2003, Hutchings et al 2010). Although outdoor scenes are more complex it is possible to describe perceptions of it in equally rigorous terms. The outdoor scene consists of physical properties and the psychophysical and psychological responses they initiate. Our interactions with an outdoor scene can be considered in terms of four scalable elements. Many factors will be quantifiable digitally and effects of actual physical data, determined by digital and visual imaging, such as traffic speed and town lighting factors can be built into the developed model.

1. CITY COLOUR AND APPEARANCE PLANNING MODEL

A model for an active city appearance dynamic is shown in Figure 1. It is divided into four stages. In stage 1, the city and its environment consists of physical properties (e.g. buildings and roads), which when viewed, create in the individual subject basic perceptions (stage 2) through a psychophysical model. There are five basic perceptions: visual structure, colour, gloss, surface texture and translucency. These, through a psychological model, form the basis of our derived perceptions (stage 3) which include our expectations of the space. Finally, we can complete a full quantification of any outdoor space via its impact and psychological effects (stage 4). This in turn will give councils a powerful tool for manipulating and designing the city space to maximise visitor attraction and appreciation in a sustainable way. Derived perceptions and impact can be predetermined by the city council or general public as the special features to represent the city in question.

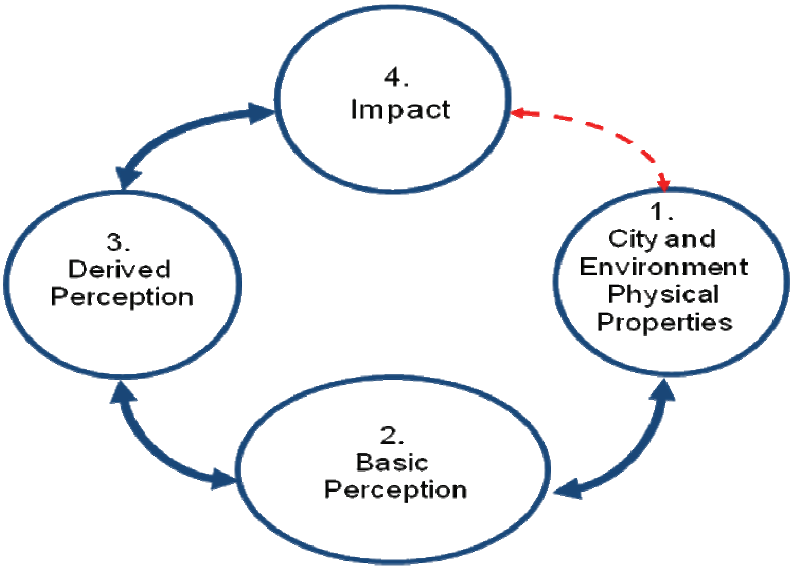

Figure 1. City colour and appearance planning - a model for constructive, qualitative and quantitative city planning

All senses are involved in the appreciation of an environment, and many city streets are noted, for example, for particular aromas and sounds, and the sense of touch occurs when we are in contact with others or when rain falls. These senses are vital to our complete understanding of the scene, but most of what we know about it arises from the visual sense on which this paper is concentrated.

This paper is divided into three sections – environment physical properties, our expectations of the environment, and the environment impact.

2. PERCEPTIONS OF THE PHYSICAL PROPERTIES OF THE SCENE

The city environment consists of two groups of physical properties, the static environment and added features such as the illumination and human beings.

2.1 The static urban environment

An urban environment may include constructions related to industrial manufacture and offices, domestic, social or religious buildings, routes through, such as roads and walkways, trees and street furniture. The presence of such elements can be specified in terms of perceived proportions of, for example, built up area to natural materials to routes. Estimated proportions of building type, for example, manufacture to offices to domestic dwellings to religious and social buildings, also to proportions of buildings that face front and back, of building types that are active or passive. The scene has a design complexity and individual architectural elements possess design quality and life cycle.

Colours overall and accents can be scaled in terms of hue, colourfulness and lightness. Scales can be devised for building age types, building decorative complexity and quality, and surface texture variation. In addition there is a horizon and skyline. Perceptions of this can be scaled in terms of general subtended angle and proportion of the skyline filled, and its proximity. Accents, as well as colour include building type, for example, industrial or social, the angle subtended by the accent and its perceived domination of the scene in general. Routes through scene can be scaled in terms of proportions of roads, paved and unpaved pedestrian and water routes as well as their proportion to the total scene. Natural material may be present in terms of proportion and diversity, for example greenery or flowering or fruiting. Street furniture, scaled in terms of density, includes electricity and illumination supply furniture, as well as road signs.

2.2 Features added to the static environment

Features added to the static permanent environment include illumination, colour, human beings, weather and reversible additions such as litter. Illumination quality can be scaled in terms proportions of area illuminated with natural and artificial light, and in terms of intensity, quality, and evenness and pattern of distribution. Overall perceptions of colour of added features and accents, such as street art, can be scaled. Temporary added decoration can be scaled in terms of complexity and age. There are two types of dirt and litter, reversible and irreversible. Human beings are perceived in terms of numbers, sex, ages and proportions and presentation. Atmosphere is perceived in terms of feelings of temperature, humidity, rainfall, air movement, of wetness underfoot, ice, snow and visibility. There is also pedestrian, mechanical and animal movement within the scene.

3. BASIC AND DERIVED PERCEPTIONS

Basic perceptions, listed above, stage 2, are associated with each physical element in the scene, which manifest themselves in the viewer in terms of derived perceptions, stage 3.

In stage 3, derived perceptions include expectations, that is, what we expect of the scene. These can be expressed in terms of five headings.

- visually assessed safety, e.g. “I feel safe walking through this town centre.”
- visually assessed identification, e.g. “This is a vibrant, historical environment.”
- visually assessed usefulness, e.g. “I will find the shops I need here.”
- visually assessed pleasantness, e.g. “I feel happy walking here in this environmentally friendly area.”
- visually assessed satisfaction of the expected outcome of our involvement with the scene, e.g. “I will have had a good day in this welcoming city.”

For specific applications we can scale for specific expectations, such as degrees of perceived sophistication, historicity, intimacy or sustainability.

4. VISUAL AND PSYCHOLOGICAL IMPACTS

Stages 2 and 3 result in visual and psychological impacts, stage 4 of the planning model. Visual impact can be summarised in terms of a model comprising degrees of warm to cool and hard to soft. This is based on the colour image scale which summarises colour impact effects (Kobayashi 1998) but can equally well be used for other visually perceived properties (Hutchings et al 2012). For example, for town centres the model can be used to express scene impacts from, for example, the design elements, materials, lighting, and human behaviour. Colour impact can also be expressed in terms of colour zone model descriptors (Green-Armytage 2002).

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Scenes produce psychological effects and may lead to different degrees of happiness, or of being in control, these provide leads to total appearance design. For example, anxiety arises from feelings of uncertainty and powerlessness. So, design and lighting can reduce uncertainty and in the UK sight of a policeman reduces feelings of powerlessness.

END NOTE

A powerful tool for the city planners is encompassed within the methodology outlined in this paper. This methodology leads to a description of, for example, a town centre, in terms of the expectations, impact and psychological effects on the inhabitant and the visitor. Visual scaling and associated instrumental and imaging techniques provide potent tools for increasing understanding of the environment. For example, the very powerful effects of colour and colour distribution in the city centre can be summarised using image mosaic techniques (Hiraki et al 2008).

REFERENCES

Green-Armytage, P. 2002. Colour zones, explanatory diagram, colour names, and modifying adjectives, Proc Ninth AIC Congress, 2001 Rochester, editors Robert Chung, Allan Rodrigues. Washington: SPIE The International Society for Optical Engineering, 976-979.

Hutchings, J.B. 2003. *Expectations and the food industry - the impact of color and appearance.* New York: Kluwer/Plenum Publishers.

Hutchings, J.B, M.R Luo, Li-Chen Ou. 2012. Quantification of scene appearance—A valid design tool? Color Research and Application, volume 36 (1): 4-12.

Yoshinao Hiraki, Y, S. Sakai, T. Sato, T. Ishida, A. Hansuebsai. 2008. Colour/place association: measuring place-correlation in Kyoto and Bangkok cityscapes through mosaic images. AIC Interim Meeting, Stockholm, paper no 167.

Kobayashi, S. 1998. *Colorist, a practical handbook for personal and professional use*, translated by Keiichi Ogata, Leza Lowitz. Tokyo: Kodansha International.

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oral paper

Chromatic mutations in suburban areas

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ABSTRACT

Urban sprawl produces hybrid territories, neither urban nor rural, which superimpose to old structures or extend them, hence creating very complex visual environments. Quite strikingly suburbanisation, which has been taking place over several decades, has also generated areas characterized by specific chromatic palettes, breaking radically away from usual palettes of traditional cities. The important chromatic mutations occurring in suburban areas have not yet attracted much scientific interest. Therefore, the main purpose of this paper is to describe emerging chromatic palettes that can be observed in suburban areas so as to show how new colour arrangements, largely designed along market demand and offer, change our daily environment which influences consumers and residents behaviours. Two specific types of suburban areas will be investigated: "franchised" commercial zones and periurban housing districts.

1. INTRODUCTION: NEW COLOURS OF URBAN SPRAWL

> Urban sprawl is commonly used to describe physically expanding urban areas. (…) Sprawl is the leading edge of urban growth and implies little planning control of land subdivision. Development is patchy, scattered and strung out, with a tendency for discontinuity. It leap-frogs over areas, leaving agricultural enclaves. (European Environment Agency 2006: 6)

Individual motorisation shaped the city during the last century: from a compact configuration, the city developed a diffuse and informal aspect, not clearly limited. Automobile dependence became a feature in those suburban zones: the use of an automobile became not so much a choice but a necessity (Newman et al. 1999). Urban sprawl produces hybrid territories, neither urban nor rural, which superimpose to old structures or extend them, hence creating very complex visual environments. The process of sprawl concerns a large part of the territory and continues to grow at an unprecedented rate.

Starting with the hypothesis that each historical architectural epoch has its own chromatic ranges and that the city is 'chromatically polynuclear' (Garcia-Codoner et al. 2009), the main purpose of this paper is to highlight the emerging colour palettes which reveal the urban mutations over several decades. In spite of these profound changes, the description of structures and forms in suburban areas are rather deficient (Mangin 2004). In the same way, the important chromatic mutations occurring in these zones have not yet attracted much scientific interest. Most existing publications focus on the colour of historic cities, in search for heritage values and collective identities expressed by traditional colours.

Two specific types of suburban areas will be investigated: "franchised" commercial zones and periurban housing districts. Both zones meet specific planning logics, deeply inspired from the American model, in which new colour arrangements, largely designed along market demand and offer, change our daily environment which influences consumers and residents behaviours.

Figures 1-2. "Franchised" commercial zone and periurban housing district (Liège, Belgium).

2. "FRANCHISED" COMMERCIAL ZONES

Making its first appearance in the US, the commercial zone model (including shopping centers and entertainment areas) is located outside the city and connected to the road network. It is characterized by these basic requirements: accessibility, land availability and visibility. Commercial zones grow along highways and near interchanges, allowing dual access, on one hand for deliveries and on the other hand for customers with cars (Fellmann et al. 1997). The main purpose is definitely to encourage consumption and the use of coloured devices therefore finds its *raison d'être* in the commercial competition: each franchise has to be more present, more readable to attract the consumers.

There are two kinds of commercial buildings. Most of them can be considered as "decorated sheds", according to Robert Venturi (Venturi et al. 2007). They appear as disordered volumes, with low variety of forms and covered with garish colours, separated from each other with parkings (Gibout 1997). In some other cases, saturated colours cover the entire building: the outer shell representing the brand and reciprocally the brand being identified by the façade. They are symbols just as Venturi's "duck" building.

The common denominator of commercial zones is an apparent profusion of signs with over-saturated colours, breaking radically away from usual palettes of traditional cities where a monochromatic trend can be observed (Nguyen et al. 2011). Such colour patterns have an impact on the automobile visual kinetic; in spite of the obvious mess, colour plays a part in space memorization. Inspired from the world of comics and advertising, the colour patterns are being used to confer some form of visual identity to places and buildings. These are identifiable at large distance, because these colour codes are engraved in the consumer's memory (due to media hype) as a kind of "alerts", so that he is able to recognise reassuring consumption habits.

3. PERIURBAN HOUSING DISTRICTS

The individual house symbolizes the dream of home ownership. In these peripheral zones, life is idealized: more security, quieter, closer to nature, a "small city" or "village" atmosphere (Mancebo 2007). Periurban housing districts appear as enclosed areas that break away from the context (the extreme forms being identified as gated communities), but are not absolutely isolated from work and commercial facilities, the car having made it possible to keep the connection. They have largely been idealized in advertising, movies and American TV shows.

Chromatic palettes of housing districts are basically the results of sociocultural and economic factors. Developers often use the same local picturesque palette of colours based on pastel shades (yellowish or reddish) with little variation. Scenic and popular values, which can be associated with the post-modern theory, are reflected in housing districts, to attract the largest number of potential residents. In this way, it is not surprising that the rise of post-modernism in the 70's and 80's corresponds to the period of development of these "pavilion" areas.

> The postmodern reaction of the 1970s and 1980s brought about a host of architects concerned with the references to history and to the environment, and color in architecture also acquired a new meaning under these orientations. (Caivano 2006: 357)
> Then in the eighties, under the rise of post-modernism, colour became suddenly suspect. Post-modernism wanted to dignify the world with real materials – granite, travertine, marble – only beige or a purplish colour like brick were considered as 'classy' and sufficiently mature. (Koolhaas 1999: 14)

Many housing settlements are hence characterized by uniform chromatic palettes, even though the periurban model would somehow address a quest for more individuality. This illustrates the existing contradiction between the demand formally expressed by inhabitants and the resulting visual environment as provided by the market (Mangin 2004).

4. TOWARD A GENERALIZED CHROMATIC PALETTE

The process of urban sprawl and the chromatic mutations which accompany this phenomenon are not expected to be reverted in a short time frame. This evolution affects all parts of the territories in which new spatial configurations infiltrate, split, crush, and replace old ones. Two types of specific chromatic palettes in suburban areas have been discussed, the over-satured colours in the commercial zones and the pastel shades in the housing districts. Despite their different appearances, both colour patterns act in a similar purpose: attracting the prospective buyers of consumer goods and houses, with the use of visual flashy signals and "post-modern" popular values.

In many cases, we can find coexistence between commercial zones and housing districts in a fragment of territory, flashy and pastel palettes alternating or juxtaposing (Figure 3).

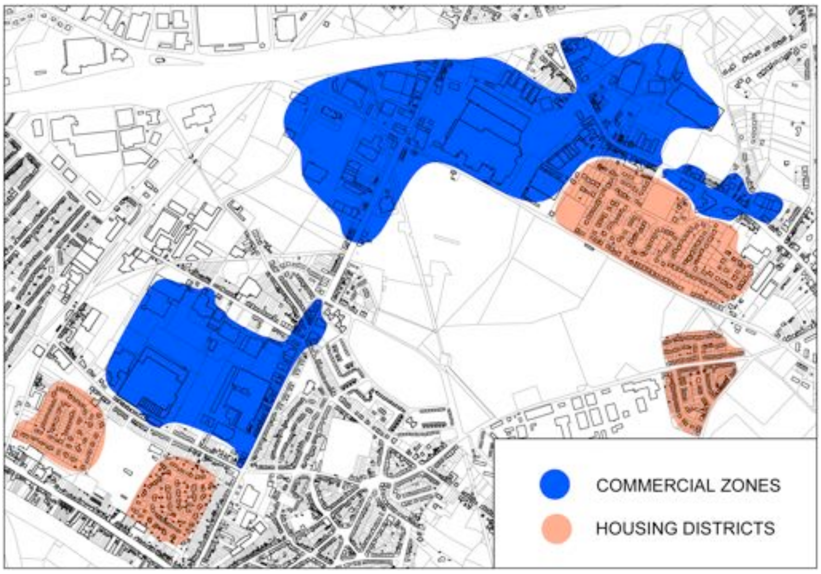

Figure 3. Coexistence between commercial zones and housing districts in an urban fragment (Liège, Belgium).

Moreover, the periurban devices move in the heart of cities: mass-market products (international retailers, leisure areas, hotel chains) settle in the centers while housing districts take place in the former industrial wastelands to form residential enclaves.

The chromatic mutations tend to become widespread and, as a result of economic development and globalization, a dilution of traditional models can be expected in the built environment to form indefinable hybrid colour patterns mixing new and old palettes. This will result in a loss of identity and coherence in urban territories, in conjunction with a cultural homogeneity of lifestyles.

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REFERENCES

Caivano, J.L. 2006. Research on Color in Architecture and Environmental Design: Brief History, Current Developments, and Possible Future. *Color Research and Application* 31 (4): 350-363.

European Environment Agency. 2006. Urban sprawl in Europe - The ignored challenge. *EEA Report n° 10/2006*: 6.

Fellmann, T. and B. Morel. 1997. Métropolisation et archipels commerciaux – Le grand Marseille et ses enseignes. *Les Annales de La Recherche Urbaine n°78*: 21-27.

Garcia-Codoner, A., J. Llopis Verdú, A. Torres Barchino, R. Villaplana Guillén, and J. Serra Lluch. 2009. Colour as a Structural Variable of Historical Urban Form. *Color Research and Application* 34 (3): 253-265.

Gibout, C. 1997. Les entrées de ville : une affaire de commerce ou d'hospitalité. *Les Annales de La Recherche Urbaine 78*: 109-113.

Koolhaas, R. 1999. *OMA 30: 30 colours*. Blaricum: V+K Publishing.

Mancebo, F. 2007. Accompagner les turbulences : une périurbanisation durable, priorité aux cheminements des habitats. *Les Annales de La Recherche Urbaine* 102: 51-57.

Mangin, D. 2004. *La ville franchisée – Formes et structures de la ville contemporaine.* Paris: Editions de la Villette.

Newman, P. and J. Kenworthy. 1999. *Sustainability and Cities – Overcoming Automobile Dependence.* Washington, D.C., Covelo, California: Island Press.

Nguyen, L., J. Teller, S. Reiter. 2011. Chromatic characterization of urban fragments: Validation of a user-oriented protocol through the study of Hors-Château street (Liège, Belgium). In *AIC Color 2011*, *Proceedings*, ed. by V.M. Schindler, S. Cuber. Zurich: pro/colore. Conference proceedings on CD.

Venturi, R., D. Scott Brown and Izenour. 2007. *L'enseignement de Las Vegas.* Seconde édition. Wavre: Editions Mardaga.

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Interior colour design effects on preferred level of light

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ABSTRACT

This study focused on the relationship between interior colour design and preferred level of light. We tested the hypothesis that preferred light level would significantly increase when applying countershading colour design and decrease when applying co-shading colour design. The aim was to identify measurable effects on energy consumption. A test-room, equipped with two alternative lighting scenarios, was painted three times: uniformly warm grey, countershaded and co-shaded. The same 29 observers, male and female of varying ages, made totally 8 adjustments with a dimmer in each colour design – in two different practical situations, from both fully lit up and complete darkness, in each lighting scenario. The total energy consumption for each adjustment was registered by a wattmeter. Each person's results were compared to his/her own and data analysed statistically. The results shows that applied counter- and co-shading principles, working on convex objects where essential shape defining differences appear between planes, cannot be directly applied in the concave room. Thus we failed to achieve efficient co-shading. Unintended effects suggest that applied principles worked rather like *disruption* and that essential shape defining differences in a room appear within each plane. The countershaded room, however, significantly increased the energy consumption – up to 25%.

1. BACKGROUND AND PROBLEM

Colour and light are functionally inseparable in our experience. Understanding their interaction is essential for creating good environments for human life, yet a lot of research is still to be done. In this study we focus on the relationship between interior colour design and preferred level of light, with the aim to better understand colour design effects on interior shape defining patterns given by lighting, and the more precise goal to identify measurable effects on energy-consumption. The project is reported in detail in a Swedish publication (Häggström & Fridell Anter 2012).

Previous research suggests that the spatial organisation of coloured surfaces in a room can affect the perceived level of light (Fridell Anter 2011). We assumed that the preferred level of light depends on the degree of visibility of shape, so that a colour design that enhances visibility of shape should require lower level of illumination than a "neutral" colour design, and that a colour design that decreases visibility requires a higher level of illumination. This function is so fundamental that it ought to measurably affect the preferred level of light. Applying concepts from the *Colour-Shape Interaction Analysis* (Häggström 2009) we formulated the hypothesis that the preferred level of light would increase significantly when applying *countershading* colour design and decrease significantly when applying *co-shading* colour design, compared to preferred level of light with a uniform colour design.

2. METHOD

This pilot study used a test room equipped with two sets of luminaries, creating typically different lighting scenarios: one undirected with mixed light sources and one clearly directed with LED-spotlights. Walls and furniture were painted three times to give us first a uniformly warm grey room, then a countershaded and finally a co-shaded version with the same warm grey main impression. Counter- and co-shading were done by adding darker and lighter nuances in approximately the same proportions but with reversed spatial distribution, that is: countershading with lighter nuances on more shadowed planes and darker on more lit planes; co-shading with darker nuances on more shadowed planes and lighter on more lit planes. Interior decoration details were added to create a more normal semi-private atmosphere.

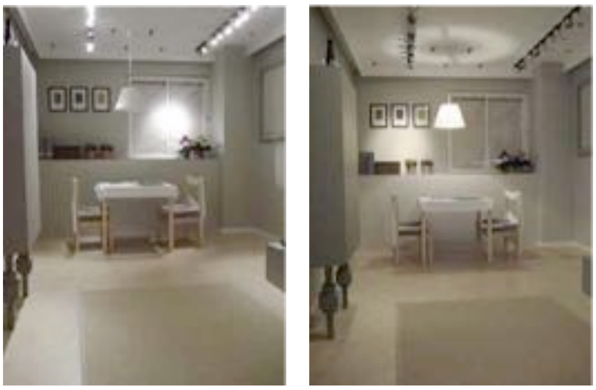

Fig. 1. The two lighting scenarios in the uniformly warm grey test-room: On the left side the clearly directed scenario and on the right side the undirected scenario.

The test included 29 observers, male and female of varying ages, participating through all the study. A form with detailed instructions for the procedure and documentation of values was used, varying the order of judging systematically, starting with dark or light and with directed or undirected scenario.

Each lighting scenario was judged separately. The observer used a dimmer to increase or decrease the total level of light. Between every visit to the test room the observers spent approximately 5 minutes in a daylight room where the level of illumination was reasonably controlled by blinders and complementary artificial light.

Two different practical situations were judged every time the observer visited the room. First the observer was asked to move around in the room and dim up/down to the lowest acceptable level for "staying in this room a whole day without doing anything particular". Next, the task was to set the most suitable level when sitting by the table, looking at pictures in glossy magazines "as if you were going to make a collage of them". Both situations were judged twice in each lighting scenario, starting both from completely switched off and from fully turned up light (to avoid the starting-point effects observed by A Logadottir 2011).

The energy consumption for each judged situation was registered with a wattmeter. Watt-values were later recalculated into mean lux-values based on illuminance measurements at 103 points (33 on floor, 70 on wall) at 4 different watt-levels for each scenario. A wide range of other factors, from outside weather and lux-values in the daylight room to self-estimated difficulties with glare and darkness, were also documented.

To overcome the differences between personal preferences of light level, we analysed the results by comparing each person's results with his/her own in the different experimental situations. The two scenarios were also analysed separately, and all data analysed statistically.

A complementary study was carried out, using 100 observers (55% female, mainly engineering students and in the age 20-29). The subjects were asked to compare two simple counter- and co-shaded empty scale-model rooms, judge differences in lightness and freely comment on other perceived differences. Because of the rough experimental set up resulting in slightly different lighting (both in colour and intensity of light) the two models switched place so that half of the subjects judged the co-shaded model in the lighter position and the other half judged the countershaded model in the lighter position.

Fig. 2. The scale-model rooms, here with the countershaded model, that was judged to be lighter, on the left side where the light was weaker and cooler, and the co-shaded model on the right side, where the light was more intense and warmer.

3. RESULTS

The method of reusing the same observers and comparing each ones result to his/her own proved successful: In spite of huge differences between individuals the subjects were surprisingly consistent with themselves. This was clearly confirmed by the data from five observers that had to remake the third round a week later – with practically identical procedure and design, and remarkably similar result, as shown in figure 3 below.

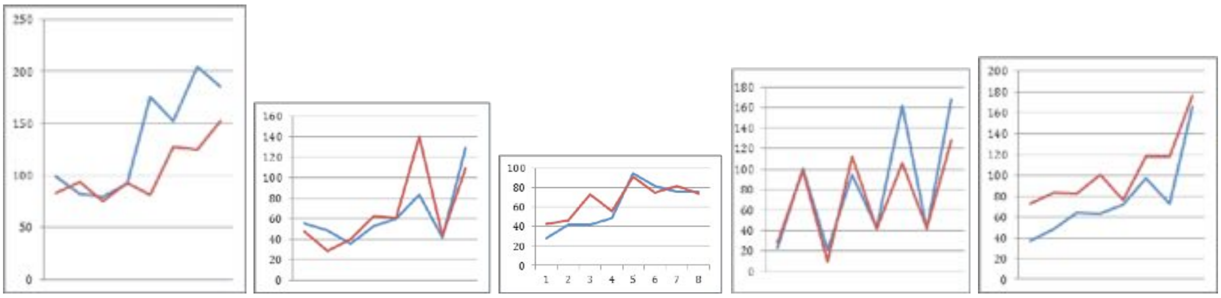

Fig. 3. Lux-mean values (vertical scale) for all adjustments, made by subjects no 12, 15, 16, 24 and 25 which repeated the test in the co-shaded colour design. The graphs show values in undirected (horizontal position 1-4) and directed lighting scenario (horizontal position 5-8): Blue line represent the first time and red line the second time one week later.

The scale-model study confirmed that the room with countershaded planes, that significantly required higher level of light in the full scale study, still was perceived as lighter than the room with co-shaded planes, surprisingly even in the measurably darker position. In both positions the co-shaded was perceived as sharper, or richer in contrasts. In addition a position depending difference in hue was observed – and also photographically documented.

In our result, in spite of resulting in a lighter appearance, the applied countershading significantly increased the preferred level of light. However the assumption that our co-shading should decrease the preferred level of light was contradicted. We suggest that this negative result does not really falsify the second hypothesis, but may instead be explained by unforeseen difficulties to accomplish a functioning co-shading design. It may be like clapping hands in time with music – there are innumerable ways of clapping out of time, but only one way to do it precisely in time.

The applied counter- and co-shading principles work well on convex objects, where essential shape defining differences appear *between* planes. Because of the importance of reflections between walls in a room, these principles cannot be directly applied in the concave room. While just reversing the spatial organisation of darker and lighter coloured surfaces we also achieved unintended effects on the overall colour-impression – and clear differences in hue "taken" from the light was observed in the model study. In addition much bigger differences in nuance could be used (without getting visible) for counter- and co-shading on the planes of convex objects, like furniture, than on the concave room walls. This suggests that the applied principles worked more like *disruption* (Häggström 2009), disturbing shape defining pattern and hence, like camouflage, reducing visibility of shape (Häggström 2009, 2010 & 2011).

Our conclusion is that essential shape defining variations in a room appear also, or rather, *within* each plane. Thus we accomplished no efficient co-shading but with the applied "countershading" we decreased visibility of shape and caused significantly increased energy-consumption – up to 25%. The results show the potential for both saving energy and improve visibility – and with that human wellbeing – by merely avoiding, or adjusting, extra "light consuming" spatial distribution of surface colours.

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REFERENCES

Billger, M. 1999. *Colour in Enclosed Space: observation of colour phenomena and development of methods for identification of colour appearance in rooms.* Gothenburg: Chalmers University of Technology.

Cott, H. B. 1940. *Adaptive Coloration in Animals.* London.

Fridell Anter, K. 2011. OPTIMA. *Metodstudie om färg, ljus och rumsupplevelse. SYN-TES rapport nr 1.* Stockholm: www.konstfack.se/OPTIMA

Häggström, C. 2009: "Visual Distinction between Colour and Shape – a functional explanation applying camouflage concepts in analysis of colourdesign effects on experimental relieves" in ed. D. Smith et al.: *Proceedings from AIC 2009*. CD. Sydney: Colour Society of Australia.

Häggström, C. 2010. "Colour design effects on the visibility of shape: Exploring shape defining design concepts in architectural theory and practice", in ed. P. Zennaro: *Colour and Light in Architecture*. Verona: Knemesi

Häggström. C. 2011. "Spatial Visibility: Camouflaging functions of recommended colour design solutions for improved accessibility", in ed. V. M. Schindler: *Interaction of Colour & Light in Arts and Sciences.* Proceedings from AIC International Conference in Zürich.

Häggström. C. & K Fridell Anter. 2012. *Ljusförstärkande färgsättning av rum. SYN-TES report no 4.* Stockholm: www.konstfack.se/SYN-TES

Logadóttir, Á. 2011. *Occupant Controlled Lighting: Investigation of the Method of Adjustment.* Ph.D. Thesis. Danish Building Research institute, Dep. of Energy and Environment, Aalborg University.

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oral paper

Colour and Light in the Re-Imagined Birth Environment

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ABSTRACT

The act of birth is a primary rite of passage, for both spirit and body, for both mother and child. The hospital maternity environment – today the predominant site for birthing in developed countries – is a contested and complex site of human becoming/being (Fahy, Foureur, and Hastie 2008); (Davis-Floyd et al. 2009). One of the few medical spaces that anticipates joyful experience, it is also a place of fear and stress. It may suddenly become a place of decisive action in crisis. It holds, always, the dreaded possibilities of grief, of 'failure'. How are these emotional aspects of birth reflected in the environments we create for mothers, babies and supporting participants? This research posits that *colour and light,* as vital aspects of the physical and ephemeral environment, hold rich potential for forming/transforming human experience. It seeks to bring forward new insight into colour and light as important elements of birth centre design. The results provide initial elements of a 'pattern language' for colour and light use that may be seen as a paradigm shift in design concepts for the hospital birth environment of the 21st century.

COLOUR, LIGHT AND BIRTHSPACE

Light and colour within the birth environment may seem to be design luxuries, 'selling points' for marketing new birth centres in hospitals, or pleasantries of local or global fashion trends. As attempts at 'pastel' or 'neutral' strategies for promoting 'relaxation', colour 'schemes' have limited (perhaps even negative) impact on the psychophysiology of birth process and experience.[1] Yet 'white' light and its partner darkness, and colour manifested through materiality or light, are potentially profound elements of the 'poetics' of space,[2] (Bachelard 1994) and may offer emotional and psychological resonance (Odent 2007) of import to the participants in the birth process, including mother, child and caregivers.[3] This practice-based art/architecture research project explores colour and light as factors in creating 'positive emotional valence'(Isen and Reeve 2006). Consideration of material and ephemeral sensory experience as capable of limiting the stress hormones that stall labour processes (Hodnett et

[1] *Persons subjected to understimulation show symptoms of restlessness, excessive emotional response, difficulty in concentration, irritation, and in some cases, a variety of more extreme reactions. This conclusion should be considered very seriously by those who propose a white or neutral environment; such environments are anything but neutral in the effects they have on their occupants.* (Mahnke 1996: 24-25)

[2] "*An empty space is marked off with plain wood and plain walls, so that the light drawn into it forms dim shadows within emptiness. There is nothing more. And yet, when we gaze into the darkness that gathers behind the crossbeam, around the flower vase, beneath the shelves, though we know perfectly well it is mere shadow, we are overcome with the feeling that in this small corner of the atmosphere there reigns complete and utter silence; that here in the darkness immutable tranquility holds sway.*" (Tanizaki 2006)

[3] See BUDSET (Birth Unit Design Spatial Evaluation Tool) criteria, including 'Cascade of Fear' and 'Aesthetics' sections (Foureur et al. 2010)

al. 2009) brings colour and light into focus as potential collaborators in 'normal birth' processes. As Lepori and Franck (2000) have noted:

> …the world of matter, of materials shaped and combined to make buildings, of light and shadow, air and water, is alive and enlivens us...it is the source of emotions, dreams and aspirations, the basis of our psychic existence as well. What is built is not only of practical import but of psychological significance also. (Lepori and Franck 2000: 78)

Similarly, 'Health Futurist' Leland L. Kaiser comments:

> All of us are the sum total of our life experience. Our experiences take place in environments. A design for an environment is therefore a design for human consciousness. We should think of patient care spaces as opportunities to provide valuable new experiences that alter patient awareness in health-giving ways. (In Sadler and Ridenour 2009: ix)

For an impression of contemporary birth spaces colour/light use see Fig. 1 & 2 below: a new hospital labour room in Toronto and a freestanding birth centre in Germany.

Fig. 1 Sunnybrook Hospital, Toronto
http://sunnybrook.ca/extras/tour_wb/index.

Fig. 2 German Birth Centre
http://www.geburtshaus-altdorf.de/ html

My research-through-practice has to date involved two rounds of studio investigation, working loosely and experimentally to produce physical models and to capture photographic images of observed aspects or elements of models or drawings. Narrative audio and textual pieces are recorded during and following production of work. Textual research periods precede and follow studio exploration, but do not coincide with it. Fields of study include colour and light in art and architecture; 'birth studies' from various disciplines including biology, medicine, midwifery, psychology and anthropology; sensory design including neuropsychology/phenomenology, biophilic and salutogenic design; and research on architecture as space from feminist and phenomenological perspectives. My previous professional work as and artist/designer working with glass, colour and light in architecture, well as my own personal experience of childbirth, provide background and tacit as well as explicit knowledge embedded in the project. (Balabanoff 2011) (McLachlan 2012)

The camera is utilized as a 'viewing device', which allows a small object or construction to be investigated under various lighting conditions or from different viewpoints. It produces a secondary layer of photographic work that 'observes' and 'interprets' the physical objects, and renders them as lively participants in a conversation about colour, light, space and material and ephemeral conceptions. A third layer of information augments this 'pre-verbal' process - voice recordings, which capture thoughts occurring, triggered by the work. And fourthly, a written analysis sifts 'significant' insight from this process into suggestions for possible inclusion in a final representation of key concepts.

The ideas generated by my intuitive and playful practice-as-research are by no means a finite set. They are seen, rather, as provocations, or glimpses of possibility. Every suggestion might be implemented in an infinite number of possible interpreted realizations, by different artists, designers, and individuals, in concert with specific cultural contexts or physical sites. A first-round informal set of concepts will contribute to a formalized set supported by specific research and theory, aimed at contributing to a set of clear recommendations.

Space does not permit a comprehensive listing and discussion of outcomes; however, the following are examples of the studio work (with observations) that are representative:

Fig. 3 Natural materials *that show the passage of time* offer materiality and sensuality that connect us to nature. Objects may be more potent than flat surfaces, as light plays upon them with infinite variety. Light coloured wood or stones accept and show subtle light and colour effects that dark materials would obscure.

Fig. 4 Colour that exhilarates and calms is colour that holds association with sun, water wind and earth. Mouthblown glass, though human-made material, is an example of a material which renders light as richly textured, whether coloured or clear - reminiscent of water…

Fig. 5 Curved space provides fluidity and gradation of light and sensation, offering subliminal and liminal messages for embodied experience. 'Soft' reflection/sheen on floor and other horizontal surfaces offer sensuality of 'glow' and contribute to altered awareness/ consciousness. Water elements provide rich variety of expression with strong positive valence. Long views and light/nature at end of a long space create sense of release and spatial variety (visual and physical). They speak metaphorically of the birth journey. Views of nature provide respite and regeneration from intensive work.

The research will be ongoing, as the focus of a PhD at SMARTlab, University College Dublin - but can be seen to offer, at present, several examples of exploration and consideration of 'poetic' aspects of colour and light which can and should be brought into play to enhance the birth environment. Psychophysiological response to colour and light is an area for further research that should be pursued with specific focus on the birth process and environment. Rather than being considered as a paint and furniture (décor) choice, colour and light should be developed holistically as a material and immaterial, physical and metaphysical sensory aid to birth processes.

> In the case of colour… the quality I call wholeness or life …is experienced as *light*. Actually this light is an inner light – a light which is mental and emotional as well as physical – a quality which makes us feel the same as we feel when in the presence of physical light, but more subtle…" (Alexander 2003: 240)

We should think beyond the 'labour' or 'delivery' room. First entrance to this environment, from arrival at the building, should offer an uplifting sensation – with saturated colour bursts light-filled foliage and pieces of the sky or water welcoming us and offering 'luminous calm'. Women's bodies should feel 'understood' and put at ease by the space and its affordances – by fluidity and aliveness of light, by softness and gradation of light on curved form…by the emotiveness offered by deep and rich colour as well as the warm or cool glow of sun or moon light ….by surprise and delight at unexpected forms or textures that capture light, fill us with wonder, give us hope.

Colour and light as aspects of interplay and harmony between matter and energy, celebrate, deepen, nuance and reveal our spiritual and embodied consciousness of birth as the primary rite of passage within the greater envelope of life.

REFERENCES

Alexander, C. 2003. *The Nature of Order: An Essay on the Art of Building and the Nature of the Universe, Book 4 - The Luminous Ground*. Berkeley: CES Publishing.

Bachelard, G. 1994. *The Poetics of Space. Boston: Beacon Press*

Balabanoff, D. 2011. Aspects of Light: Colour, Form and Space/Form/Time. In *AIC 2011, Proceedings,* ed. by V. Schindler. and S. Cuber. Zurich: pro/colore.

Davis-Floyd, R. E., L. Barclay, J. Tritten and B. Daviss. 2009. *Birth Models That Work*. 1st ed. Berkeley: University of California Press.

Fahy, K., M. Foureur and C. Hastie. 2008. *Birth Territory and Midwifery Guardianship: Theory for Practice, Education and Research*, 1st ed. Toronto: Elsevier/Books for Midwives.

Foureur, M. J, N. Leap, D. Davis, I. Forbes, and C. Homer. 2010. Developing the Birth Unit Design Spatial Evaluation Tool (BUDSET) in Australia: a Qualitative Study. *HERD* 3 (4): 43–57. http://www.ncbi.nlm.nih.gov/pubmed/21165851.

Hodnett, E.D., R. Stremler, J. Weston, and P. McKeever. 2009. Re-conceptualizing the Hospital Labor Room: The PLACE (pregnant and Laboring in an Ambient Clinical Environment) Pilot Trial. *Birth* 36 (2) (June): 159–166.

Isen, A.M, and J. Reeve. 2006. The Influence of Positive Affect on Intrinsic and Extrinsic Motivation: Facilitating Enjoyment of Play, Responsible Work Behavior, and Self-Control. *Motivation and Emotion* 29 (4): 295–323. doi:10.1007/s11031-006-9019-8.

Mahnke, F.H. 1996. C*olor, Environment, and Human Response: An Interdisciplinary Understanding of Color and Its Use as a Beneficial Element in the Design of the Architectural Environment.* 1st ed. Somerset, N.J.: Wiley.

McLachlan, F. 2012. *Architectural Colour in the Professional Palette.* 1st ed. Routledge.

Odent, M. 2007. *Primal Health.* Revised ed. Clairview Books.

Tanizaki, J. 2006. *In Praise of Shadows*. New York, N.Y.: Vintage Books.

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oral paper

From Charles Henry to Julio Le Parc: Experimental Research on Colour, Light and Motion

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ABSTRACT

This paper is an inquiry into the aesthetics of colour, line and motion of the French mathematician, physiologist and scientist Charles Henry (1859-1926). The Neo-Impressionist painters Georges Seurat (1859-1891) and Paul Signac (1863-1935) are just two examples of artists he has influenced. Henry's approach is based on psycho-physiological insights as well as aesthetic theories that lead to a set of universal laws featuring contrast, rhythm and phenomena capable of being measured. In particular, he assigned a 'direction', i.e., a degree of expansive energy, to each colour. In the 1920s Henry's ideas were published in *L'Esprit Nouveau*, a polemic vanguard review dedicated to the experimental aesthetics of Purist painters Amédée Ozenfant (1886-1966) and Charles-Edouard Jeanneret (Le Corbusier, 1887-1965) who claimed that scientific investigations of colour and optics were fundamental to their artistic approaches. The work of the Argentinean artist Julio Le Parc (1928), who has been based in Paris since 1958, explores the mechanisms of light, colour and movement. He is one of the founders of the Groupe de Recherche d'Art Visuel (GRAV, Research Group on Visual Art) in 1960. Adopting some of the Neo-Impressionists ideas in his *Alchemie* series (1988-1996) Le Parc uses a pointillist technique and in one of the paintings he poignantly reinterprets Henry's colour circle.

1. INTRODUCTION

The French mathematician, physiologist and scientist Charles Henry (1859-1926) published his *Introduction to a Scientific Aesthetics* (1885) in the fortnightly magazine *Revue contemporaine*, which he then eventually developed into a much larger work entitled *Colour Circle Presenting all Colour Complements and Harmonies with an Introduction on the General Theory of Contrast, Rhythm and Measure* (1888) followed by an enlarged edition in 1889.

With the translation into French in the 1860s of some fundamental books on the newly emerging science of physiological optics including those discussing its relation to the arts, art theory and philosophy began to move away from metaphysics to a more scientifically defined approach. The most influential publications were *The Physiology of the Colours for the Purposes of Arts and Crafts* (1866) by Ernst Brücke, the *Treatise on Physiological Optics* (1867) and *On the Sensations of Tone as a Physiological Basis for the Theory of Music* (1868), the later two both by Hermann von Helmholtz.

Some twenty years later, Charles Henry's achievement was to bridge the gap between the arts and the emerging sciences. His 'scientific aesthetics' was based on traditional principles of harmony. However, he used new psycho-physiological evidence of his time in his arguments from research reports published in the journal of the French Academy of Science as well as in contemporary academic revues. Alongside the rapidly expanding experimental psychology founded by Gustav Fechner and Wilhelm Wundt, scientists developed manifold techniques and apparatuses to classify, measure and understand the mechanisms of forces and sensations. Simultaneously new models of vision led to the adoption of new theories of colours.

2. COLOUR AND MOTION

2.1 Colour, motion and emotion

In his 1885 essay, Henry took up the theories of physiognomy as applied to the arts by the French art critic Charles Blanc (1813-1882) who popularized them in his *Grammaire des arts du dessin, architecture, sculpture, peinture* [Grammar of the Arts of Drawing, Architecture, Sculpture, Painting] (1867). Physiognomy as understood in the nineteenth century was an attempt to define the character of persons by interpreting and judging their physical appearance. In particular, Blanc revived the reflexions by Dutch artist D. P. G. Humbert de Superville (1770-1849), whose *Essai sur les lignes inconditionnels dans l'art* [Essay on the Unconditional Lines in Art] (1827) was based on the interpretation of the human face in terms of three abstract expressions of lines or directions. Humbert determined their aesthetic value relating them to emotional experience and also attributing colours to them (Figure 1). He attributed white (blanc) to the horizontal line that expresses the equilibrium of one single movement; white symbolizing the feelings of calmness, pureness and modesty, all expressions that a saint evokes. He related red (rouge), the colour of a flame, to the expansive movement of lines diverging from a vertical symmetry, signifying explosive agitation as of a bacchante or dancer represented in Greek paintings. And referring to a converging movement like that of penitent Saint Mary Magdalene with her hands folded on her breast, deep in grief, he associated the colour black (noir), symbolising depth and darkness. As well, Humbert related these three types of directions to redheaded, blonde and black-haired people.

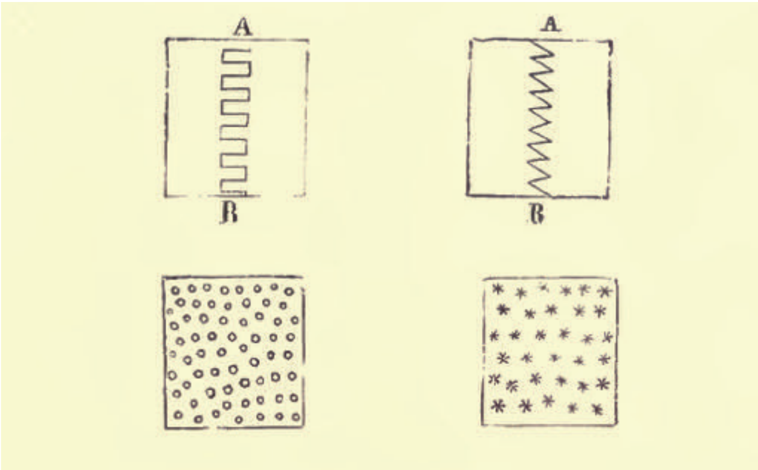
Figure 1. The Dutch art scholar and artist D. P. G. Humbert de Superville attributed in 1827 symbolic colours to abstract lines or directions:
Red (rouge) to divergent lines, white (blanc) to horizontal, and black (noir) to converging lines.

Charles Blanc compared physiognomy characteristics of the human face to elements of artistic creation, e.g. lines and forms in architecture and sculpture. Using the analogy of abstract figures representing expressive gestures, he discussed proportion, symmetry, order and harmony, topics of treatises on aesthetics since Leonardo da Vinci's *Vitruvian Man* (c. 1485). Colour theories, however, developed in a quite different way in the second half of the nineteenth century.

2.1 Colour, vibration and optical mixture

Although Charles Blanc pleaded for the supremacy of form embodying the absolute, and colour the relative and inferior to form, he recognised the existence of 'strange' phenomena concerning optical effects of colours and was fascinated by the practical value of the laws of harmonious colouring that Michel-Eugène Chevreul (1786-1889) elucidated in his *De la loi du contraste simultané des couleurs* [The Principles of Harmony and Contrast of Colours, and Their Applications to the Arts] (1839).

Figure 2. Optical mixture as explained by Charles Blanc: 'Two colours in juxtaposition or superposed in such or such proportions,... will form a third colour that our eye will perceive at a distance... This third colour is a resultant that the artist foresaw and which is born of optical mixture.'



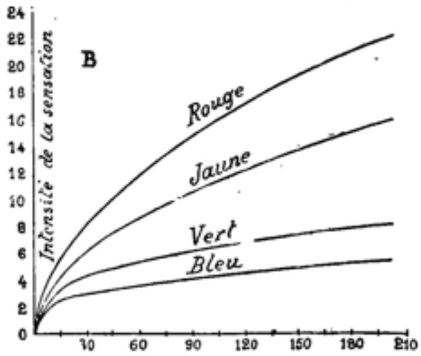
From then on these 'vibrations' were thought of as a quality inherent in colours. Although Charles Henry judged Charles Blanc's remarks on colour not to be correct – with the exception of quoting Chevreul – he adhered to Blanc's discussion that forms have the power to evoke emotional expressions. In his colour theory, Henry assigned a movement or progressive direction, i.e., a degree of expansive energy or dynamogeny, to colours.

2.1 Colour, dynamogeny and inhibition

The concept of dynamogeny is a fundamental notion of Charles Henry's theory. In late-nineteenth-century discourse it was used in the fields of physiology, biology and medicine to describe the generation of power, force or energy, especially the muscular or nervous energy that is produced by stimulation. Both in theory and in practice, Henry aimed to study and represent the seemingly unquantifiable and subjective phenomena of aesthetics by using objective mathematical formulas. Issues that developed as a result of this aim included the establishment of a basis and methodology for measuring dynamogenous or inhibitory forces or nervous irritation and how a given colour stimuli causes deviation from the state of equilibrium. These were articulated and explored as part of a psychophysics that is defined today as a branch of psychology that quantitatively investigates the relationship between physical stimuli and the sensations and perceptions they affect.

Charles Henry borrowed from French physician Augustin Charpentier (1852-1916), whose research results on colour and light from the physiological point of view were successively published in the proceedings of the Academy of Sciences in the 1880s.

Figure 2. Augustin Charpentier's graph shows that at the same luminous intensity colour sensations are not equal. The demonstration concerns red (rouge), yellow (jaune), green (vert) and blue (bleu).



Against this background, Henry set up a correlation between varying colour intensities and the more or less dynamogenous direction that could be attributed to a colour. This research led to the construction of a colour circle representing Henry's own psychophysiological theory of dynamogeny and inhibition in which the effects of differences of light intensity upon the senses determine the colour order. Red, which he considered as the most dynamogenous colour, is associated with an upward direction expanding from the bottom to the top; yellow is envisioned as flowing horizontally from left to right; greenish blue is depicted as moving downwards from top to bottom; and violet blue flows from right to left.

The colour circle was intended to help in the systematic search for complementary colours as well as colour harmonies. His aesthetic protractor and triple decimeter were developed to enable the study of lines, forms and colours in order to improve their aesthetic harmony.

3. CHARLES HENRY AND L'ESPRIT NOUVEAU

Henry's diverse explorations led him to establish a set of universal laws featuring contrast, rhythm and measure that applied to lines and forms, as well as to colours and sounds. His cross-disciplinary approach and the formulation of abstract models of expression were taken up in the 1920s. Henry's ideas were published in *L'Esprit Nouveau*, a polemic vanguard journal dedicated to the experimental aesthetics of Purist painters Amédée Ozenfant (1886-1966) and Charles-Edouard Jeanneret (Le Corbusier, 1887-1965), who claimed that scientific investigations of colour and optics were fundamental to their artistic approaches. Henry's colour circle appeared on the facing pages with Le Corbusier's article *Des yeux qui ne voient pas…* [Eyes that do not see…]

4. JULIO LE PARC'S KINESTHETICS

The explorations of the Argentinean kinetic artist Julio Le Parc, who has been based in Paris since 1958, led him to consider 'the artistic phenomenon in terms of a strictly visual, non-emotional experience located in the plane of physiological perception'. One of the founders of the Groupe de Recherche d'Art Visuel (GRAV, Research Group on Visual Art) in 1960, he adopted some of the Neo-Impressionists ideas in his paintings of the *Alchemie* series (1988-1996). Le Parc uses a pointillist technique and poignantly reinterprets Henry's colour circle.

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"Livecolour colourinhabiting" in são cristóvão, portugal

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oral paper

ABSTRACT

"LiveColour Colourinhabiting" is an action that aims to express individual identities and to create a new local identity, image and public space; in so doing, it intends to stimulate a more integrated development of the individual and society. In São Cristóvão, a small village of rustic houses from a deeply-rooted chromatic culture of coloured door-frames, windows and skirtings set against a background of stark white facades, the local residents were challenged to create and select drawings and local expressions to be painted onto their traditional residential facades. From my immersion in the population, and through an interventionist methodology, I requested that each participant bring and share personal objects with affective and aesthetic relevance, as well as verbal expressions of oral tradition or individual thought. From these elements grew a negotiated work that produced a set of drawings set within a logical path. The process culminated in the painting of facades, and served as a touchstone for image renewal (on individual and group levels) and memory rescue, a way of relating to and living within a space. The project satisfied some deep human needs – for participation, identity and affection – and, above all, served as an exercise of aspiration, Appadurai (2004).

1. LIVECOLOUR IN SÃO CRISTÓVÃO – RESEARCH CONTEXT

LiveColour Colourinhabiting is the case study for my PhD in Design, under the theme "Collaborative Paintings in Residential Facades" at the Faculty of Architecture - Technical University of Lisbon, in collaboration with the Faculty of Architecture Design and Urbanism - University of Buenos Aires. *LiveColour* proposes to distinguish the houses on a street or residential neighborhood by adding drawings built from elements of personal identification, developed with each resident, and grouped under a unifying concept. Thus is created a uniqueness of place and action, and a singularity of place and people. Through a participatory process, we seek to discover, engage and share material, and to negotiate decisions, with the ultimate goal of spurring personal development and collective participation. This idea is supported by the values of sustainability defined by Ehrenfeld (2008), and also searches to understand which human needs (Survival, Protection, Affection, Understanding, Participation, Leisure, Creation, Identity and Freedom, Max-Neef (1986: 237-8)), are addressed during the course of the action.

São Cristóvão is a typical village in the municipality of Montemor-o-Novo, Alentejo, Portugal, with fewer than 800 inhabitants, clean streets, and mainly single-storey family houses. In the Alentejo region, the chromatic culture of the rustic houses is characterized by white facades, and the use of colour in door-frames, windows and skirtings, a practice that, according to Gil (2010), followed from the Islamic tradition. In São Cristóvão, the act of painting returns every year in the form of ritual festivities that solidify the local visual culture, Mathew Rampley in Vilas Boas (2010:30), even if the more traditional whitewashes, flourishes, and natural pigments have gradually given way to flat synthetic paints. A formerly more diverse colour palette, which was found not only in the decorative elements of homes, but also in the main background colours of their façades (from oral interviews, it seems these colours corresponded with local social stratification and meaning codes, such as the use of gray to signify mourning), is today reduced to a particular copy of the traditional blue and yellow. From a social standpoint, as with many other Portuguese villages, São Cristóvão is facing problems of aging, high rates of unemployment and lack of opportunity for young people. São Cristóvão offered the possibility of working in a small community in which the walls strongly participate in the local visual culture and serve as a kind of calling card. The village also had prior experience with other participatory projects, such as Local Agenda 21. In addition, LiveColour had been accepted in the artist residencies "New Forms and Techniques in Transition," produced by the local NGOD Oficinas do Convento, and received institutional approval from both the Municipality of Montemor-o-Novo and the Village Council. From this context, it was deemed desirable and mutually beneficial to execute LiveColour Colourinhabiting in São Cristóvão.

2. RESEARCH METHODOLOGY AND PROCESS OF LIVECOLOUR

In São Cristóvão the concept of LiveColour was to challenge the inhabitants to paint drawings and local verbal expressions on their door-frames, windows, chimneys and skirtings. The starting points for these drawings were significant personal objects and spoken expressions of oral tradition or individual thought that, for the participants, evoked emotions or aesthetic meaning.

LiveColour Colourinhabiting follows a participatory research in immersion and spans four different phases of action: Presentation; Exhibition of sketches, photo-montages and final drawings for the paintings; Painting; and Evaluation, all between October 2011 and July / August 2012. In each stage, previous goals and objectives were settled, especially those relating to possibilities for people to participate. In addition to the data (photos of personal objects, verbal expressions and sketches) that was produced during the drawing process, field notebooks chronicled interviews and informal conversation, all of which will be subject to analysis. During the Evaluation phase (yet to be completed), two surveys will be administered, one to the participants and another to the population, to assess and validate the conclusions drawn from the data.

3. RESULTS AND ANALYSIS

Shortly after the Presentation of the project, the participants stabilized around twenty inscriptions. The entire work, other than the Evaluation phase, developed over the course of eight months, with eighteen houses painted, (www.vivercor.com). The resulting data are being analyzed in terms of participation, human needs and the relation between the drawings and their importance to participants and the broader village population. After much effort to establish the participants' personal trust, the participants' response to the methodology proposed to them – through the phases of trust, negotiation and intimacy – seemed in keeping with the academic literature relating to the promotion of participatory processes, Bergold and Thomas (2012). Also, consistent with Max-Neef's (1986) research on this type of activity, the data points to the satisfaction of the central need for participation (inherent to the nature of the activity). The data also suggests that the action helped satisfy needs for affection, identity, creation and leisure.

As for the process of creating the drawings, it was interesting to find, on the one hand, that the participants relatively quickly adopted the proposed concept and understood the importance of using drawings on the front walls, but that, on the other hand, adherence to more traditional practices resulted in some barriers that precluded some of the more innovative concepts. Thus, the location of the drawings on the façade (on chimneys, in revival of what had been a dying tradition) and the choice of pre-existing paint colours sometimes fell under the yoke of more traditional ideas (to illustrate, in only two cases was the design polychromatic).

A deeper content analysis of the text and objects brought by the participants has been performed, with the understanding that the produced drawings and their meanings depend on the participants' purposes and intentions. The 21 objects in question – mainly objects associated with the place, handicrafts (e.g., laces) and common objects of mass production – were brought for their aesthetic value, personal value, and relevance to location. The participants chose to bring sentences that reflected quotations by published authors and local or commonplace expressions, with content that was either poetic in nature, chosen for the value of its message, or revealing of some familial connections or personal identifications. A review of the field notes shows that the objects and texts relate closely to the participants' identities, and also may constitute personal statements or memorials to others relatives, or serve to confirm family ties. It is also interesting to see a difference between the choices made by participating residents who live full time in São Cristóvão vs. those of participants who lived elsewhere primarily, but who own second homes in the village. The latter group took greater care to relate the drawings to local attributes of the place, valuing more authenticity, genuineness and exclusivity, under a guiding notion of cultural landscape. I believe that the nature of the objects and contents of the phrases chosen foresee their understanding and recognition by the non-participating population. This point assumes greater importance if we consider that the action will make sense, and the drawings remain, only if fully understood, accepted and valued by local people.

4. CONCLUSION

The challenge of the action LiveColour Colourinhabiting was launched in São Cristóvão, a whitewashed village of Alentejo, where the annual ritual of painting the facade is part of the local culture. In the context of the present research, intended primarily to study which human needs are met by the communitarian and participatory process of painting residential facades, the concept for São Cristóvão was designed - to provide a uniqueness to the village, to create a path of paintings born from the participants' personal belongings, to foster personal development and explore ways of participation. Thus, the participants produced personal items from which many sketches and drawings were developed, negotiated, and painted. This process helped develop and reinforce some traditional decorative places, helped innovate by grounding the drawings in emotional source material, and brought a poetic sensibility through the introduction of the written word onto building facades. Reading the data collected thus far from different parts of the process, the main goals, both individual and collective, seem to have been fulfilled. From content analysis of the produced objects and from written notes taken during field research, we may conclude that the action made it more possible to meet the need to participate, and to express and create identity and affection. It is also important to note that the resulting set of drawings and sketches may be seen as an archive of elements associated with the people who brought them, which give them a widespread recognition, edification and care by locals, "a project that will stay in the memory" as one participant described it. This recognition, coupled with the affection that the action involved, is the nexus of hope for the work's growth and sustainability. It is also here that the relational part of the action, based on a survey of the aesthetic encounter, Traquino (2010), enhances and confirms itself through the appreciation that people attribute to meetings, interviews as well as the individual research for further information to share with the community.

Prior to completion of the Evaluation phase, it would be premature to make conclusive pronouncements about LiveColour Colourinhabiting's future, the dynamics of the colour-inhabiting process, or its impact on the village's dynamic, especially when such actions were so anchored on trust that required much time to develop. But while I cannot predict whether the drawings will remain, or be later substituted, I do believe that the foundations of a territorial attribute have been laid, and that the creation of a territorial brand, image, identity for the village is underway.

Looking at the work as a whole, I believe that, beyond paintings or participation, this action is about "lifting the spirits," about hope and motivation, the kindling of desire and ability to modify the environment, to help give what Appadurai (2004) defined as aspiration. I believe that here dwells the highest relevance of LiveColour Colourinhabiting.

ACKNOWLEDGMENTS

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REFERENCES

Appadurai, A. 2004. The Capacity to Aspire: Culture and the Terms of Recognition. in Rao, V. And Walton, M., (eds.) *Culture and Public Action.* Palo Alto, California: Stanford University Press.

Ehrenfeld, J. R. 2008. *Sustainability by Design*. Washington: Yale University Press.

Max-Neef, M. 1986. *Economía Descalza. Señales desde el Mundo Invisible*. Buenos Aires, Montevideo: Editorial Nordan.

Traquino, M. 2010. *A construção do lugar pela arte contemporânea.* Ribeirão, Portugal: Edições Húmus.

Vilas Boas, A. 2010. *O Que é Cultura Visual?* Porto: Multitema.

Gil, M. 2001. *As Cores do Alentejo - uma viagem entre a ciência e a tradição.* 32min. http://vimeo.com/23162373. Accessed: June 18, 2012.

Bergold, J.; Thomas S. 2012. *Participatory Research Methods: A Methodological Approach in Motion.* http://www.qualitative-research.net/index.php/fqs/article/view/1801/3334. Accessed: April 12, 2012.

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The Color Expressions in the Traditional Costumes of Taiwanese Indigenous Peoples

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ABSTRACT

Atayal woven materials are a distinct example of how ethnic symbolism can be expressed through the combining of color and fabric patterns in weaving and dying. In order to understand Atayal fabric color use and distribution, this research first utilizes PANTONE FASHION + HOME cotton planner to contrast fabric color, and after comparison, color specimens are input one at a time into ColorSchemer Studio's color wheel statistics system. In order to analyze Atayal fabric colors, this study particularly performs color scope analysis on sub-groups for which research specimens are relatively abundant, such as the Tayal's Beishi group and Nanao Group; and the Sediq's Wushe Group, Wanda Group, and Taroko Group. Beishi group fabrics use a comparatively wide range of color and a more diverse number of combinations. The main colors they use include white, red, orange, yellow, green, blue, and other colors. The colors used by the Wushe Group and Wanda Group in their fabrics include white, red, blue and others. While the number of specimens collected for this study is limited, it is possible to understand, what the color preferences of sub-tribes are through their color schemes. The most predominant color schemes involve similar colors, contrasting colors, and complimentary colors.

Keywords: Indigenous peoples, Atayal, fabrics, color

1. Introduction

1.1 Research Motivation

The clothing of various indigenous peoples varies to different extents from tribe to tribe, and the garments each tribe wears have their own cultural or symbolic meaning. The woven materials of the Atayal People are a very distinct example of this. The Atayal are the second largest tribe of Taiwanese indigenous peoples and, from an anthropological perspective, the Atayal include two major linguistic dialects: the Tayal and the Sediq. Their distribution extends from Taiwan's north to its central and eastern regions. From the north the area they cover includes Taipei County's Wulai and extends to Hualien County's Hsiulin Township, Shohsi Township, Wanrong Township, and other regions. The Atayal can be divided into as many as 25 sub-tribes, and their traditional costumes are the most unique among those of Taiwan's indigenous peoples.

In view of this, this research performs comparative analysis with respect to Atayal traditional apparel to interpret its expression in color and better understand Atayal material culture.

1.2 Research purpose

Mori Ushinosuke(1917), Sato Bunichi (1942), and other Japanese scholars indicate the Atayal were excellent at weaving cloth, and excelled at creating both textiles and rattan-woven vessels. What is more, various sub-tribes of the Atayal exhibited different transformations in how they utilized color as a result of living in different environments. This also led to the gradual formation of different styles within each sub-tribe. The goals of this research are:

1. Understand what the colors in Atayal fabrics are intended to express, as well as their symbolic meaning.
2. Perform contrast analysis on Tayal and Sediq fabric colors to determine their similarities and differences.

2. Literature Review

2.1 Atayal Traditional Clothing

In discussing Atayal's Gaga (the core of Atayal culture), Tien Tze-I (2001, 233) asserts that Utux (the dead and their spirits) fear the color red. For this reason, this tribe wears clothing dyed dark red to frighten away these spirits. In addition, the rhombus pattern woven on the front of these garments represents the eye of the forefathers and is worn for protection. The design on the back of garments uses complicated woven patterns in order to ward off the Utux.

Traditional Atayal clothing integrates sewn and draped styles in its apparel. In general, the composition of traditional clothing can be divided into daily, work and ceremonial costumes. According to Tadasu (1999, p.79), Atayal clothing can roughly be divided into 7 categories. These include wide sleeved garments, vests, square robes, chest coverings, leggings, waste coats, capes, and other items. There are differences in the ornamentation men and women wear. For example, men wear hats, while women wear bandanas. Men's hats are woven from rattan, and some have a visor in the front, or a bear skin covering (with the neck covered with a half-moon shaped piece of fur). Ceramic buttons can also be used as decoration.

2.2 Atayal Weaving Materials

The primitive materials used in the past included the juice of plant roots which was extracted and used to boil the threads used to make clothing. For example, the sap coming from Dioscorea matsudae could be used to dye threads the brownish color of black tea. For black, threads were placed in lye, mud or smashed Lagerstroemia subcostata. By contrast, for ochre color, threads were placed in lye or a compound made with the pounded corm of cassava which was mixed with water.

3. Research scope and methodology

3.1 Research samples

From 1990, the Taichung Cultural Center was able to collect a large number of Atayal textile samples because of their location. At present, this Center is one of the larger collections of Atayal artifacts Taiwan in Taiwan. Therefore, this research takes museum collections as the object of its research. In organizing its research, this study takes 23 Atayal fabrics as its research sample, and takes these as the basis for understanding Atayal clothing (Chart 3-1).

Chart 3-1 Taichung Cultural Center Atayal fabrics Collection

(Source: Taichung Cultural Center)

3.2 Color Comparison

In implementing this research, in addition to the question of commonality of use concerning colors in textile manufacturing, we also are concerned about the reflective nature in conditions concerning color. The standards put forward by PANTONE Company are accepted globally for color systems and researching color. Ultimately, this study chooses FASHION + HOME cotton planner's fabric color comparison system. In addition, for fabrics color cope description, we use the Live Scheme color wheel function from Color Schemer Studio (color analysis software) and input the color samples derived from fabric comparison one by one to understand Atayal fabric color schemes.

4. Atayal fabric color analysis

The sample of this research is the 23 items of the Atayal fabrics from the Taichung Cultural Center: Beishi group (Miaoli County Taian Township, Taichung County Heping Township)1; Malikoan group (Nantou County Ren-ai Township and Sinzu County Jianshih Township)1; Quchi Group and Dakekan Group(Taipei County Wulai Township and Taoyuan County Fuxing Township)1; Nanao Group(Yilan County Nanao Township and Datong Township)2. The Sediq's samples are as follows: Wushe and Wanda Groups (Nantou CountyRenai Township)2; Taroko group(Nantou County Renai Townshipand Hualien County Hsiulin Township , Wanrong Township, Chohsi Township , Jianshih Township, and other areas of Hualien)6.

5. Conclusion

This sections sums up the above analysis of Atayal fabric color, for which, at present, there are a relatively large number of research specimens for sub-tribes such as the Tayal, which include the Beishi group and the Nanao Group, and the Sediq, which includes the Wushe Group, the Wanda Group, and the Taroko group. Our research takes these research samples and inputs them one at a time into ColorSchemer Studio's color software and performs colorscope analysis. The beshi Groups color use for fabrics is comparatively wide ranging and they use a diverse number of color combinations which mainly include black, white, red, orange, yellow, green, blue, and others.(Figure5-1). The colors used by the Nanao Group include black, red, yellow, blue, and others (Figure5-2). The Wushe Group and Wanda Group fabrics utilize the colors black, white, red, blue, and others (Figure5-3). Taroko group fabrics are white, red, green, blue, and others (Figure5-4). While this research presents a limited number of samples for research, through color an examination of color distribution, we can understand preferences in sub-tribe specimens tend to express themselves with similar colors, contrasting colors, and complimentary colors.

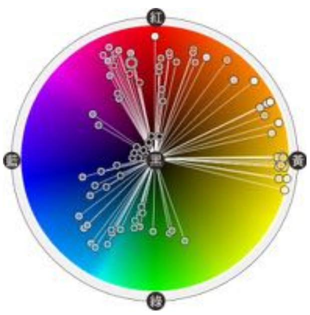

Figure5-1 Beishi group fabric color distribution (created for this study)

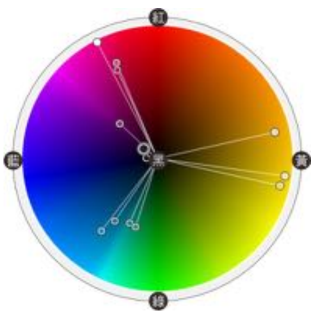

Figure5-2Nanao Group fabrics color distribution (created for this study)

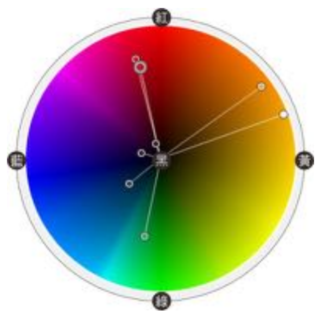

Figure5-3Wushe Group、Wanda Group fabric color distribution(created for this study)

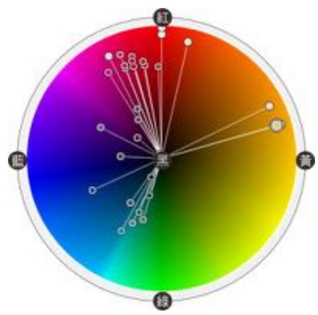

Figure5-4Taroko group fabric color distribution (created for this study)

REFERENCES

Mori Ushinosuke, 1917, Record of Taiwanese Aboriginals (Vol. 1),Taipei: Nantian.

Sato Bunichi, 1942, Research on the Primitive Art of Taiwan's Indigenous Races, Taipei: Nantian.

Suzuki Tadasu, Trans. Wang Mei-jing, 1999, Customs of Taiwan's Indigenous Peoples, Taipei: Yuanminwenhua.

Tien Tze-i, 2001, Taiwan's Indigenous peoples-Atayal, Taipei: Taiyuan.

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The language of color in textile design

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ABSTRACT

We live surrounded by fabrics, and the chromatic choice is one of the fundamental tasks of the textile designer. For a long time the decisions about the materials to be used, have been defined by the limited availability of them; currently with the myriad of synthetic materials both information and material open up to unimaginable possibilities for conceptual design. In order to decide the color composition, and conceiving that some communication occurs through the colors of fabrics, the textile designer has to face different environmental considerations: traditions, history, trends and fashions, i.e., the social codes. In the textile productions the references to their origins are underlying.

1. COLOR TEXTURE

To the texture of the color fabric we can approximate little by little ... approaching from a distance we can see the general tone and perhaps some contrast, a little closer we get to identify the forms, and even closer we can find the details and textures.

The color of a particular material is inherent to the structural composition of the bodies, to the observer´s perception, to the illuminating energy and to the material ways in which light is scattered. The technology of color makes the color; the material is the reflection face and it´s the stimulus that motivates potential sensations.

In textiles, the color is created. The fibers, dyes, and the ways to link them are chosen. To design fabrics also means to choose how color will be implemented: the selection of visible radiation emitted and reflected, and their ways.

Smooth or polished surfaces tend to reflect the light falling on a regular basis, and this usually causes the sensation of gloss. This feature can be seen in the continuous filament fiber produced synthetically, where the light is reflected uniformly generating a perception of greater glossiness. In the case of synthetic materials during manufacture it is possible to control their physical parameters, its cross section, the length fiber, hence the appearance can be variable from one to another. In contrast, irregular surfaces tend to reflect light diffusely in all directions, with multiple reflections within the same surface before being directed towards the observer, and generating as a consequence an assimilated matt appearance. These features are observed, for example, in short fibers of natural origin such as wool. A synthetic fiber could simulate the natural fiber effect, but, by definition, a natural fiber can not be predetermined.

The methods to altering the color of a fabric lie in the materials, the techniques and the technologies processed. Therefore, textiles have dissimilar characteristics according to their components, to their construction mode, and also to their surface finishes (all of this also defines the end use).

The smallest unit repeated in the fiber, or in the product of the union (whether physical or chemical) between fibers with the dyes, could be considered as a "cell" of color. While each "cell" would be defined by its uniqueness, a repetition of it in a considerable area would be noticeable as a color field. The extent of this repetition causes the quality textile surface and provides the unique visual color texture. The minimum unit texture could be smooth or rough, this can generate a more bright or more matt appearance, with smooth and regular texture or with a rough and irregular aspect.

This material consideration means that the same red dye from a cotton fiber generates a different color from the one that is obtained in a mercerized cotton fiber, and also differs from the color that is obtained in a wool, jute or silk fiber; by the same way that the color obtained in a synthetic fiber could have a brightness that not all the naturals fibers can reach to reflect.

Thinking about the color to be produced when a textile material is created, we have to consider a fourth dimension: in addition to hue, saturation and brightness, we have the matter: the material.

It is known that:

• The tone or hue is what gives the "name" to a color. The hues that are commonly defined with a simple name (one word), are those that have the particular characteristic to be different between them (are general and culturally "visible") and yet include in their appointment a variety of shades that match the same name and are delimited from each other. For each radiation a different hue is recognized. Considering the fabrics and how they reflect light, it is noted that, not just the physical surface affects the reflections; also the chemical components can alter the stimulus lighting, the selecting of a certain radiation emitting color, the slowing effects, the transforming energy, and thus the possibility to generate the variability from the tones, phenomena of phosphorescence or fluorescence.

• When the dye seems indeterminate, that is, lacking a prominent saturation, the vision and assimilation perceived as a neutral color, is known as desaturated. The saturation color is related to its intensity or strength. A saturated color appears in its full definition of the perfect (ideal) tone. And thus to desaturate this ideal tone, it means that begins to lose the characteristic strength, and the color is “turning off”.

• In turn, all colors are susceptible to tend to clarity, approaching to the white, or closer to a maximum darkness, associated with black. The reference of the *chiaroscuro* of a color, its association with light and darkness, provide the information from another dimension: the value.

• Referring specifically to the textile material, a new dimension of color appears: the "technology". It is linked to the surface of the material constituting the subject and the ways light is reflected: the physical aspect of color appearance.

2. TEXTILE MATTER

Signals

It is therefore color technology what first makes explicit and communicates its own material existence. In ancient times, the fibers and filaments used to produce textiles, as well as the dyes used to give a different color to the original, were obtained directly from nature. The textile production, from the first times, has provided information about a particular geography, a clime, a technology, a cultural situation, an economic development, also about the social, religious and psychological circumstances. The colorful textiles revealed their natural availability; making evident a particular fauna, a vegetation and a soil. Under these conditions their valuation was subject to the cost of the elements acquisition. Successive technological breakthroughs, and especially the development of chemistry, brought new colors to humanity. From mid-nineteenth century with the emergence of the first synthetic dye produced industrially: the Malveina (Perkin), and in continuing developments during the twentieth century, new processes, some families of dyes, regenerated fibers and the novelty of the synthetic fibers arrival appeared. These synthetic products extracted from oil refining, made possible their massive production and the consequent diversity of colors "invented". The material essence of the color ceased to show any geographical origin, and the variables of the evidence changed. Today the origin could be traced knowing the origin of a new technology, or a patent, or an innovate product such as inclusions of photosensitive materials. Anyway, the new background also shows the times, the chemical laboratory works, the production volume, and the trends. The new hidden plastics (still being constitutive of material), after a while makes that impacts occur, the effects are discovered in the public and private costs and benefits, and also through the valuations.

Fabric design. Senses

Taking into account that the textile material is an object that communicates, it can be noted that there is some coding and a valuation which generates that some people choose certain textile for one or another occasion, for whatever reason. Considering the diversity of the techniques (construction, interventions, etc.), the various criteria on which the choices about the color palettes and the way to use them can be based by the design objectives. The requirements could be outlined by basic needs, by specific issues, or by aesthetic surrounding like fashion or trends. The textile will be designed differently in order to cover basic necessities, or to satisfy a fashion product. In the first situation the design will seek to respond directly and with an accurate communication to capture the simple attraction; probably searching the known functional codes. In the second situation, even being functional textiles, the objective task will be to recognize the values and beliefs of a specific group. The textile functions could determine how the color could be used to signal something, to reflect a certain amount of light or create a particular intention feeling, maybe cause controversy, provoking dissimulation or some allusion. On the one hand the language of textile colors has plenty of expressive resources to communicate, but on the other, usually this codes use to be implicit. The "message" is the design, and the expected reception is the acceptance.

Focusing design, functionality, context to a particular recipient, it's possible to "talk" directly using basic resources to achieve understanding or, if circumstances allow, it is possible to play with the expressive resources. The goal is to recognize the user codes. Recognizing the design of fabrics as a creation of meaning, and color as one of its exponents, it can be seen that in these applications and materials exchange, certain communications are produced.

Codes

Substances or objects in the natural environment, referring to substances not colored by man, are characterized by a color that distinguishes and makes them particular, as in the case of the sun, the soil, vegetation, different metals, blood, skin color, cotton. Although these objects admit diversity of tone variations, it is their own texture what makes possible to identify and define them. However, when the color is re-created, the tone is given intentionally; the sign of this attribution begins to respond to a particular circumstance or intention framed in a context. The use of textile materials in their own color or texture or the formal representation of any element (whatever the technique of representation may be) which refers to a substance by the treatment and the use of color, allows a direct association with that object. The use of color devoid of direct relations with explicit denotations can cause or not formal references to specific configurations. Sometimes, the design emphasis is set on the information of the form, others on color; both are always together in variable proportions.

The material world of objects and colors created exceeds any manual of meanings; however the cultural constructions of both, objects and meanings, are circumstantial emergent about conceptions and availability. The meanings are often linked to beliefs, ideologies, trends, fashion or implicit paradigms, which for some reason, or perhaps need, are socially assimilated and accepted, resulting in the generation of a common code (implicit). Over time and with the permanence of the code, it's possible to generate a "stable" concerning net, to which the new creations can be associated (in a given context). So, when something is seen for the first time, it could be directly related to something already known and socially understood.

History, social experience and learning, show the imprints that persist referring to the context reflected. The establishment of codes of social meanings and "common", with respect to color and fabrics, in practice could be originated by various ways: by the evolution of certain facts, by the own gestation of color and the direct association to their use, by the spontaneous acceptance or recognition of a color to an object, or the code can be explicitly stated as a specific objective.

Associations are related to the functions or social roles, with symbols, iconic objects and any manifestation that begins to emerge and to be representative for a social group. The meanings generated by each particular individual, are conditioned by the natural and social aspects, respond to experiences, symbolic representations, structures of thought and feelings.

Different codes and therefore different criteria may face multiple factors such as the textile's functionalities, the applications, the users. Several examples are: textile fabrics, bedding fabrics, clothing, car interiors, wall covering, home or office decor, fabrics for sneakers, for a baby, for a tropical site, for the North Pole, for indoor or outdoor use, day or night, festive occasions, sporting, aquatic use, for the next season fashion: summer 2013 ...

Color palettes are recognized according to cultures, eras, styles, genres, codes for children, youth, reminiscent to the early civilization, to aesthetics of the visual arts, to musical, literature genres, theater, film, etc.

Knowing the language codes, these can be respected, broken, combined, made fun of ... it must first be recognized that such languages have limited duration, by the continuous history and the changes. The "established" meanings, symbols and iconography of the color (considering the miscellaneous possibilities to the materials and formals) act as flexible communication networks that are "held" by the social groups who recognize it.

The "militar" green has different meanings (and symbolic density) printed on silk fabric with a camouflage motif or on a cotton gabardine. In the same way, the same green will generate another meaning in a floral fabric. In turn, thinking about them in the used contexts, it is different the holiday beach scene or a naval parade. In both motifs (camouflage and floral) morphology and materiality reinforce and anchor the senses. In the first situation the green carries the weight of the cultural reference that gives name to color, so that the reference meets the role to be an iconic symbol. The same color, in the other situation (the floral), could be described by the same words but in this case "military green" does not carry the density of its military significance. In contrast, associations prompted by the floral motif will stimulate other sensations. Also the floral could diverge the senses; it's different if the flowers are blooming, fading or subtle. On the other hand, if any of those flowery were printed with the green "apple" that would change the history.

Each aspect has its own strength in the overall significance, and weights (visual, symbolic and representative) are balanced by the loads (content) to be allocated.

The textile's color design is projected conceiving the potential meanings which suggests. The textile composition and its use, counts with the wide polysemy of the color, with the forms construction, and carries the responsibility that comes with the transformation of the matter.

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Colour in Industrial Design

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ABSTRACT

Colour constitutes a multifunctional design element/mean in Industrial Design (Product and Transportation Design). With particular reference to the *Offenbach Theory of Product Language* this paper looks at the potential and the various functions of colour in industrial design, analyse its interrelation with other design elements, and suggest ways to improve the understanding and handling of colour during the design process, both in education and in practice.

1. COLOUR – A MULTIFUNCTIONAL DESIGN ELEMENT

A key issue of the design process is the question of how and which design elements/means can best translate various user needs and manufacturer intentions into concrete product performances. The following (simple and complex) design elements/means can be distinguished and used in industrial design: material, form (haptic, visual), colour, *cesia*, light, surface (haptic, visual), flavour (olfactory, gustatory), sign (optical, acoustical, haptic) and also functional principle and construction principle. (I see a further novel and complex instrument for design in "mediated reality" – in computer-generated superimposition, expansion and total substitution of the environment by virtual characteristics and information.) In this paper, we will take a closer look at the potential and the various functions of colour in industrial design, analyse its interrelation with other design elements, and suggest ways to improve the understanding and handling of colour during the design process, both in education and in practice.

In general, the function of colour in our environment can be indicative, symbolic, aesthetic. In its indicative function, colour (in combination with further properties of a surface) clarifies the stimulative nature (or affordances), utility and functions of an object (or organism), by affording information about its visual significance (e.g. signal effect, equivalent classification, sub-class, camouflage), state (e.g. ripe/unripe, hot/cold, aroused), material properties (e.g. metal, wood, stone, etc.), serviceability and functional structure (e.g. leaf *v.* blossom). Here colour is (predominantly) an indication of real qualities and practical properties of an object. In its symbolic function, colour conveys imaginary qualities of the object. It indicates immaterial values (e.g. red for a sports car creates the impression of speed and power) or it may assume arbitrary symbolic significance (e.g. the same red in a different context may stand for Socialism, the fire service or a particular brand). In its aesthetic function, colour can influence shape and the formation of the Gestalt. Determining factors are the formal aesthetic relations between colours (contrast, affinity, harmony, field size and distribution) and their (two- and three-dimensional) arrangement (cf. Oberascher, 1993).

These general functional categories may also (individually and in combination) be used systematically in industrial design, providing a considerable potential for the product designer. In all cases, colour serves exclusively for visual communication. (It is true that dark-coloured surfaces absorb sunlight more than light ones do, but a differentiated haptic perception of colours is not possible.)

In order to assess the significance and possible product benefits of colour in comparison (and in combination) with other design features, however, classification in a theoretical system or model can be helpful. Specialist literature (marketing, design theory, psychology, sociology) offers various approaches to organising product requirements, performance, function and effect.

Starting from theoretical works by Gros, Löbach and Schürer, Heufler (2004) presents a model of product functions. Basically referring to the *Offenbach Theory of Product Language* (see below), this model compares the practical product functions – analogously to linguistics – with product-language or sensory functions, divided into formal aesthetic and semantic functions, subdivided in turn into indicative and symbolic functions. Since this model has proved successful not only in the theory, but also in the practice of design, it is used preferentially at the Joanneum University of Applied Sciences in Graz, Austria. In addition, it combines well with the general colour functions mentioned above; this will be discussed later in more detail.

First, however, some fundamental reflections on the relation between colour and form. In visual perception, these are inseparable. In the visually perceptible world there exist no colourless forms. A form with no colour whatsoever (e.g. a completely transparent glass form) cannot be perceived visually. There must be a perceptible contrast between an object and its surroundings in at least one dimension of the colour space (lightness, hue, chromaticness) for it to be differentiated from its surroundings – that is, for a visual separation between *figure and background* – so that a form can be recognised. There are, however, colours without form. The blue of the sky, for instance, can be perceived as an isolated property. According to the classification of possible modes of appearance of colour carried out by David Katz in 1911, the blue of the sky is a "*field colour*" which, in contrast to "*object colour*" is perceived as not belonging to any object, but is simply extended, and cannot be localised in space. The eye can see into it, but not through it. Thus form cannot exist without colour, but colour can exist without form. The distinction between colour and form is not a visual process, but a mental abstraction. Visual shape, however, always consists of an integration of colour and form.

In the design process, form is generally treated independently of colour and generally given priority. This approach, frequently criticised by colour theorists in architecture, seems to be much more plausible for industrial design. Many commodities and investment goods must first of all fulfil physical (or "practical") functions, and often include a high degree of haptic interaction. Under this premise, form-finding should come first. Unlike colour, the form of things can be discovered using more than one sense – that is, with touch and sight. As long as physical properties, mechanical functions and handling of the product to be developed can be clarified, the colour factor may be left aside. But at the point where form is also regarded as a visual property, the question of colour can no longer be excluded. Colour can make huge optical changes to form, but form cannot change colour correspondingly. How colour contributes to the function of an object also varies greatly. For example, one could hardly make a football angular, no matter what colour it is; the colour grass-green, on the other hand, has no effect on the physical function of a ball, but would make any football match impossible

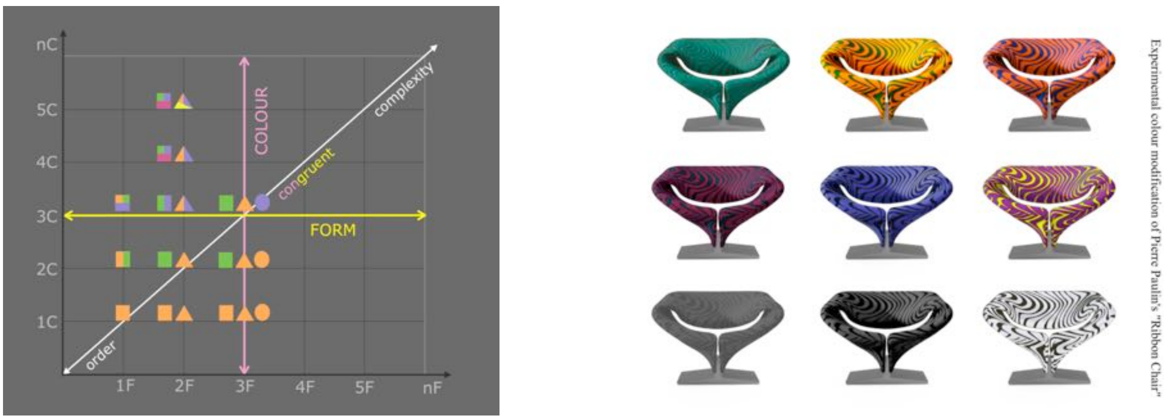
2. COLOUR AND THE "OFFENBACH THEORY OF PRODUCT LANGUAGE"

Gros and Fischer, of the Academy of Art and Design in Offenbach/Germany, adopt the terms "syntax" and "semantics" from semiotics, to describe functions in terms of product language. The semantic function conveys the nature and operation of the product (by indications) as well as ideas going beyond the practical use (by symbols); the syntax describes the formal-aesthetic rules of product design (cf. Steffen, 2000).

Colour and formal aesthetic product functions: With reference to findings in the psychology of perception and in Gestalt psychology (especially the tendency to a "good Gestalt", as postulated by Gestalt psychologists, and the Gestalt laws derived from this), the Offenbach psychologists formulated criteria for the formal aesthetic observation of design objects. Under the headings *order* and *complexity*, they established eleven design characteristics, such as simple/complex, symmetrical/asymmetrical, closed/open, equilibrium/disequilibrium. Raising the stimulus parameters and adding a variety of design elements increases the degree of complexity; lowering and reduction increases the degree of order (cf. Steffen, 2000).

Order and *complexity* are, however, only apparently opposing categories, as I aim to show by the combination/integration of colours and forms. Colour may be *congruent* or *incongruent* with form. Congruence is given when one colour is used for each form; incongruence, when several colours are used for one form, or several forms for one colour (see fig. 1). Thus for instance, a form may have a high degree of order, but at the same time, through the addition of several colours – giving an *incongruent* colour-form relation – a high degree of complexity. A fine example is Pierre Paulin's "Ribbon Chair", which is available single- or multicoloured (including a red-and-blue wave pattern by textile designer Jack Lenor Larsen). If we then add to the model the dimension of colour contrast (contrast in lightness, hue, chromaticness), the colour-and-form-related degree of order and complexity may be further differentiated. Thus all possible variants of colour-form relations can be systematically described. Moreover, this model can be expanded by further design dimensions such as *cesia*, surface structure/texture, etc.

Figure 1. Colour-and-form-related degree of order and complexity



Colour and indicative product functions: The indicative functions convey the type (product category), consistency and operation of a product. They mediate between person and technology by clarifying and visualising (or making susceptible to sensory perception) cause-effect relationship and use characteristics which are not directly perceptible. According to Langer, there must be differentiation between natural indications (e.g. smoke as an indication of fire) and artificial ones (e.g. a green light to indicate "Go!"). Artificial indications are arbitrarily established; natural indications have a natural cause-and-effect connection with their reference object (cf. Steffen 2000).

In the natural environment, colour is perhaps the most important (visual) indicator of all. As a (supposedly inherent) property, it directly visualises consistency, state and function (e.g. a brown leaf is wilted, red embers are hot, red fruit is ready to eat). In product design today, natural colour indicators for actual consistency and state (e.g. red-hot ceramic glass hob) are probably the exception. Metallic coating of plastic elements (visualised by a combination of colour and *cesia*) may give a plausible impression of metal or metallic, which may lead to false expectations and use. The fact that we still tolerate these "indication errors" is probably due to a feeling of being compensated by the symbolic product performance (quality rating, prestige, luxury, etc.).

Operating function, system status and properties are often conveyed by colour indications (e.g. red = standby, green = switched on; red = warm, blue = cold). These are as a rule artificial indications/symbols which are not self-explanatory, but the significance of which has to be interpreted (and learned) in the practical, situational, cultural context. A colour indication cannot always be naturally/artificially clearly assigned to one or other category. A dark base or pedestal conveys more stability (one of the functional indications mentioned by Steffen) than a light-coloured one, since dark colours are generally felt as "heavy" and lighter colours as "lightweight". But colour cannot indicate the physical weight (or inertia) of a body. Our perception of dark colours as "heavy" may stem from the circumstance that in the open air light falls mainly from above, so we normally expect objects to be light/illuminated at the top and dark/shaded at the bottom. (In nature, reversal of these conditions – e.g. dark clouds, light from below – is ominous and unsettling.) Thus a dark base lends an object more optical stability, because it appears in accordance with our system of (visual) experience of top and bottom.

Colour and symbolic product functions: Symbolic functions refer to meanings and ideas associated with a product. In contrast to indicative functions, they not only denote an object, but indicate its (emotional, social, cultural, etc.) connotations (cf. Steffen 2000).

Colour can contribute considerably and variously to the symbolic effect of products. Object and colour symbolism are mutually dependent; colour symbolism may be determined by the object (e.g. red in a warning light means something different from red in a bedside lamp); on the other hand, it can completely overlay the (original) object symbolism (e.g. the symbolism of pink would make all DIY tools seem like toys). Although each colour has many and ambivalent meanings, it is possible to distil from these a stable core meaning, which cannot be overridden by the coloured object. Today, for instance, yellowish-green is a symbol for "organic", probably because it signals fresh plant growth and the cycle of nature. By means of a yellowish-green label, a product can readily be positioned as "organic", whereas the colour of an organic product (e.g. a red pepper) does not signal it as "organic". Neither can red be taken as a symbol for "cold" or "cooling" (e.g. for a sunburn cream). Thus it is the meanings associated with the colour itself that "colour" a product connotatively. This is best demonstrated by representing a product in a variety of colours, and comparing the resultant connotations. Thus in my projects with design students at the Joanneum University of Applied Sciences in Graz, a black chain-saw was evaluated as "a professional high-performance tool, robust, heavy, expensive and loud", whereas a pink chain-saw was "a low-performance DIY tool, fragile, light, cheap and quiet".

Summary: For any given product, colour can fulfil indicative, symbolic and aesthetic functions (individually or simultaneously), thus offering industrial design multiple possibilities for formulating requirements as expressed in terms of product language. Colour can, however, also contribute to other (practical, ecological, economic) product functions. Take, for example, the problem of sustainability: if we use archetypal (and thus largely timeless) colours (such as black, white or red) rather than currently fashionable, "trendy" colours, the product life-cycle – that is, the acceptance and continuing use of a product – can be considerably extended.

REFERENCES

Heufler, G. 2009. *Design Basics – Von der Idee zum Produkt*, Zürich, Verlag Niggli

Oberascher, L. 1993. *The language of colour*. In *AIC Color 1993, Proceedings, Volume A*, ed. by A. Nemcsis and J. Schanda, Budapest: Technical University of Budapest, 18/1-4.

Steffen, D. 2000. *Design als Produktsprache – Der "Offenbacher Ansatz" in Theorie und Praxis*, Frankfurt, Verlag form GmbH

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oral paper

Colour Shift Behind Modern Glazing

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ABSTRACT

The necessity of a dramatic reduction of energy consumption in buildings causes the need for much higher energy efficiency. Regarding façades, the easiest way to obtain this is to reduce the size of windows. A conflicting issue is the resident's needs for sufficient daylight level, visual comfort and a nice view. To meet these seemingly conflicting needs, new glazing materials are being developed, to be used as transparent windows or transluscent façades. As these coatings and materials can be regarded as colour filters, they might cause colour shifts in interiors situated behind such glazings. The main goal of the project was to explore how much the colours change their visual appearance due to a given type of glazing and in which direction they change, e.g. hue and nuance. The study was carried out by observers in the overcast sky simulator at NTNU, and NCS colour samples were tested in a scale model, to which different glazing samples were fixed. All the tested glazings showed the same typical patterns for colour shifts. Although the colour shifts appeared somewhat weaker for the translucent glazings than for the transparent glazings, the tendencies presented are, with small variations, valid for all tested glazings.

1. BACKGROUND

1.1. Project background and objectives

In the global discussions about climate change and energy-efficiency, architecture has moved to centre-stage as buildings offer the biggest energy-saving potential. Until recently, most windows were made of double layer glass, but new demands have lead to a more widespread and accepted use of triple layer glass. For the same reason, new materials are being developed to provide better thermal insulation, especially for use in large glass façades.

The project has been carried out in conjunction with another project dealing with daylight utilization, glare and visual communication when using trasluscent facades (reported separately[1]). The project here presented deals with glazing and its perceived impact on the colours - and the contrasts between colours - in interiors behind different kinds of transpararent and translusent glazings.

The project is a pilot study exploring how different glazings can influence the perceived colours. The two main objectives has been:

- to find relevant questions and develop methodology for testing colour rendering properties of glass, and to form a basis for further research and future analysis of new glazing solutions.
- to evaluate and present colour rendering properties of transparent and translusent glazings available on the market in 2011, thus providing guidance to architects, designers or

[1] The Norwegian Research Council, project 526192- p10_011 Tanslucent facades. A guide for use of translucent facades will be published lated this year. Web address: www.forskningsradet.no.

contractors in the choice of glazing or the design of colour schemes for interiors lit with daylight filtered through such glazings.

1.2. The effect of glazing on perceived room colours

Whereas there are stricly formulated demands on the energy saving aspect of glazing, there are no regulations dealing with their impact on perceived light and colours inside the buildings. The colours that we perceive in a room are essential for our perception of the room atmosphere and for visual clarity and experienced quality of light.[2] A window glass or a translucent façade distorts the wavelength distribution of incoming daylight and thus is likely to affect our perception of colours in the room.

2. METHOD

2.1. Conditions

The experiment was carried out in the Artificial Sky in the Daylight Laboratory at NTNU, simulating a totally overcast sky, based on the CIE Overcast Sky model.[3] [4] Two trained observers made visual matching of colour samples seen behind the tested glazings and in a reference situation. Twentyeight (28) colour samples from The Natural Colour System (NCS) were chosen to give a wide distribution of hues and nuances, and used as reference samples.

The samples were places in a scale model (app. scale 1:10 of a bedroom), with two identical chambers. The model was covered with a non-reflecting black, matte paper, and hole on top allowed the observers to look into both chambers at the same time. All glazings were tested twice, with the colour samples seen against a white and a black background, similar background for both chambers. In order to give the colour samples the same illuminance, vertical blinds were used in front of the chamber offering the highest light transmittance.

2.2. Procedure

A reference colour sample were placed in the reference chamber and compared to the comparison samples placed behind the test glazing in the test chamber. The observers assessed which of a large number of comparison samples - two and two at a time - looked the same as the reference sample seen in the reference chamber. The aim was to investigate situations with both filtered and unfiltered light, or the effect of translucent versus transparent glazings, simultaneously filtering daylight into a room.

3. RESULTS

Observations against white and black background showed that colour shifts were slightly larger when the samples were seen against black bakground as when seen against a white background. This result was expected for two reasons; the importance of adaptation luminance and the fact that we use white as an anchor for judging all other colours in our visual field.[5] With both backgrounds, the colours shifted in the same direction. As our aim was to detect patterns and tendencies rather than exact measurements of colour shifts, we decided to use only the observations against black ground for further analysis.

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[2] Recent studies of the spatial interaction between light and colour have been carried out within the transdisciplinary Nordic research project SYN-TES. See Fridell Anter 2011 and Häggström & Fridell Anter 2012.

[3] For a comprehensive scientific presentation of the artificial sky, see Matusiak & Arnesen 2005.

[4] ISO 15469 CIE S 011/E Spatial distribution of daylight – CIE standard general sky.

[5] White as an anchor for judging colours in our visual field, see Klarén & Fridell Anter 2009.

Observations showed that surfaces with pale colours - with little blackness and low chromaticness - are very liable to shifts both in hue and nuance, whereas stongly chromatic, intense colours and dark colours tend to be much more stable.

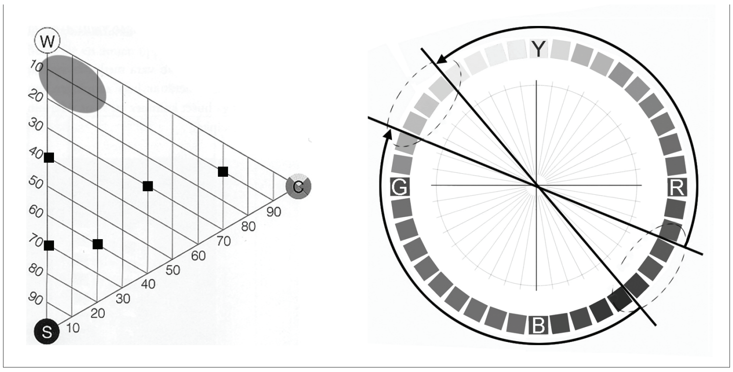

Figure: To the left; approximate area where the nuances proved sensitive to nuance shift caused by glazings (shaded area). The points show tested nuances that did not prove sensitive to such nuance shifts. To the right; principle of hue shifts.

Typical pattern for hue shifts is shown in the NCS circle; the pale colours seen behind the tested glazings in comparison with how they look in unfiltered daylight. The arrows shows the directions of the colour shifts; from a colour sample seen in daylight to the same colour sample as seen behind the test glazings. The figure shows only the directions, not the sizes of the colour shifts. The lines through the circle points to the violet and yellow-green "breakpoints" for the colour shifts. Different glazing can give various breakpoints. Within the oval, stippled areas, the colour shifts are therefore extremely difficult to predict.

Typical patterns for nuance shifts varies in different areas, here shown in the NCS tringle. Pale samples with nominally yellowish or greenish hues, and nominal neutral greys, tend to get the chromaticness increased when seen behind glazing. For samples with nominal hues between red and blue, the opposite was found and the chromaticness was typically reduced. The palest light blue sample assumed a distinct chromaticness in a hue between yellow and green. All these shifts seem logical, given the fact that all glazings had an obvious greenish colour and thus functioned as green filters for daylight.

4. CONCLUSIONS AND DISCUSSIONS

Results shows that the transparent glazing tends to give quite strong colour distortions compared to unfiltered daylight (e.g. open window), and that the tranlucent glazing have a similar pattern, although not as strong. However, these results were reached in a specific laboratory situation and are fully valid only in similar circumstances. The next, and very important, question is to what extent these shifts would occur in real buildings using these glazings.

The most important difference between the test situation and a complex real life situation is that in normal situations you are adapted to the existing light, and colour constancy will make you perceive the colour of a surface more or less the same as in another light situation. This means that you would not perceive these strong colour shifts in a room with the filtered light as the only light source. The existence of (near) white surfaces in the room would enhance the adaptation and colour constancy, as opposed to the totally black surroundings used in the test. On the other hand the colour constancy is considerably weaker in light very different from the natural light and its continuous spectral distribution.[6] Thus, the rule of adaptation and colour constancy cannot easily be predicted in situations other than the tested ones.

Still the tests give ground for conclusions that are essential for the perception of colours in real rooms. The range of colours perceived in the interior will decrease, which will make the totality look more dull and monotonous than when lit though an open window. The balance and contrasts between different colours will be affected, since in some colour areas the contrasts between different coloured surfaces will change drastically, and in different directions, when seen behind the glazing as compared to unfiltered daylight.[7] Since darker and more intense colours are much less affected by the glass, these things can mean that a colour scheme based on hue similarities or on subtle colour differences will change and maybe be ruined if the glazing is not considered throughout the design process.

If different light situations are combined in the same room, this will disrupt the adaptation which might make colours look very different in different parts of the room. For example, if a window - in a row of windows using low-energy glazing - is to be opened and lets in unfiltered daylight, the colours will be perceived dramatically differently. If we are adapted to the greenish light, the unfiltered daylight will be seen as redish blue and also more intense and bright. The daylight will reveal colour contrasts that can hardly be seen when the windows are closed, and certain colours in the room will change character dramatically. If transparent windows are placed in a translucent façade, the light coming in through the windows will be perceived more intense and slightly greener than the dim, diffuse light let in through the translucent glazing. How this will affect our colour perception depends on how we are adapted to the whole, and this will in turn depend on the location and the relative size of the two types of glazings.

In real buildings there are, in addition, a variety of different artificial light sources with different light colours and different colour rendering capacities. Their interacton has not been examined or discussed within this project.

REFERENCES

Fridell Anter, K. (2011) OPTIMA. *Metodstudie om färg, ljus och rumsupplevelse*. SYN-TES rapport 1, www.konstfack.se/SYN-TES.

Häggström, C. & Fridell Anter, K. (2012) *Belysningsförstärkande färgsättning av rum*. SYN-TES rapport 4, www.konstfack.se/SYN-TES.

Klarén, U. & Fridell Anter, K. (2009) *Så vitt vi vet. Nominellt kulörta färger som vithetsankare*. http://www.konstfack.se/sv/Forskning/Konstnarligt-utvecklingsarbete-KU/KU-projekt/Avslutade-KU-projekt-2009/.

Matusiak, B. & Arnesen, H. (2005) *The limits of the mirror box concept as an overcast sky simulator.* The Lighting Research & Technology.

Valberg, A. (2005) *Light Vision Color,* Chichester: John Wiley & Sons, Ltd.

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[6] For thorough understanding of the visual system and colour vision, see Valberg 2005.
[7] The importance of the contrast range is discussed in Fridell Anter 2011 p 38-40.

oral paper

Colorfulness and Reflectivity in Daylit Spaces:

Quantifying indoor color reflectance in terms of experience and performance

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ABSTRACT

Color reflectivity is valuable not only architecturally and aesthetically but also in terms of performance. The higher the reflectivity of a space the more evenly light is distributed in the space. Reflectivity can improve the performance of a building's system and also increases the occupants' sense of well-being. Given the benefits of color reflectivity, why are rooms not typically designed with reflective surfaces? The research focuses on the connection between daylight and color reflectivity, the perception and performance in understanding how to optimize reflectivity in interior spaces to improve lighting efficiency and visual comfort.

1. INTRODUCTION

The manipulation of surface reflectivity in order to alter our perception of space has a long architectural history ranging from the hall of mirrors at the Chateau of Versailles to contemporary examples such as the Chapel of St. Ignatius at Seattle University in Washington. In the Chapel built by architect Stephen Holl, reflectivity is used to reveal and highlight the texture of the plaster, giving it an arresting presence that causes us to focus on the diffuse surface. Reflectivity is not only valuable architecturally and aesthetically but also in terms of performance. Daylit spaces with high reflectivity distribute the light better, are brighter, and therefore more efficient. As the distance from the window increases, the available daylight in the room is provided decreasingly by the sky and increasingly by the reflectivity of the interior surfaces. Spaces that have high reflectivity have a lower contrast between the brightness of the light at the window and that of the interior room surfaces. Increasing reflectivity not only increases the daylight in a space but also distributes it more evenly, improving visual comfort. The effectiveness of daylighting as a strategy to reduce the use of electric lighting is increased by higher surface reflectivity. This is significant because 70% of U.S. electrical energy production is used by buildings, most of it for electrical light. Therefore daylighting is an important strategy for saving energy and reducing greenhouse gases that cause global warming.

Given the benefits of high reflectivity, why are rooms not typically designed with reflective surfaces? There are several anecdotal reasons that interior architecture tends to use interior surfaces of low reflectivity. Colors that are perceived to be richer, such as deep reds and blues, have low reflectivity. Dark colors and heavy materials, such as red velvet, still seem to be more elegant and valuable than light-colored linen. Likewise, dark wood finishes like mahogany or wenge, seem richer than light-colored ones like maple or ash. This is a result of our aesthetic values. (A social reason). Floor coverings that have lower reflectivity are seen as easier to keep clean. (A practical reason). Designers overestimate the reflectivity of colors. (A physiological reason) Our aesthetic valuing of deep colors thus conflicts with the high reflectivity that is more effective for daylighting.

HYPOTHESIS The average reflectivity of an interior space can be increased without changing people's perceptions of, for example, the color and reflectivity of the space.

2. SIGNIFICANCE OF THE PROJECT

In our research we focus on the experiment of testing and evaluating spaces. Using models, we will compare the measured reflectivity with human subjects' perceptions of the same space. In our project we conducted experiments using color games and models of rooms to compare subjects' perceptions of colors and reflectivity to actual measured reflectivity. Although these are preliminary experiments and results, the implications were of sufficient interest to continue the work. Observations have been collected, and since the set-up and models can be reconstructed anytime, the experiments provide a source of data. Multiple personal tests are now being conducted. The number of human subjects will be increased in a larger experiment.

Our hypothesis is that low reflective interior surface effects like rich color can be achieved with little change to the space's overall reflectivity. In the case of rich colors, some surfaces (for example, walls) play a less important role in delivering average room reflectivity than others. These walls for example, are candidates for locating color if those same surfaces are primary to the perception of the overall color of the space. The higher the reflectivity of a space the more evenly light is distributed within the space, diminishing the contrast in brightness between the window and the walls, which results in greater visual comfort. There are two ways that reflectivity apertures can improve the performance of a building's systems.

First, by saving energy: daylight is more efficient at providing light than most electric light sources, so less heat is produced for the same amount of light. Therefore, high reflectivity in a building can reduce not only the building's use of electric light but also its use of cooling energy. As a result, it can reduce peak energy use, as well as total energy consumption.

Second, visual comfort increases with the use of daylight because daylight is the light source that most closely matches the human visual response (psychological and physiological benefits). It often takes a lower level of daylight to perform a task than it would to perform the same task in electrical light. A good visual environment created by windows and reflective surfaces affects a person's ability to see objects in a room properly and to perform visual tasks. Reflectivity also adds a sense of spaciousness to a room, which makes it an important design element. There is an opportunity to develop integral design early in the design process that incorporate reflective surfaces to help satisfy the genuine desire to have natural light in a room.

4. GUIDING RESEARCH QUESTIONS AND EXPERIMENTS

A series of experiments were done to test the hypothesis. These experiments were designed to answer these questions: Can we achieve the perception of (deep/rich) colors while also providing reflectivity? How can the reflectivity of an interior be increased while maintaining the richness and depth of color to provide spatial variation?

Since everything we see results from emitted or reflected light, the reflectivity of surfaces in a room (walls, floor, furnishing etc.) is a large factor in how we perceive and experience the space. Diffuse surfaces determine the distribution of light in a space and their reflectivity determines the amount of light in the space. Beyond its aesthetic value, surface reflectivity determines how efficient daylighting is. For example, classrooms with a window on only one side average a daylight factor that varies from 0.7% when the average surface reflectivity is low, to 1.5% when it is high—a change of 50%. It is clear that high reflectivity is important, but most commonly used materials and finishes are not very reflective, as one can see from the measurements below. Final finishes for surfaces common in interior spaces, such as wood, linoleum, and fabric, have a maximum of 40% Light Reflectance Value (LRV).

Furthermore, the colors most often used for interiors are in the low reflective ranges, because designers typically overestimate the reflectivity of colors, and most of the colors available in the commercial color palette are in these low reflectivity ranges. The availability of high reflective colors in the “Off White” palette is also rather limited.

5. EVALUATION OF REFLECTIVITY. “THE COLOR GAME”

5.1 The first experiment:

The “Color Game” was an experiment set up to observe how people perceive colors, because their perception of color influences their choice of color—an issue of special importance to an interior designer. A set of 150 colors (matte surface) with a range of 0-90+% Light Reflectivity Value (LRV) were mixed up and divided into five groups of 30 different color patches. A matrix consisting of 10 different pages for 10 reflectivity percentage ranges (0-99%) was hung on the wall in a horizontal continuous line. On each matrix page were two rows of each four cells, each the size of the color patches. Under each column was a line, indicating that the result will be noted there. A group of 30 people was divided into six groups. Each group was given 30 color patches and had to rank the LRV of each one by putting it in the top row of the matrix. They then checked their conclusions against the actual LRV of the colors. If they had chosen the right color, the patch remained in the top row. Otherwise, it was put in the appropriate category in the cells below, with a remark on the line where they had it before. For example, if the LRV was 20%-29% and they had the patch in 40%-49%, they indicated +II. Out of thirty colors, each group on average correctly evaluated only five colors. Most of the other colors were perceived to have a higher LRV than they actually had. Most colors in the range of 30%-80% were perceived as having a 20% higher reflectivity than they actually had.

This shows that designers tend to overestimate the reflectivity of colors. Colors in the LRV ranges of 0-9% and 90+% were usually correctly perceived. Obviously these colors are easier to evaluate.

5.2 The colorfulness of color. The second experiment:

In this experiment, we looked at techniques that have been used architecturally, such as reflective surfaces. We used a set of experimental measurements to test anecdotal knowledge about the perception of color in space. Seven identical boxes, or models, were built out of black foam board so that no light could go through the edges. The inside was covered in white for high reflectivity. Each box was 8 x 8 inches in plan and 8 x 8 inches in elevation. One side had a central opening: a 2-inch square aperture, or “window.” On the opposite side was a central view port of half an inch diameter. The side, or “wall,” with the 2x2” opening was colored in a range of 7 different commercial colors, varying in Light Reflectivity Values from 0% to 99%. In this experiment 30 participants were tested for their perceptions of color. The boxes, each with a different shade of red on the inside surface of the wall with the window, were observed in different light levels. Observations (monocular) were made at a distance of 5 to 6feet. Despite the actual performance of the Light Reflectivity Value in the color range of seven shades of red, the boxes with the “LRV 40.2% and 37.8%” were perceived by most of the observers to be the most colorful.

This result contradicts the assumption that colors with the lowest reflectivity values are the most colorful.

5.3 The third experiment:

In this experiment, we built a series of boxes (as in the second experiment), or models of interior rooms, to address the question of reflectivity under changing room configurations. Each of the boxes represents a room with a window on one side, as described in the previous experiment. One set of boxes had the color at the window side. Another set of boxes had the color on all fives sides except the window side.

The project was designed to study the relationship between the amount (size) of color—and its location and reflectivity—and the human perception of it, along two variables:
How the daylight factor changes under the same light conditions; and
How people perceive the color of a room as the amount, location, and reflectivity changes.

The boxes provided a limited point of view. Participants could not see the whole space; they could only see the opposite wall with the window and a quarter of the neighboring walls. The experiment shows that the Average Room Reflectivity (ARR) changes very little within the range of colors from an LRV of 7% to 68 % if only one wall is colored. But the ARR changes dramatically when all five sides are colored. The question asked was: Which is the most colorful room?

Each version of the boxes tested (1-walls colored or 5-walls colored) showed the same result, which indicates how important the field of view is and that controlling the view is a way to make a space appear colorful.

6. CONCLUSION

These experiments showed that the eye is capable of making separate judgments about color reflectivity, and therefore the results provide a proof of our hypothesis: That designers/people overestimate colors and can't tell their Light Reflectivity by just looking at the color or the surface. That the most colorful colors are not necessarily the darkest ones and that the average rooms can appear very colorful without changing room reflectivity. The implications from these results are that designers should not rely on their intuition but need tools to optimize color reflectivity and the use of other surfaces and materials of higher reflectivity in interior spaces to improve lighting efficiency and visual comfort without losing the design effect. Daylighting is well documented, as is the architectural role of reflectivity, but the connection between daylighting and reflectivity and color reflectivity needs to be further explored. Further testing will be done to determine how position affects the perception of color.

Our hypothesis is that low reflective interior surface effects like rich color can be achieved with little change to the space's overall reflectivity. In the case of rich colors, some surfaces (for example, walls) play a less important role in delivering average room reflectivity than others and are candidates for locating color if those same surfaces are primary to the perception of the overall color of the space.

These results will be evaluated to find a rule for the perception of color, which will lead to design applications for the use of color in interior spaces. This will be pursued further in a large experiment.

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oral paper

Wide Area Color Signal Estimation from Reflected Image on Cornea Surface

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ABSTRACT

This paper proposes a method for estimating the wide area color signals of the surrounding scene from a reflected image on the cornea surface. While the conventional systems for estimating a distribution of the wide area color signals required specific and expensive devices and careful calibration, in this paper, the human eyeball is used to develop a simple imaging system without the specific devices. First, we show a corneal imaging system. Second, we correct geometric distortion of the spherically reflected image. Third, we estimate the spectral power distributions of color signals in the surrounding scene from the noisy camera outputs. Then, we extract the specular component of the reflected image on the cornea surface, according to the position of incident ray. The performance of the proposed method is shown in experiments in details.

1. INTRODUCTION

When we observe human eyeballs, we notice that the surrounding scene is reflected to the eyeball surface as an image. A part of incidence ray from the scene is specularly reflected on the cornea surface. This specular reflection image on the cornea surface includes useful information about the surrounding scene in wide viewing angle. In the previously proposed corneal imaging system (K. Nishino and S. K. Nayar. 2006), the specular reflection was used to reveal what the person was looking at. This work, however, did not intend to infer color signals, but intended to acquire the structure of objects. The conventional methods for estimating color signals in wide viewing angle generally used a mirrored ball (S.Tominaga and T.Fukuda. 2007) or a fisheye lens (S.Tominaga, T.Fukuda, and A.Kimachi. 2008). However, these systems require specific and expensive devices.

This paper proposes a method for estimating the wide area color signals of the surrounding scene from the reflected image on a cornea surface. The eyeball is used instead of the mirrored ball. It has a merit that we can estimate the wide area color signals in a simple measuring system. In addition, this method has a variety of applications in the image technology field.

2. CORNEAL IMAGING SYSTEM

The shape of the outer surface of the cornea can be approximated as a sphere. Because the cornea is transparency and smooth, it behaves like a window glass. The specular reflection image on the cornea surface has the wide visual field of about 160 degrees.

Figure 1 shows the geometry of light reflection on the cornea surface. A part of incidence ray from the scene is specularly reflected on the cornea surface, while the other part is transmitted into the inside of the eyeball. The transmitted rays can be classified into two passes according to the position of incident ray. One class of rays passes through the pupil, and the other reflects on the iris. Therefore, light reflected from the most part of the cornea is composed of the two components of diffuse reflection on the iris and specular reflection on the cornea surface.

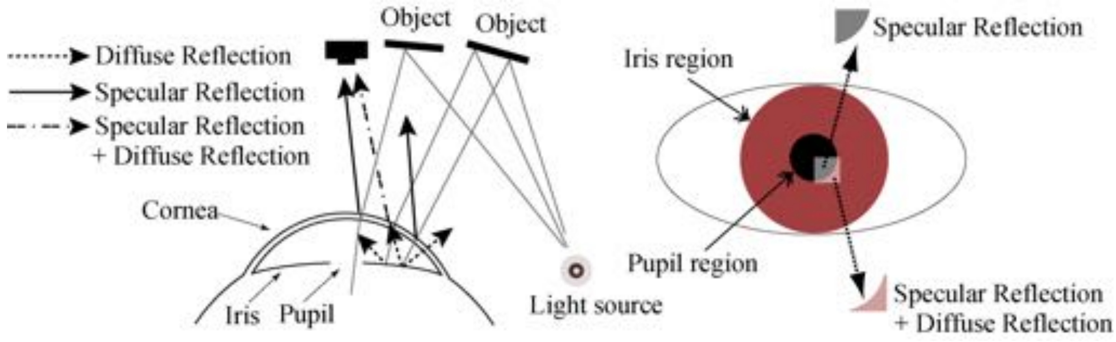

Figure 1. Geometry of light reflection on the eyeball.

3. GEOMETRIC IMAGE CORRECTION

We apply a simple gnomonic projection to correct the spherical geometric distortion of the reflected image. Figure 2 (a) shows a model of the gnomonic projection applied to the captured image on the cornea. The average radius of curvature r_c is 7.8 mm and the diameter of the iris d_i is 11.5 mm. *O* is a center of the corneal sphere. For each point on the sphere, we take the ray from the center of the sphere *O* through that point, and map it to the point where the ray intersects the tangent plane. Figures 2 (b) and (c) show examples of the captured image and the corrected image, respectively.

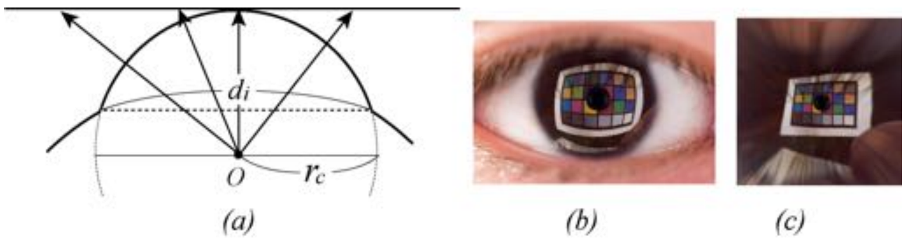

Figure 2. Geometric image correction of the captured image.
(a)model of the gnomonic projection, (b) observed image, (c)corrected image.

4. COLOR SIGNAL ESTIMATION

The Wiener estimator is used to estimate the spectral distributions of color signals of the surrounding scene from the corrected cornea image. The image sensor outputs ρ_i are modeled as a linear equation

$$\rho_i = \int_{400}^{700} E(\lambda) R_i(\lambda)\, d\lambda + n_i \qquad (i = R, G, B), \tag{1}$$

where $E(\lambda)$ is the color signal incident to the imaging system, $R_i(\lambda)$ is the spectral sensitivity function of the *i*th sensor, and the noises n_i are mutually independent, zero mean, and have a variance σ^2. Each color signal is represented by a 61-dimensional column vector by sampling the spectral distribution with 5 nm interval in the visible wavelength region [400, 700 nm]. Let $\mathbf{R}$ be a 61×3 matrix of spectral sensitivity, $\mathbf{C}_{ee}$ be a 61×61 matrix of correlation of the color signals, and σ^2 be the variance of camera noises, respectively. Moreover let $\boldsymbol{\rho}$ be a three-dimensional column vector of the RGB sensor outputs. Then, the estimate of the color signal vector $\mathbf{E}$ can be described as

$$\mathbf{E} = \mathbf{C}_{ee}\mathbf{R}^t\left(\mathbf{R}\mathbf{C}_{ee}\mathbf{R}^t + \sigma^2\mathbf{I}\right)^{-1}\boldsymbol{\rho}. \qquad (2)$$

To determine $\mathbf{C}_{ee}$, we used a database of more than 500 surface-spectral reflectance for artificial objects and natural objects, and a set of ten illuminant spectra, including an incandescent lamp and daylights.

Note that the color signals from the iris region consist of the specular reflection at the cornea surface and the diffuse reflection at the iris. On the other hand, the color signals from the pupil region consist of only the specular reflection. We assume that an object surface in a scene is captured across the boundary between the iris region and the pupil region. Let $\mathbf{E}_{\mathrm{I(S+D)}}$ and $\mathbf{E}_{\mathrm{P(S)}}$ be the estimated color signals for the iris region and the pupil region, respectively. Then the color signals $\mathbf{E}_{\mathrm{I(D)}}$ of the diffuse reflection for the iris is estimated as $\left(\mathbf{E}_{\mathrm{I(S+D)}} - \mathbf{E}_{\mathrm{P(S)}}\right)$. Therefore, the color signals of the specular component for the iris can be obtain by subtracting $\mathbf{E}_{\mathrm{I(D)}}$ from $\mathbf{E}_{\mathrm{I(S+D)}}$.

5. EXPERIMENTAL RESULTS

A commercial high resolution RGB three channel camera, Canon EOS 60D, was used to capture the reflected images on the human cornea surface. The image size is 2052×3088 pixels, where each color channel is represented in 12 bits.

5.1 Results for a Color Checker

For the detail analysis of estimation accuracy, the Macbeth Color Checker was placed in front of a human subject. We extracted the cornea from the subject's facial image and estimate the color signals from the respective color patches. Figure 3 shows examples of the spectral estimation results, compared with direct measurements by a spectro-radiometer. The vertical axis is normalized by the white patch's value of the Macbeth Color Checker. The root mean square error (RMSE) was computed between the estimates and the measurements. These suggest the accuracy of color signal estimation.

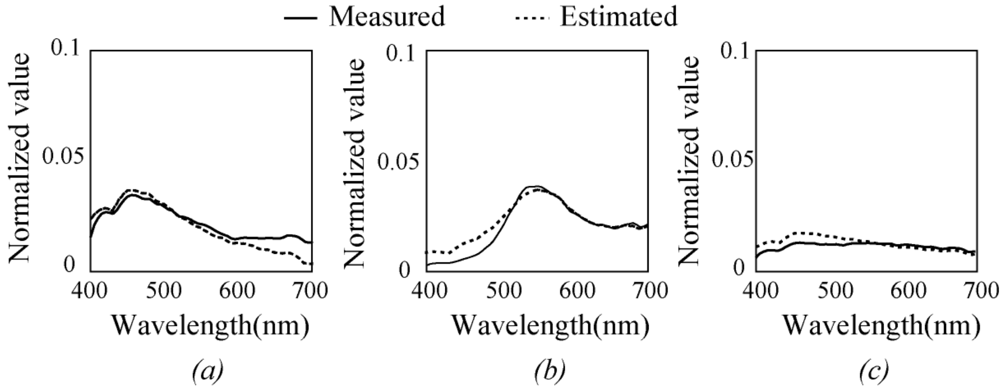

Figure 3. Estimation results for the Macbeth Color Checker.
(a) blue sky, (b) yellow green, (c) neutral 5.

5.2 Results for a natural scene

Finally, we examined the feasibility of the proposed method under natural environment so as to show that the method can provide reliable estimates of the wide area color signals. Figure 4(a) shows the captured image that was corrected geometrically and trimmed to improve the appearance of the object. Figure 4(b), (c), (d) show the estimation results of color signals for Area 1-Area 3 in the scene. The comparisons between the estimates and the measurements suggest the reliability of the proposed corneal imaging system based on the reflected image on the cornea surface.

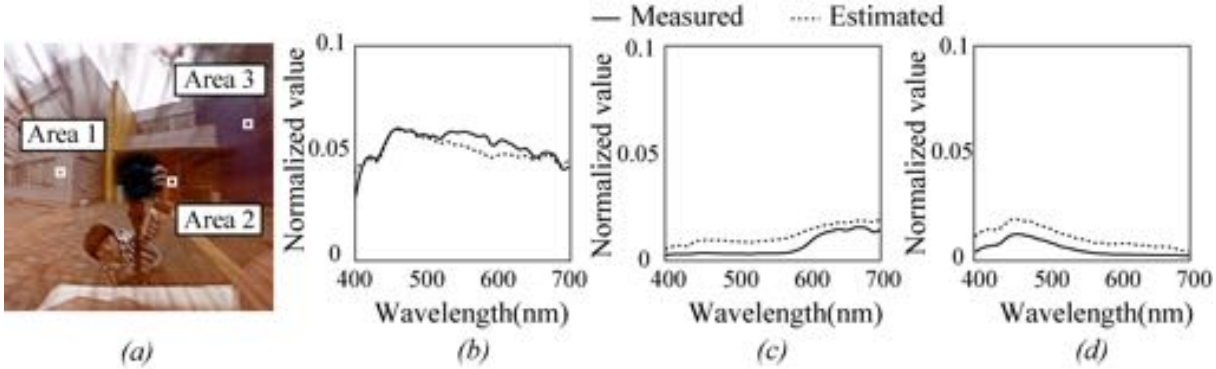

Figure 4. Estimation results of color signals for a natural scene.
(a) Captured image, (b)Area 1:Gray wall, (c) Area 2:Red door, (c) Area 3:Blue wall.

6. CONCLUSION

We have proposed a method for estimating the wide area color signals of the surrounding scene from the reflected image on a cornea surface. A digital color camera and the human eyeball were used to develop a simple imaging system without the specific devices. First, we showed the corneal imaging system. Second, we corrected geometric distortion of the spherically reflected image. Third, we estimated the spectral power distributions of color signals in the surrounding scene. Then, we extracted the specular component of the reflected image on the cornea surface. Finally, the experiments were executed in some scenes. The results demonstrated that reliable color signals over a wide area in a scene could be estimated by the proposed corneal imaging system.

REFERENCES

K. Nishino and S. K. Nayar. 2006. Corneal Imaging System: Environment from Eyes. *International Journal of Computer Vision* 70(1): 23-40.

S.Tominaga and T.Fukuda. 2007. Omnidirectional Scene Illuminant Estimation Using a Multispectral Imaging System. In *Color Imaging XII: Processing, Hardcopy, and Applications, Proceedings,* ed. by Reiner Eschbach, Gabriel G. Marcu. San Jose, 6493: 649313-1-649313-8.

S.Tominaga, T.Fukuda, and A.Kimachi. 2008. A High-resolution Imaging System for Omnidirectional Illuminant Estimation. *Journal of Imaging Science and Technology* 52(4): 040907-1- 040907- 9.

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oral paper

The Inconstant Colour of Green

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ABSTRACT

Studies of colour in space are complex. Many components need to be considered. Thus, the experience of a colour depends on a number of things: the individual's colour vision, illumination, the way the light is reflected, colours meeting in different distances in the room, the colours on various materials, colour phenomena, colours of adjacent surfaces and their surroundings. The subject of this paper is the inconstancy, the non-solidity of a colour hue. In a course this spring semester at the KTH School of Architecture in Stockholm, a group of students chose a ”soft, light and inconstant” green colour to work with; *a non specified green* to use their own expression. Some green hues are bluish and some green are yellowish but this green can change in all directions. The group of students staged a short urban experiment using the green colour by creating a film sequence. In this paper, via the student's work, I want to evoke and highlight this quite "anonymous city colour in everyday public space". The examination will be discussed in line with the theories of Heisenberg and Merleau-Ponty.

THEORETICAL GROUNDING

In physics, the *Uncertainty Principle* is an established concept. Quantum mechanics – the branch of physics that examines reality at the atomic and elementary particle level – can predict *probabilities* but never know with certainty what happens to the particle being observed at the micro-level outside the established laws of nature (Zukav 1979). The only thing that can be determined is what we observe directly in the very moment of observation, according to the German physicist Werner Heisenberg. We know what we have when the observation begins and when it ends, but we cannot speculate on the events in-between (ibid.). The Heisenberg Uncertainty Principle is the result of nature's ambiguity, that is, that the various processes of nature are characterized by uncertainty. The particles being studied are also affected by the study itself. – This relation of uncertainty can be translated into the consideration of colour. Since colour tones shift, regardless of the method of study and other circumstances, the colour can only be determined in the particular moment the colour is being observed.

The French philosopher Maurice Merleau-Ponty, for his part, brings forward an idea of perception as an unreflected experience (Merleau-Ponty 2004). His phenomenological philosophy focuses on perception, on how we apprehend colour in space, and he also describes perception. We take in and perceive the world, he says, as a *reduction*[1]:

> Thus my sensation of redness is *perceived as* the manifestation of a certain redness experienced, this in turn is the manifestation of a red surface, which is the manifestation

[1] In Husserl's *phenomenological reduction* (or *epoché* – refrain, do without), the world is divided up by uncovering the phenomenon being studied and placing the ingrained conceptions within parentheses – that which does not belong to the matter at hand is placed within parentheses (Olsson 2004: 32).

of a piece of red cardboard, and this finally is the manifestation or outline of a red thing, namely this book. (Merleau-Ponty 1967: xi)[2]

Here, "reduction" means that perceptual impressions are limited, the sensations are held together by colour. For example, via a redpainted wall, the things are gathered together into a common perception. A link can be established between nuances and other coloured things. Therefore, a dress is bound up with and interacts with – in its various materials, fabrics, and fibers – other red hues. It is worth noting that Merleau-Ponty focuses on the colour red. It is only the colour red that recurs in his essays. Neither green nor blue nor any other colour occupies his interest (to the same degree). Nevertheless, this paper deals with the complementary colour to red, the green.

COLOUR IN ARCHITECTURE

A course this spring semester, *The 5th Dimension: Colour in Architecture*, at the KTH School of Architecture in Stockholm, dealt with colour in architecture from ancient times to contemporary buildings. A special theme was the colours of the Middle Ages. Therefore, the course included a study visit to the National Historical Museum and the medieval ecclesiastical art exhibition with its polychrome altarpieces. Furthermore, the course showed the 19th century architects' interest in antique, medieval, oriental and vernacular colours. In line with the theme, the course discussed colour theory and colour phenomena. The students also had to observe the relation between the visual perception of colour and paint as a material. The course pointed out that colour is a material regardless of whether it is painted, a dyed fabric, a coloured piece of Plexiglas or a brick-red tile. Colour can also be applied as coloured light or be luminous through a glass painted window. Different colour materials exist in different cultures such as ceramic tiles in Islamic architecture, mosaic pieces in Byzantine basilicas and the red and blue patterned textiles in a Laplander village. Together with Johan Mårtelius, professor in History of Architecture, I was the responsible teacher for the course.

In the course the students' assignment was to analyse an allotted colour on a sheet of paper. Their task was to examine and pay attention to the specific qualities of the colour sample – for example, a blue colour is never only blue. The colour has a shade of darkness or lightness, and the blue hue can move towards green or red. The students should derive the colour historically and geografically from different epochs and cultures. In addition, they must consider how the searched colour may be used today. In oral presentations using Power-Point the students brought forward their results. In a next step, we created a lobby exhibition with the students' work. The exhibition showed the results of the course assignment: 22 groups – from the fourth and fifth grades at the school – worked with 22 different colour shades.

THE COLOUR GREEN

A group of students in the course chose a light and indefinable shade of green. The two students, Maria Teresa Almeida and Francisco Pinto Rocha from Portugal, guest studying in Sweden, examined the colour and stated that it is not a primary colour and not a solid colour. This green can change and thus carry many different names or designations. Instead of trying to attach the colour to a specific RGB code, the students Almeida and Pinto Rocha called it a

[2] Following Husserl, Merleau-Ponty use the concept apperceived in order to characterize "perception as such", a conscious apprehension of impressions in the form of "co-perception" (Merleau-Ponty 2004: note 47).

non specified green. They talked about their nuance of green as a process of oxidation, "a chemical alteration of copper". In addition to the oral presentation, the group created a short film (Almeida and Pinto Rocha 2012). In order to display how the "soft, light and inconstant" colour green functions in the environment, Almeida and Pinto Rocha staged a minor urban experiment. They took a piece of cloth in the same green colour as the sample, and filmed it in different locations around the city. We can notice that other colours are reduced, instead this certain colour appears and takes attention. The green exists in the context of the city, in line with Merleau-Ponty's saying that things are gathered together into a common perception via a colour.

THE COLOUR PARTICIPATES IN THE SURROUNDINGS

Merleau-Ponty writes about the red as various instances of *participation* in a larger perception, which, in the visual picture, also represents a *separation* and a distinguishing of various things that possess redness (Merleau-Ponty 2004: 255). The colour is like a knot in the fabric of the visible, an intertwining that is dependent on the surrounding structure. – If it does not fix the red, the red will resume its atmospheric existence, writes Merleau-Ponty. But in the existence, as well, the colour has a connection with the surroundings:

> The red color is yet a variant in another dimension of variation, that of its relations with the surroundings: this red is what it is only by connecting up from its place with other reds about it, with which it forms a constellation, or with other colors it dominates or that dominate it, that it attracts or that attract it, that it repels or that repel it. In short, it is a certain node in the woof of the simultaneous and the successive. (M-P 1968: 132)

The colours are perceived simultaneously, or as following upon one other, in order then to be incorporated in the fabric of the visual picture, or simply to become a part of the atmosphere. Being aware of this connection among various shades of red expands our perceptual ability. I interpret Merleau-Ponty's simultaneous or successive vision in two ways: partly that the red parts, by dint of their redness, are incorporated into a common visual picture; and partly that an interaction arises among the colours, which makes the redness emerge and be perceived.

Merleau-Ponty finds the red in the moment of a fixing and strengthening between nuances and coloured things (ibid.: 131). Exactly this is done in the film by Almeida and Pinto Rocha. We can fix our eyes on the green cloth, moving the eyes to the green facade, and further perceive the church roof coated with verdigris as the same colour hue. Moreover, when we turn our head from the film, the eye seeks out the green scarf belonging to a lady beside us.

TACTILE PERCEPTION

Our experiences of the visual have a connection with touch – it is the same body, the same observer, who looks and feels (Merleau-Ponty 1968: 134). The tactile belongs to the sense of touch, but the tactile is also apprehended by the eye. Because of its ability to move, it can be said that vision has the advantage in the perceptual process. Merleau-Ponty puts this as follows: the tactile "has been engaged to visibility" (ibid.). Nevertheless there is an "overlap" between the touched and the touching *and* between the perceptible and the visible (ibid.). Merleau-Ponty speaks of the intertwining of vision and the visible, and an interaction between them (ibid.: 139).

Already in his *Ten Books of Architecture* from the first century B.C., the influential Roman architect and engineer Vitruvius mentions our green colour. What is more, his designation is tactile when he uses the word *verdigris*, "aerugo" in latin, which means copper-rust or verdigris deposit: ”In Rhodes they put shavings in jars, pour vinegar over them” describes Vitruvius, and this they put in plates of copper. They cover the jars with lids to prevent evaporation, and after a time the copper is transformed into verdigris green (Vitruvius 1960: 219). The interaction of the original colour, the material, and the process of making gives the actual colour.

THE ELUSIVE COLOUR

Merleau-Ponty’s red colour is a pronounced strong colour. Aside from this, I think we can transfer Merleau-Ponty’s argument to our green hue. In the students’ urban study, we see how the green, so to speak, find other green things in the environment. The green becomes evident and tactile through the fabric’s flickering in the wind. At the same time, the green hue is elusive and constantly changing, in line with Heisenberg’s reasoning about the *Uncertainty Principle.* This green is particularly elusive depending on it’s light hue, and also because it is mixed up with several other colours. As we have seen, it does not obtain independence as one of the four primary colours: not as red, not as yellow, not as blue, not even as green. Nonetheless, our elusive green “has been engaged to visibility”, it overlaps and interacts with our entire urban space.

REFERENCES

Almeida, M.T. and F. Pinto Rocha. 2012. *22 non specified green.* Stockholm: KTH School of Architecture

Merleau-Ponty, M. 1967. *Phenomenology of Perception*. London & Aylesbury: Routledge & Kegan Paul

—. 1968. *The Visible and the Invisible.* Evanston: Northwestern University Press

—. 2004. *Lovtal till filosofin* [Panegyric to Philosophy]. Eslöv: Symposion

Olsson, G. 2004. *Färgperspektiv – kunskap och forskning om färg i arkitekturen* [Colour Perspectives – Knowledge and Research on Colour in Architecture]. Stockholm: Institution of Architecture, Royal Institute of Technology (KTH)

—. 2009. *The Visible and the Invisible: Color Contrast Phenomena in Space.* Institution of Architecture, Royal Institute of Technology, Stockholm: Axl Books

Vitruvius. 1960. *The Ten Books of Architecture*. New York: Dover Publications

Zukav, G. 1979. *The Dancing Wu Li Masters: An overview of the New Physics.* Cambridge University Press

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oral paper

Always Something Else
- Levels of experiencing colour and light

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ABSTRACT

This paper springs from a project about concept formation in the field of colour and light, and presents a graphic model describing possible constituent relations between colour and light experiences. A deeper understanding of colour and light experiences calls for a coherent and well-defined structure that can be used to describe connections and distinctions between experiences of different kinds. This also can contribute to understanding of how colour and light concepts are related to each other. We experience the world holistically. Our experiences of colour, light and space have many aspects. Their relations to different levels of experience always have to be considered.

1. BACKGROUND

Meaningful experiences of the world are parts of a coherent whole. We *see* colour and light, but what we so vividly, *experience* is a coherent spatial world full of life and meanings. There is a tight perceptual attunement between us and our environment. The experienced world is in ecological balance with the world around. Hardin (1993:xii) concludes that there is no "reason to think that there is a set of external physical properties that is the analog of the fourfold structure of the colors that we experience"

When perceiving colours our vision does not recognize the absolute intensity or the absolute spectral distribution of radiation that reaches our retina. Valberg (2005:286) states that, instead, *distinctions* and *relations* are registered. In this sense you could say that colour and light experiences are natural but non-physical.

Our visual system is developed for a continuous spectrum of light and gradual changes between different illuminations, and under these circumstances we perceive colours as more or less constant. Our visual sense adapts to current light conditions: What we perceive as white in a given illumination functions as a perceptual "anchor" for perception of lightness (Gilchrist et al. 1999) and hue (Klarén and Fridell Anter 2011).

Even if we experience that an object has almost the same colour in different lights, we can at the same time perceive a slight tone of colour that reveals the character of the light. For nominally achromatic surfaces this effect is more obvious than for nominally chromatic surfaces. We may experience that a surface is white, but we feel at the same time that it is illuminated with a light of a special colour and intensity.

Merleau-Ponty (2002:355) discusses how we experience the surrounding world in different ways depending on situation. He makes a distinction between two *modes of attention*: *the reflective attitude* and *living perception*. This distinction is significant to our perception of colour and light. In living perception colours are manifested to us in the totality of spatial relations. Depending on modes of attention, a nominally white wall lit by 'warm' sunlight can be seen (with a reflective attitude) as slightly yellowish or (with living perception) as the "proper" or "real" colour of the wall experienced beyond the perceived colour. We suggest that this spontaneous colour experience is called *constancy colour* (Klarén 2012:24).

All these colour and light interactions are what makes us perceive space visually. Normally we have no difficulties in making distinctions between what is caused by the light and what by the qualities of surfaces. The logically distributed colour variations caused by light, reflections and shadings are to our intuition natural and indispensable spatial qualities.

In addition to the basic perceptual processes and the direct understanding of the world around, human comprehensive experience of colour and light is also dependent of culture. Imaginations, conceptions and ideas *about* the world provide a context to our sense experiences. Noë (2004:1–3) remarks that adaptation is not limited to basic physiological reactions. It is both perceptual and cognitive and derives its origin from multiple sources, external as well as internal. Human experience of colour and light in space is made up from interplay of the individual and the world on many levels.

2. LEVELS OF EXPERIENCE

The human experience of colour and light is multidimensional and dynamic. Its totality cannot be easily described**.** Instead a deeper understanding of colour and light experiences calls for a coherent and well-defined structure that can be used to describe connections and distinctions between different levels of experience. This can also contribute to understanding of how colour and light concepts are related to each other.

Figure 1 shows levels of experience - from experiences based on *categorical* – basic – *perception* through *direct experience* of the world around to the *indirect experience* imbedded in cultural expressions.

2.1 Categorical perception

The *categorical perception* gives basic spatial and temporal structure to experience of the surrounding reality. It embraces the basic perception of colour, light and space; colour distinctions and colour similarities, perception of contours and contrasts, balance, verticality and horizontality, movement, etc. The ultimate purpose of categorical perception is to build a comprehensive mental image of the human world: "A reality without well-defined borders is divided up into distinct units by our perceptual mechanism" (Peter Gärdenfors 2000:20. My transl.) . By natural selection man has been endowed certain perceptive and cognitive tools for survival and this is basically common for us all. Categorical perception is in some respects determined genetically, but for the most part acquired in early life.

2.2 Direct experience

By direct experiences we gradually learn through living how to recognize and understand colour and light in the world around. Making use of natural perceptual abilities and interplaying with the physical world humans (and other living creatures) develop perceptual skills; we can intuitively catch the spatial significance of colour and light and the emotional content of spatial situations. Direct experience is dynamic, comprehensive and spontaneous; perceptions, feelings and emotions form a coherent whole.

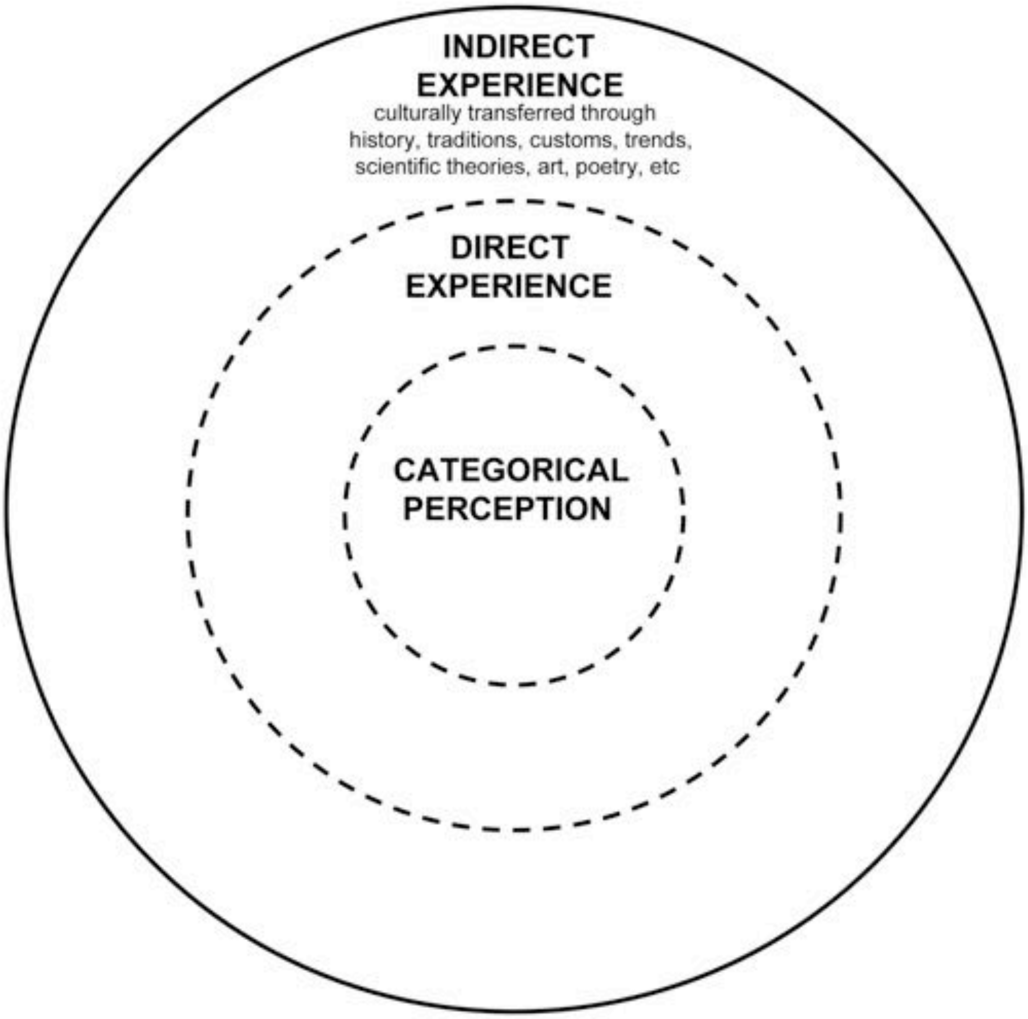

Figure 1. Experience levels (Model by Ulf Klarén)

2.3 Indirect experience

The outer circle embraces concepts and models that help to understand or give perspective to the experienced phenomena in the two inner circles. Indirect experience imbedded in cultural expressions – history, traditions, customs, trends, scientific theories, art, poetry, etc. – form a cultural context that all experiences of necessity are related to. History, scientific theories and theoretical models provide a basis of explanation and analyses, traditions and customs serve as guiding rules, art and design, literature and poetry summarize common experiences; art and design with expressive symbols and appearance of space, literature and poetry with symbols of language.

The cultural and social contents can change and be reinterpreted, but can never totally be taken in or controlled by the individual. It is implicitly present in all perceptions. Abstract figures or words can be associated with symbolic meanings; a colour combination, a special light or a space – as well as many other visual phenomena – may be associated to concepts or feelings. Thus indirect experiences can provide meanings and feelings to phenomena based on direct experiences and categorical perception. Cultural colour and light symbols are, however, basically social understandings. They are arbitrary and can be changed or replaced. Cultural symbols may not be mistaken for the intuitive and emotional content of direct experience.

Indirect experience can relate in different ways to phenomena described in the two inner circles. Concepts used for specifying spatial light situations or perceptual light qualities and concepts used in perceptual colour theory aim to describe a *direct* experience. Likewise a painting describing a special light and colour experience can serve as a concrete artistic 'model' for how we can attend to light and colour in the real world. On the other hand, concepts that describe the outer world in abstract terms based on physical analyses with quantitative *measurements* and *instrumental methods* have an *indirect* relation to experienced phenomena.

The three experience levels are mutually dependant and implicitly present in all perceptions. A perceived distinction between a red colour and other colours is a basic – categorical – perception. The experience of the colour of a wall – whether in light or shadow – is a direct experience of the world around. The knowledge that red has a special position in a colour system, or that red surfaces absorb electromagnetic radiation in a special way, or that red houses may be of high social importance, is based on indirect experience.

3. CONCLUSION

Colour and light are, indeed, "always something else", but our experience is not without structure or laws and there are certainly many concepts describing human experience. One could even say that there are too many – and disparate – concepts to be useful in communication. What is emphasized here, however, is the lack of a coherent and well-defined structure of content. The experience of colour and light has many aspects, and their relations to different levels of experience must always be considered. If colour phenomena are abstracted from their natural connections to light, spatial order and cultural context the causal relations behind them become inconceivable and mystified. Without a comprehensive structure of content it is not possible to see how different kinds experiences – and concepts – are related to each other, or in what respect they refer to different aspects of reality.

REFERENCES

Gilchrist, A., C. Kyssofidis, F. Benato, T. Agostini, J. Cataliotti, X. Li, B. Spehar, V. Annan and E. Economou (1999). An Anchoring Theory of Lightness Perception. In *Psychological Review* 1999, Vol. 106, no. 4, 795-834.

Hardin, C. L. (1993). *Color for philosophers: unweaving the rainbow*. Indianapolis: Hackett Publ.Company.

Gärdenfors, P. (2000). *Hur homo blev sapiens.* Nora: Nya Doxa

Klarén, U. (2012). Natural Experiences and Physical Abstractions – On epistemology of colour and light. In *Colour and Light – Concepts and Confusion.* Ed. by Harald Arnkil. Helsinki: Aalto University. Also available online on http://books.aalto.fi

Klarén, U. and K. Fridell Anter (2011). Colour and light in space: Dynamic adaptation and spatial understanding. In *Proceedings of the Midterm Meeting of the International Colour Association, Zürich, 2011,* ed. by Verena M. Schindler and Stephan Cuber (www.aic-colour.org)

Merleau-Ponty, M. (2002 [1962]). *The Phenomenology of Perception*. London, N.Y.: Routledge.

Noë, A. (2004). *Action in Perception*. The MIT Press, Cambridge.

Valberg, A. (2005). *Light Vision Color*. Chichester: John Wiley & Sons.

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oral paper

Color Naming Experiment using Plural Color Stimuli under Different Viewing Environments

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ABSTRACT

This paper analyzes the effect of the viewing environment on a person's color perception based on psychophysical experiments. In conventional psychophysical experiments for analyzing the color appearance, researchers have generally used a single color stimulus. However, in our daily life, we are surrounded by colorful objects in different viewing environments. In this paper, we therefore use sets of plural colors consisting of 90 PCCS patches as test color stimuli and analyze the effect of the viewing environment in which the colors appear on color perception. For all test color samples, ten environments are prepared by varying the following conditions: (1) visual medium: monitor and real patch; (2) background color: black, gray, and white; and (3) arrangement of the target color samples: ordered and random. As a result, we can classify the color naming results under the ten viewing conditions into three definite groups based on the cross-correlation coefficients. We then show that color naming results when plural stimuli are used depend on not only the display medium and the contrast effect generated by the background color but also the spatial effect generated by the display layout.

1. INTRODUCTION

The ability to specify colors by color names is considered to represent a higher level of color perception. Investigation of the color vocabulary that people use is important not only in the field of color science but also in other fields, such as linguistics and ethnology. In conventional color naming experiments using a priori clues, color patches were generally used under a standard illumination condition. However, in real-world scenes, most objects are seen three-dimensionally, which often include illumination effects such as gloss, shading and shadows on the surfaces. In our previous work, we performed the color naming experiment based on 2D or 3D color samples rendered on a display device, where a set of 15 basic color terms in Japanese was used for color specification (Tanaka et al. 2011). However, in this experiment, the viewing environment was fixed to the displayed colors.

This paper analyzes the effect of the viewing environment on people's color perception, where the target color samples are set up in the real-world and on a monitor. First, we develop a color term collection system. Second, we prepare various modes of presenting all the test color samples using different backgrounds and display media. Using our system, we then perform fundamental color naming experiments for native Japanese. Finally, we investigate the effect of the viewing environment to the subjects' color perception.

2. COLOR NAMING EXPERIMENTS

We used sets of plural colors consisting of 90 PCCS (Practical Color Co-ordinate System) patches as test color stimuli, and prepared ten different experimental conditions as shown in Fig. 1. We used two different display media, an EIZO ColorEdge CG221 calibrated monitor and real color patches for observing the color stimuli. For the monitor, we prepared three background colors: black, gray, and white. For the color patches, we prepared two background colors: black and gray. All test samples were presented in two different layout arrangements: ordered and random.

2.1 Color terms

We collected recalled color terms used in the modern Japanese language over several decades (Tominaga 1985, 1987) and found that a set of 15 color terms, comprising gold, silver, turquoise, and yellow-green in addition to Berlin and Kay's 11 basic color terms (Berlin et al. 1969), could be considered as consistently important color terms in Japanese daily life (Tominaga et al. 2010). We then designated these 15 color terms as a set of Japanese basic color terms, from which the subjects selected proper color terms in the experiment.

2.2 Experiment on monitor

Figure 2(a) shows a screen-shot of our color term collection system displayed on the monitor when the color patches were presented in an ordered arrangement. Each color patch is a rectangle measuring 10 mm × 16 mm (visual angle: 0.8° × 1.3°). The background for the entire color stimulus consists of a rectangle measuring 300 mm × 480 mm (visual angle: 25° × 40°). First, a subject selected one of the displayed 15 color terms using radio buttons located at the top of the screen. Second, the subject clicked on the appropriate color patches that represented the selected color term. The color term was then displayed on the clicked color patches. Figure 2(c) shows a screen-shot of the random arrangement displayed on the monitor. The size of the color patch rectangles and the background for the entire color stimulus were the same as in the experiment in which the colors were presented in an ordered arrangement. In this system, the subject was allowed to compare the color appearance among the color patches and replace the selected color term with the most suitable color term.

2.3 Experiment using PCCS real patches

Figure 2(b) shows the real-world test sheets that comprise real PCCS patches presented in an ordered arrangement. Each color patch was the same size as in the experiment in which a monitor was used as the display medium. The colored background on which the entire color stimulus was presented consisted of a rectangle measuring 270 mm × 380 mm (visual angle: 20° × 30°). A subject selected the appropriate color term from the 15 color terms, and wrote it down on an answer sheet. Figure 2(d) shows real patches distributed randomly. A subject picked a color patch and moved it to the tag of the most appropriate color term.

3. EXPERIMENTAL RESULTS

For 63% of the color sample, modal color terms, which were most frequently answered by the subjects, were the same between monitor images and real patches across all ten viewing conditions. However, at the boundary between different color terms, colors were assigned depending on the viewing conditions. We classified the color naming results under the ten conditions into three groups based on the cross-correlation coefficients of modal color terms for 90 colors, as shown in Fig. 3. (1) Group 1 consists of results by seven conditions: four with the black background and three displayed on the monitor. These results have high cross-correlation coefficients greater than 0.88 within the group. (2) Group 2 has only one result by the condition that comprises random distributed samples on the gray background displayed on the monitor, which has low cross-correlation coefficients to compare to the other conditions. (3) Group 3 consists of results by two conditions using actual PCCS patches displayed on the gray background color.

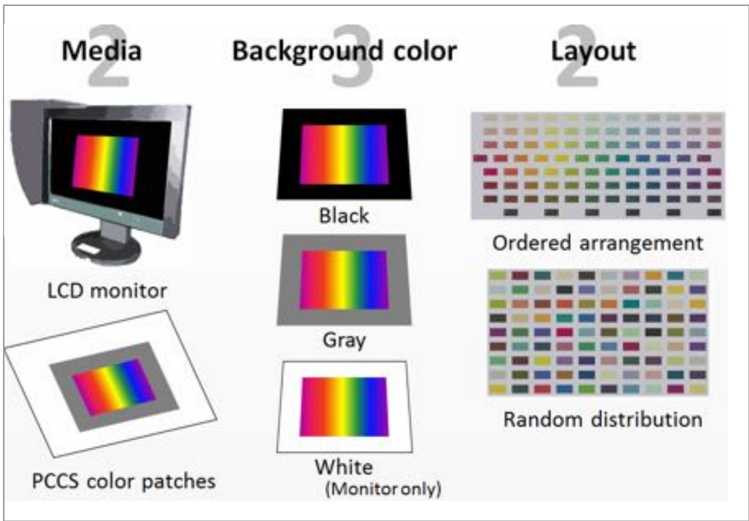

Figure 1. Combination of experimental setup.

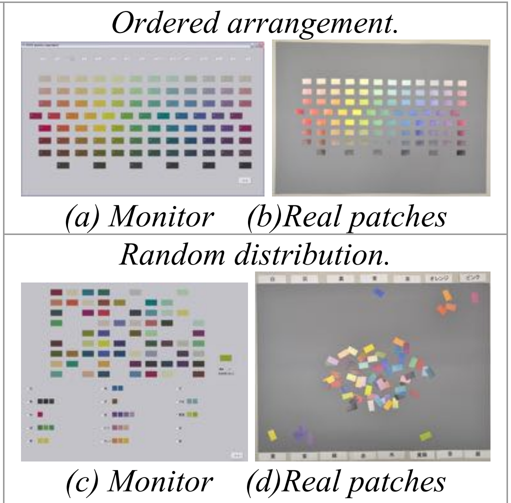

Figure 2. Experimental setup.

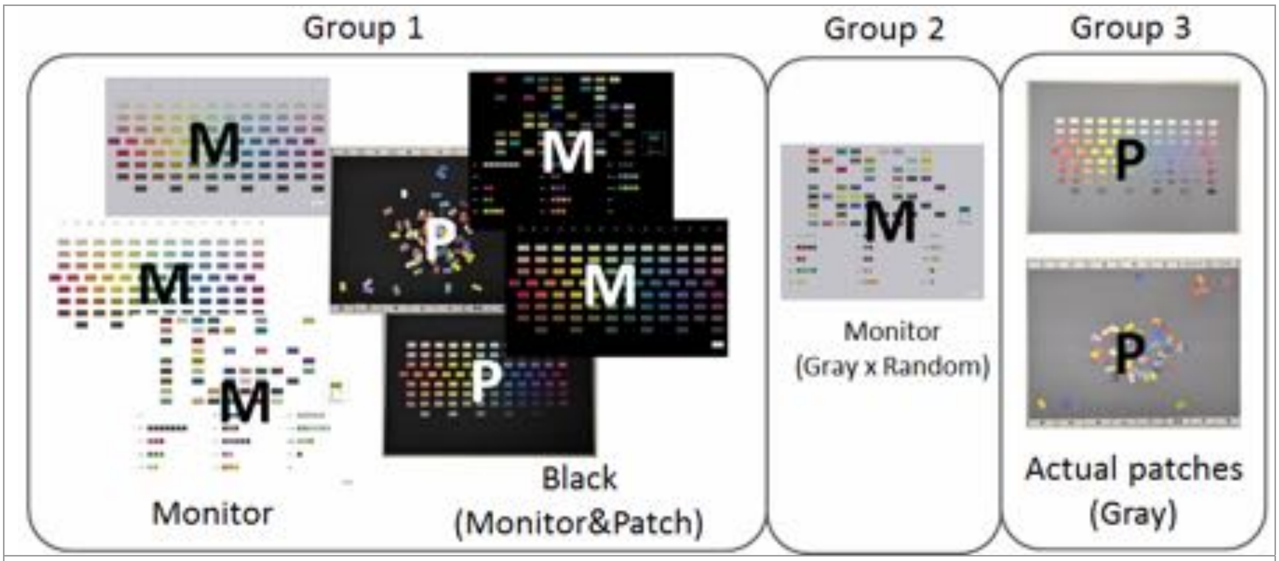

Figure 3. Classified color naming results.

As shown in Fig. 3, the results are summarized as follows: (1) color naming results using real patches were classified into different groups depending on the background color: black or gray, (2) color naming results using the black background color was consistent to all four conditions, (3) color naming results using the gray background color were classified into different groups depending on the display media. Interestingly, (4) two color naming results under the conditions with gray background and displayed on the monitor were classified into different groups depending on whether the layout was ordered or random arrangements. This result shows that color naming using plural stimuli depends not only the display media and the contrast effect generated by the background color but also on the spatial effect generated by the display layout. The subjects found that the random layout was more puzzling because of its complexity than the ordered arrangement layout. This characteristic was most evident in the case of color stimuli displayed on the gray background color when the contrast between the colors was low.

To investigate the issue more deeply, we prepared another random layout and performed the same experiment. The modal color distributions between the two random representations differed. This result shows that when a random layout is used, human color recognition becomes inconsistent. In real-world scenes, the colors are usually presented at random. Therefore, further consideration concerning the interesting results using plural stimuli is required.

4. CONCLUSION

We have performed color naming experiments using sets of plural colors consisting of 90 PCCS patches, and analyzed the effect of the viewing environments to color perception. Ten test environments were prepared for all the test color samples. The experimental results indicated that for 63% of the samples, the same modal color terms were given for all ten viewing conditions. However, we could classify the color naming results into three groups, based on the cross-correlation coefficients. In our experiment, when plural color stimuli were used, the color naming at the boundary between different color terms changed depending on how the color was presented. The results suggest that we should consider how the effects of spatial properties influence color naming in the real-world.

REFERENCES

Berlin, B. and P. Kay. 1969. *Basic Color Terms Their Universality and Evolution*. University of California Press.

Tanaka, M., T. Horiuchi and S.Tominaga. 2011. Color Naming Experiment Using 2D And 3D Rendered Samplers, in *Midterm Meeiting of the AIC, Proceedings*, 90-93.

Tominaga, S. 1985. A color-naming method for computer color vision. In I*EEE Int. Conf. on Systems, Man, and Cybernetics, Proceedings*. Osaka, 573-577.

Tominaga, S. 1987. A computer method for specifying colors by means of color naming. *Cognitive Engineering in the Design of Human-Computer Interaction and Expert Systems*, ed. by G. Salvendy. Elsevier Science Publishers, 131-138.

Tominaga, S., A. Ono, and T. Horiuchi. 2010. Investigation and Analysis of Color Terms in Modern Japanese. In *SPIE Electronic Imaging, Proceedings*, 7528, 752804-{1–8}.

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oral paper

WHAT IS A NATURAL COLOR? NATURAL COLORS AND CONSUMER EXPECTATIONS

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ABSTRACT

The purpose of this paper is to explore some relationships between color and the expectations of the user/consumer, regarding the concept of what is natural.

We have been developing a program at university whose main goal is not only to introduce design students to the study of natural dyes but also to impart knowledge that can contribute to the use of natural dyes as added value in textile products design.

In a preliminary survey, we tried to find answers to the following questions: What is a natural color? What is a natural colorant? We could observe that the concept of what is "natural", apart from the obvious relationship with nature, was associated to certain hues and to certain color perception linked to a feeling more than to an objective description.

The concept of purity appears to be linked to both material and symbolic factors. There is a clear dichotomy that contrasts natural-pure-unpolluted-ecological with industrial-chemical-pollutant. If we consider the categories of the expectations described by Hutchings and Ronnier Luo (2009), the colors defined as natural appeared as visually assessed safety.

We decided to determine with greater precision what aspects of visualization of the textile product are perceived as more "natural", given the positive assessment associated with such concept. To that end, a first broadening of the survey is being implemented, using a scale of semantic differential (more natural – less natural) applied to a group of ten colors, to five hues of the same color and to five samples of different textile materials of the same color.

1. PROJECT

Within the framework of the research project UBACyT "Color and light in urban spaces, design, and in the context of social and semiotic human practices", conducted by Prof. José Luis Caivano, we have been developing a program at university whose main goal is not only to introduce textile design students to the study of natural dyes but also to impart knowledge that can contribute to the use of natural dyes as added value in textile products design.

Part of the project activities have been previously presented in Nirino and Damiano(2010) and in Nirino(2011); more specifically those related to the development of dyeing processes and catalogs of dyed samples.

We started from the premise that the use of natural dyes can contribute to increasing added value in textile products. On the one hand, the cultivation of dye plants is suitable for the possibilities of Small Family Farming, a model of productive development that follows domestic strategic guidelines. On the other hand, there is a growing group of designers, users and consumers committed to sustainable design.

Rupérez (2008) states that

> "The area of economic benefit and environmental impact of positive value that we consider more sustainable is the desirable area, where the company's operations should

be carried out. It is the win-win area, where the benefits of the of the company's economy and the environment go hand in hand."

Therefore, it is fundamental to determine the most efficient way of carrying out and communicating this adding of value. With the purpose of beginning to understand the user's perception with respect to colorants and natural colors, two surveys were conducted, whose development is explained hereinafter.

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2. METHOD[1]

2.1 Survey No. 1

Characteristics: Exploratory research, non-probability samples, direct survey.
Number of people polled: 108, ages between 20 and 80.
The questions asked were: What is a natural color? What is a natural colorant? What products have natural colorants? What is the difference between natural and synthetic colorants? Which one do you prefer? Would you pay more for a product dyed with natural colorants? If we take a wool shawl that costs $100, how much more would you pay if it were dyed with natural colorants?

In this case, we will focus on the answers obtained for question No. 1

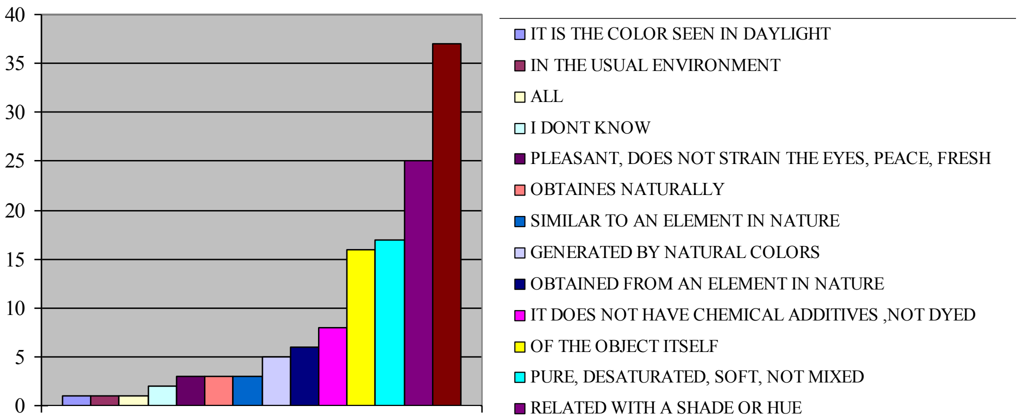

Table 1

RELATED WITH A HUE	
LIGHT	7
WHITE	3
NEUTRAL	3
GREENISH, YELLOWISH, BROWNISH, ORANGE	3
ECRU	3
BEIGE	3
LIGHT SKIN	1
GREEN	1
BASIC	1

We can see certain concepts that are repeated in the user's perception and that can be useful when communicating the use of natural colorants in a specific product and when the color palette of the product is selected. In the second survey, we wanted to corroborate if the colors and color parameters selected remained the same when showing their material samples to respondent.

2.2 Survey No. 2

Subjects: Thirty-nine persons (twelve male, twenty-seven female) between 20 and 70 years of age. Thirty-two of them have completed higher education (tertiary or university) or are attending college. They all live in urban areas in the province or in the City of Buenos Aires.

Semantic scale: A semantic differential scale with the word-pair "natural-non natural" with a 7-step scale was applied to:

[1]Due to limited space, only three tables could be shown

- a set of ten colors, identified through letters (see Table 2)
- a set of five luminosity values of two different colors: green and brown (see Table 3).
- a set of five blue materials (wool, linen, Tencel, silk, acrylic). In this case, respondents were asked to justify their choice.

Sets a) and b) are of dyed woolen top. This material was chosen since all the previous work associated to the surveys was conducted to improve the chain of wool value and because the material is more widespread in Argentina for the use of natural dyes.

The surveys were carried out by college students majoring in Textile Design, following the previous instructions.

3. RESULTS.

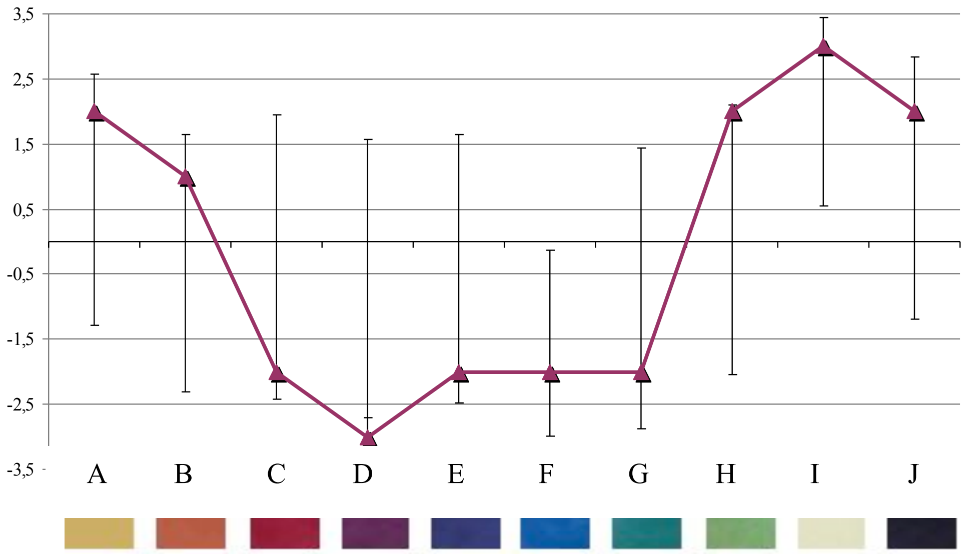

Table 2

A yellow
B orange
C red
D purple
E blue
F cian
G d green
H l green
I ecru
J black

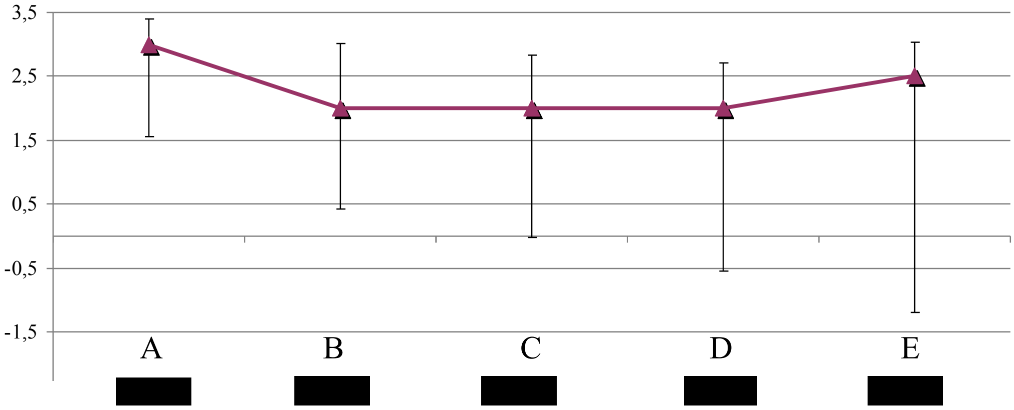

Table 3

The colors perceived as the most natural ones are first ecru and black. In this case, we can assume that they are influenced by their material appearance: they are two colors that can be obtained in wool that has not been dyed. Warm colors appear second, and cool colors appear last. The least natural colors are purple, cyan and bluish green.

In the green scale, there is a moderate predominance of the perception towards the non-natural pole; the least natural are the light hues.

In the brown scale, there is a marked preference towards the natural pole: the lightest hue is chosen as the most natural; thus, confirming the results of chart No. 1.

Tencel is the least natural, and linen and silk are the most natural. The perception of a rough surface, as opposed to one with a satin sheen, is the most usual selection basis. Nevertheless, these results are a bit confusing since, different from the other samples, many respondents touched them and their opinion was influenced by this other perception. As regards the hue selected for the samples, the perception of blue is confirmed as unnatural; the respondents clarified that what they consider natural is the material, not the color.

4.SOME CONCLUSIONS

Although the survey is not comprehensive, these initial results let us reflect upon some considerations.

We understand that the concept of "nature" and "what is natural" is a social construct. The perception that something has this characteristic is related to safety feelings and purity. If this perception is transferred to some of the aspects of a product, it will therefore have positive connotations.

When it comes to color, the most natural is the one perceived as "not dyed", not modified chemically. According to the user, the most natural color will be the one that it belongs to a specific materiality. Since these perceptions do not necessarily match the reality of the object, there is an ethical question related to the communication of the properties of the product. On the other hand, the use of natural colorant shall be transmitted in a specific way if we want it to be an adding of value.

On the whole, the assessments of the second survey confirm the color selection of the first, except for the case of green. A reason could be the particular hue of green selected, which is not related to the material of wool.

Finally, in this particular case, the use of wool samples seems to be a determining factor when selecting a value on the scale. It would be advisable to repeat the survey with various supports with the purpose of comparing the results.

REFERENCES

Hutchings, J. and M.Ronnier Luo. 2009.Appearance Science Applied to Design. In *AIC Color 2009, Proceedings*, ed. By Colour Society of Australia Inc., Sidney, Australia, 122.

Nirino, G and P.Damiano. 2010. Food colorants: its use in the dyeing of textiles *AIC Color 2010, Proceedings*, ed by Grupo Argentino del Color, Buenos Aires, Argentina.

Nirino, G. 2011, The Added Value of Natural Dyes in Product Design. In *ISEND Europe 2011, Proceedings*, ed. By ARRDHOR-CRITT Horticole, La Rochelle, France.

Rupérez, José Angel. 2008. *Ecodiseño. Necesidad social y oportunidad empresarial*. Zaragoza: Fundación Ecología y Desarrollo.

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SYN-TES
Interdisciplinary Research on Colour and Light

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ABSTRACT

Colour and light have largely been considered as belonging to two different fields of knowledge, having disparate theoretical, terminological and methodological traditions. This creates a ground for misunderstandings and obstructs a fruitful interdisciplinary and inter-professional collaboration. A survey over international research literature from 2006 -2011 shows that there has been only little research on the spatial interaction between colour and light, but that the interest for this area has recently increased. The interdisciplinary Nordic research project *SYN-TES: Human colour and light synthesis. Towards a coherent field of knowledge* was carried out during 2010-11. Colour and light experts from Nordic universities and companies investigated different aspects of the spatial interaction between colour and light and its importance for human beings. This paper deals with the general learnings from the process. Specific results are presented in other papers at this conference.

1. BACKGROUND

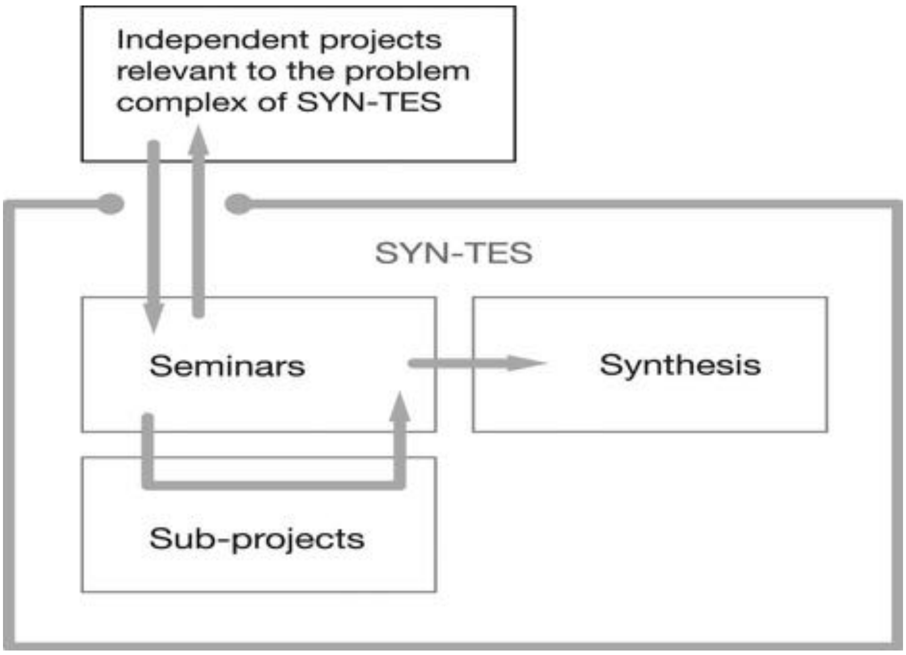
Colour and light are inseparable in our experience of the world and together form our visual experience of space. Until now, colour and light have, however, largely been considered as belonging to two different fields of knowledge, having disparate theoretical, terminological and methodological traditions. This creates a ground for misunderstandings and obstructs a fruitful interdisciplinary and inter-professional collaboration. The interdisciplinary Nordic research project *SYN-TES: Human colour and light synthesis. Towards a coherent field of knowledge* was carried out during 2010-11. Its main aim was to contribute to the elimination of barriers between different thematic, scientific and professional approaches and thus forward the development of a coherent field of knowledge, dealing with both colour and light from a multitude of starting points.

A survey over international research literature from 2006 - 2011 (Fridell Anter 2012a) shows that there has been only little research on the spatial interaction between colour and light, but that the interest for this area has recently increased. Two large conferences in 2010 - 11 (Zennaro 2010, Schindler & Cuber 2011) dealt explicitly with both colour and light, though most contributions still examined them separately. We therefore venture to claim that, seen in a contemporary international perspective, the trans-disciplinary approach that characterizes SYN-TES is unique.

2. TRANSDISCIPLINARY COLLABORATION

Within SYN-TES, colour and light experts from six Nordic universities and four large companies have gathered in totally eight workshops and seminars to investigate different aspects of the spatial interaction between colour and light. The participants come from the academic fields of art, design, architecture, health and care sciences, environmental psychology and visual pedagogy and from companies working with paint, lighting equipment and colour standards. Each of them was already active in research or development work regarding colour and/or light, which meant that everybody could give informed and relevant contributions to the discussions. Some seminars had a broader participation including practitioners from architecture and lighting design and a leading manufacturer of window glass. The main aim of the seminars was to learn from each other and together clarify positions, misunderstandings, agreements and disagreements. The process was allowed to take time and involved a gradually increased confidence, respect and sense of joint effort amongst participants with very different scientific and/or professional backgrounds.

Each seminar was held in the premises of one of the participating academic institutions or companies and included the use of experiment equipment, demonstration of production processes or other specifics that could mutually enhance the knowledge of the participants. Seminars were partly open also to other employees and/or students belonging to the hosting organisation. This gave each one the possibility to learn about other aspects of colour and light than those he/she usually worked with.



SYN-TES also included a number of sub-projects on more specific questions. Each of these actively involved researchers from different disciplines, and most often also practical /technical/design expertise from the participating companies. During the work, the subprojects were discussed in the seminar group and each of them had a double aim: On one hand to identify relevant questions and stimulate discussions within the seminar group. On the other hand to provide new understanding of a specific problem, involving colour, light and their interaction. Reports from subprojects were presented at the AIC conference in Zürich 2011 (Schindler and Cuber 2011, papers by Arnkil et al.; Fridell Anter and Klarén; Klarén and Fridell Anter; Matusiak et al.) and some more are presented in the AIC conference in Taipei 2012 (presenting authors Arnkil, Häggström, Klarén and Matusiak).

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3. SYNTHESIS OF DIFFERENT PROFESSIONAL AND SCIENTIFIC APPROACHES

The project highlighted a number of potential misunderstandings and supposed disagreements that had their origin in limited knowledge about different approaches and could be clarified through the discussions and joint practical research work.

One first and very obvious border ran between knowledge about colour and knowledge about light. In a slightly exaggerated way one could claim that those who choose the colours of a room and those who plan the illumination never talk to each other. An interview survey amongst Swedish architects and illumination consultants confirms the great need for educational efforts to bring colour and light specialists to understand each other. (Fridell Anter 2012b). In SYN-TES, one way of doing this was to formulate design tasks to be performed jointly by designers from paint and illumination companies. After full scale testing with observers, both the process and its result were discussed and evaluated by researchers and designers together. This promoted increased mutual understanding not only between experts of colour and light respectively, but also between the designers and technicians with their practice based knowledge and the researchers with their scientific theories and methods.

Another clear difference was that between on one hand natural sciences and technology and on the other hand perception and a knowledge based on experiences gained directly through our visual sense. In the first seminars this difference led to much confusion, and representatives of both sides found it very difficult to understand each other's viewpoints. Gradually we could sort out that many disagreements were really caused by confused terminology and by the fact that different professions or disciplines define their concepts differently.

4. MAKING THE RESULTS USEFUL

One important aspect of SYN-TES was to forward an enhanced interest for colour and light issues, within relevant professions as well as the general public. For this purpose, results are being presented in different forms, aiming at different readers:

- A series of Swedish language reports, addressing and designed for a broad readership (see www.konstfack.se/SYN-TES)
- A richly illustrated book meant for professionals and non-professionals interested in colour and light issues, in Swedish and hopefully other languages (forthcoming)
- A scientific book in English, specifically dealing with concepts and conceptual confusions (Arnkil ed. 2012)
- International conference reports and scientific articles, aimed at the international research community.

Educational efforts are essential when building a new field of knowledge. Several of the involved academic institutions have had a constant and fruitful interaction between SYN-TES research and undergraduate education of designers and architects. Research issues and results have been presented in lectures by active researchers and practitioners, and students have been involved as observers and in the development of pedagogic tools.

On the post-graduate level, a multidisciplinary PhD course on Nordic Light and Colour was held in Trondheim in April 2012, with participants from several disciplines in four Nordic countries. Within the companies that participated in SYN-TES, the project has resulted in a new approach to in-service training and courses for retail partners.

After completion in 2012 the project lives on as *SYN-TES Nordic Interdisciplinary network on Colour and Light*, open also for others than those who participated in the project.

5. CONCLUSIONS

SYN-TES has contributed to the formation of a new and coherent field of knowledge with the human experience of colour and light as its point of departure. The project has produced new knowledge that is fruitful for those working with colour and/or light in their daily practice, by:
- development and explanation of concepts, supporting inter-professional communication
- contributing to understanding of the spatial interaction of colour and light, supporting design and architectural work
- formulating and testing pedagogical and analytical methods of colour and light in space, supporting further educational efforts
- developing and testing scientific methods supporting the research of colour and light in spatial interaction

As part of the process, the group has found good ways of collaborating across disciplines and professions with mutual respect for each other´s competences.

The most important outcome of the project is the experience of creating trans-disciplinary understanding through active collaboration. We hope that the experiences from SYN-TES will stimulate others to convey similar work, gradually approaching the goal of transforming the fields of colour and light into one coherent field of knowledge.

ACKNOWLEDGEMENTS

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REFERENCES

Arnkil H. ed. 2012. *Colour and Light – Concepts and Confusions*. Helsinki: Aalto University. Also available online on http://books.aalto.fi

Fridell Anter, K. 2012a. Rumslig samverkan mellan färg och ljus. En översikt över aktuell forskning. Forthcoming on www.konstfack.se/SYN-TES

—— . 2012b. Om belysningsprojektering. Available online, www.arkus.se/. Accessed May 31 2012.

Schindler V. and Cuber S. ed. 2011. *AIC 2011 Midterm Meeting of the International Colour Association (AIC) Interaction of Colour & Light in the Arts and Sciences*. Zürich

SYN-TES: Human colour and Light Synthesis. Project website including reports from sub-projects www.konstfack.se/SYN-TES Accessed May 31 2012.

Zennaro P. ed. 2010. *Colour and Light in Architecture*. Verona: Knemesi

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A New Method to Correlate Music and Colours

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oral paper

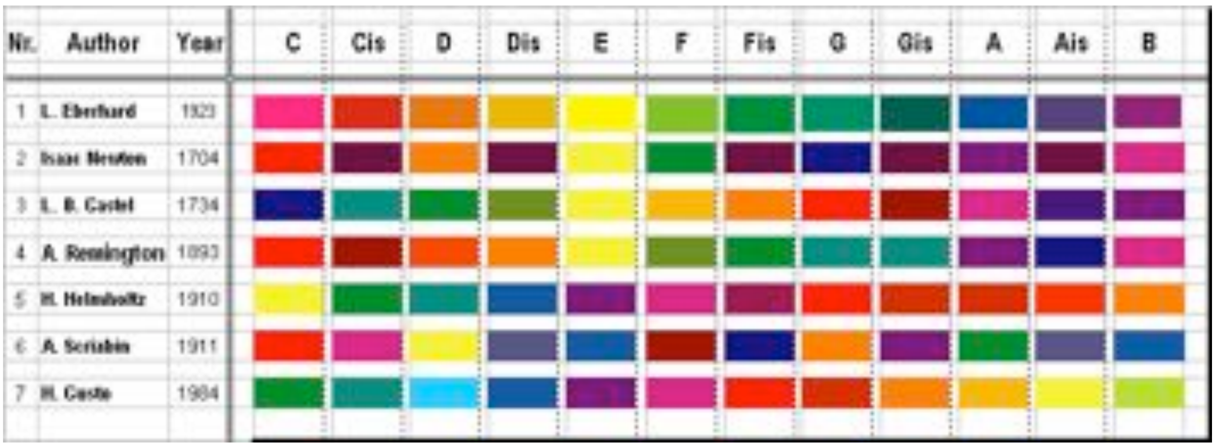
ABSTRACT

This paper describes a method to test the hypothesis that interval structures of the *Classical Music* are applicable to the spacing of harmonious colours. A special software/keyboard was developed to test this hypothesis. The work of *L. E. Eberhard* served as a basic reference. - The newly developed digital keyboard is using the *International Connotations* of *Classical Music*. An important feature of the software *CHSoft 1.0* is the high degree of adaptability. *Hue, Lightness* and *Saturation* of the colours of any of the 72 keys of the keyboard can be changed easily. Thus a multitude of different variables concerning the correlation of music and colours can be tested. - The test results using this software are still preliminary. The above hypothesis has not jet been proven nor disproved. *CHSoft* appears to be well suited for research on this and many questions.

1. HISTORICAL OVERVIEW

Whereas in *Classical Music* the analysis of sound patterns allows for the precise definition of consonances and dissonances, for colours there is no comparable mathematical model. A direct conversion/transferral of musical sounds into colours has often been tried, but the laws of physics don't allow for it, Steincke (2007: 64-69). There are many practical models to arrange for harmonic colours: 1. Comparisons with the rainbow, 2. Combining complementary colours, 3. Usage of various geometrical patterns, or 4. Applying the rules of *Classical Music* to Colours, Schwarz (1999: 87-140). The later method has been looked at by many researchers for centuries, Loef (1974), Schwarz (1999). They provided at least 28 different *Colour Sets* to be used, Hoegg (2009).

Table 1: A partial Listing of 300 Years of Music-Colour Correlations



Nr.	Author	Year	C	Cis	D	Dis	E	F	Fis	G	Gis	A	Ais	B
1	L. Eberhard	1923												
2	Isaac Newton	1704												
3	L. B. Castel	1734												
4	A. Remington	1893												
5	H. Helmholtz	1910												
6	A. Scriabin	1911												
7	H. Caste	1984												

Table 1 shows seven of these 28 *Colour Sets*, including the one of *L. E. Eberhard*. Surprisingly not even two of all the 28 C*olour Sets* were alike.

2. THE SOFTWARE CHSOFT 1.0

In 2004 the author, heir of *L. E. Eberhard (1880 – 1972),* founded *Colourmonics Studio*, a small research institute in Muenchen, Germany. The main purpose of it was and is to continue the research of *L. E. Eberhard*, especially her colour research, Eberhard (1957). Can the *Interval Structures* of *Classical Music* be correlated with the colours of *Colour Circles* at all and if so, is the *Colour Set* of *L . E. Eberhard* superior to others? To answer these questions it was necessary first to develop a software to facilitate the comparison of music and colours: *CHSoft 1.0*. This endeavour turned out to be more time- and resource-consuming than initially projected. By now it is ready for presentation and available for distribution (Windows only).

The principal functionalities of *CHSoft* are (Figure 1):

1. The **Upper left Area** of the Main Screen is to be used to show pictures or graphics for colour analyses.
2. The ***CHSoft Keyboard*** represents three octaves of a piano. The key "A" (blue) has a *frequency of 440 Hertz.* With the **+/-¼ Key** the in between-colours can be added. Thus there are **72 Colours** altogether to choose from. The most frequent colour is to be entered first. It defines the tonic (= Tonart) of the *"Musical Key"*.

   The colours of *Fig. 1* are the colours of the *"Master Palette 5"*. They were derived from scans of *L. E. Eberhards* colour tables, Eberhard (1957), with partial adjustments for metric and/or sensory equal distances. The lighter/upper and the lower/darker octaves have the same *Hues* as the saturated colours of the middle octave, but almost double respectively half the *Lightness*.

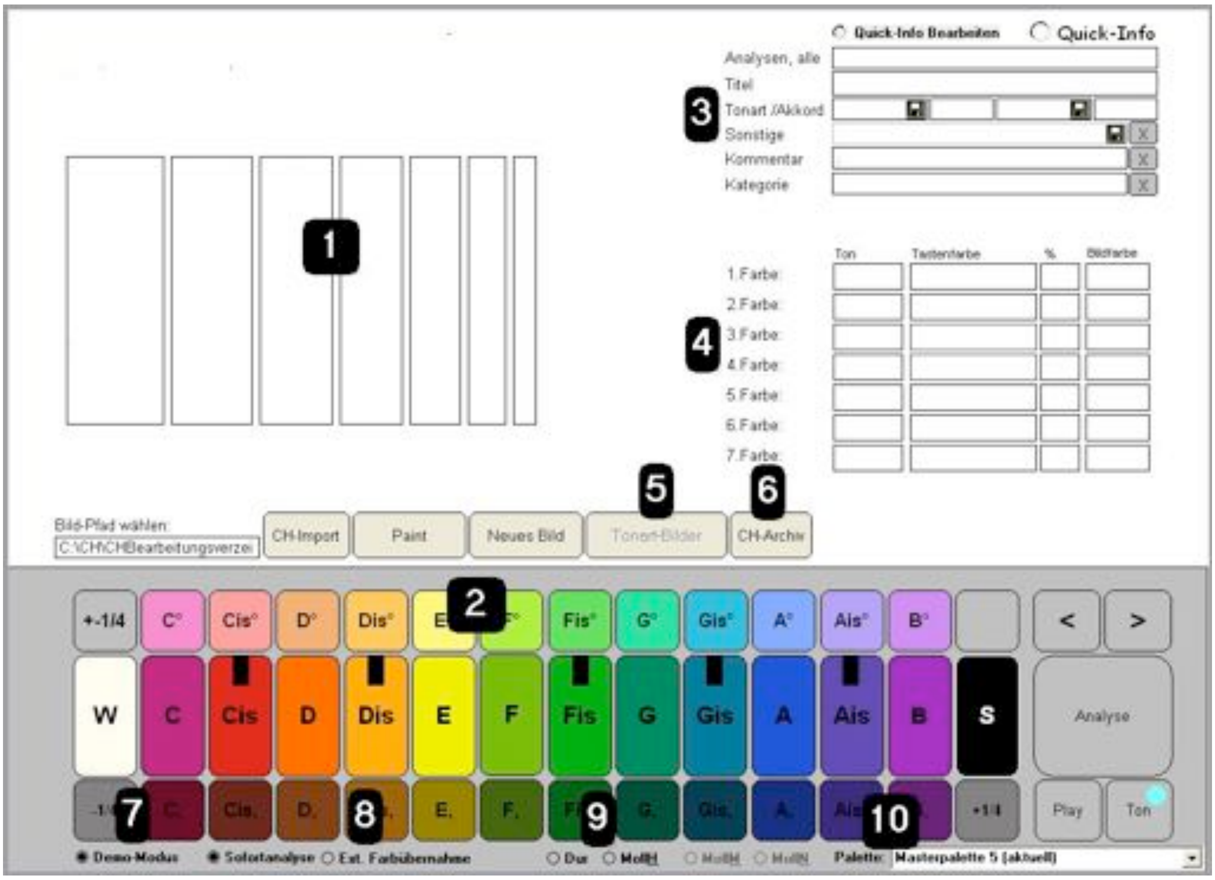


Figure 1: The Main Screen of CHSoft 1.0 with Numbers to explain it's Functions

3. The **Results Area** displays the *Musical Keys* and harmonies of the colours entered. Analogies to the interval structures of C*lassical Music* are applied. Analysed pictures/graphics can be archived and may be retrieved for further analyses.
4. The **Colour Display Area** shows the colours entered on the keyboard.
5. The folders of *"CH-Archive"* with their analyses can be **reviewed in Screen 4** (not shown).
6. ***"CH-Archive"*** can be opened directly to access all folders with stored pictures.
7. Switching to the *"**Demo-Mode**"* displays colours as columns, as delineated in the upper left area of *Figure 1*. This mode eliminates the distraction by specific picture contents. Full scale printouts of any colour combinations for test purposes are feasible.
8. The **Colour of any Key can be changed** ad lib. Precise RGB- or HLS-values may be entered. *External Colours* may also be used.
9. The ***Stencil Function*** marks all the seven notes of a chosen Musical Key. There is only one button for **Dur/Major** but three for **Moll/Minor**.
10. The field **"Palette"** allows for choosing one of twelve predefined palettes or to create new ones. After a palette has been changed pictures in *"CH-Archive"* can be viewed with the altered colours.

Further information on *CHSoft 1.0* can be found in the *User Manual CHSoft 1.0*, Hoegg (2012).

3. PRELIMINARY RESULTS AND CONCLUSIONS

Within the framework of this study *"Master Palette 5"* was used as a reference (see above). After analysing and evaluating hundreds of pictures this palette seems to support the hypothesis that the *Interval Structures* of *Classical Music* may be used to define pleasant colour combinations, specifically in the Living Nature.

However no standardized testing has been done so far. In the literature there is only one short reference to a specific test procedure, Parry (1941). *CHSoft* facilitates testing with its "Demo Mode". Using it the printout of Din A4 tables is planned. Various interval structures shall then be assessed by certain numbers of test persons.

The 72 colours of the *"Master Palette 5"* are in part the result of the personal judgement of the author and his staff. It might well be possible that changes of the *Hue*, *Lightness* and *Saturation* of the keys of the Keyboard could yield better results.

AKNOWLEDGMENTS

The development and completion of CHSoft 1.0 was made possible through the programming of Philip Koll, CSNA and Thorsten Siebert, IT-Soft, Muenchen.

REFERENCES

Eberhard, L. 1957. *Welche Farben waehle ich?* Muenchen: Deutsche Bekleidungsakademie. Also partially available online, http://www.colourmonics.de/index.php/farbsysteme/buch-und-farbvorlagen-von-l-e-1957

Hoegg, U., 2009 Historischer Ueberblick: 28 Arten Toene und Farben zu korrelieren. Available online, http://deutsches-farbenzentrum.de/2009/11/historischer-uberblick-28-arten-tone-und-farben-zu-korrelieren/

Hoegg, U., 2012. User Manual CHSoft 1.0, PDF. Available online, http://www.colourmonics.de/index.php/support/handbuch-faq
Loef, C., 1974. *Farbe, Musik, Form*. Goettingen: Muster-Schmidt.
Parry, J. B., 1941. Aesthetic appeal of Oswalds Chromatic Standards. *Nature* 147: 782-783.
Schwarz, A., 1999. *Die Lehren von der Farbenharmonie*. Goettingen / Zuerich: Muster-Schmidt.
Steincke, D., 2007. *Bildgestaltendes Verstehen von Musik.* Wuerzburg: Koenighausen & Neumann.

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Color in the Argentine Delta House

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ABSTRACT

The Parana River on its journey of 4,000 km. from Sierra do Espinhazo, N.O. of Rio de Janeiro, Brazil, before flowing into the Rio de la Plata is forming a delta of approximately 1,750,000 ha. Sastre (1940), Borodowski (2004). The Argentine Delta, an active delta, that grows constantly, is an unspoiled natural phenomenon, resulting from settlement of fertile silt and lush vegetation on a vast archipelago of 40,000 km2, area equal to half of Belgium, with 2,500 km of waterways in more than 500 rivers and streams at only 32 km. from downtown Buenos Aires, where many have chosen to live, permanently or temporarily. The Delta goes forward due to the continuous contribution of sediments that assured its development through the centuries. The group of islands expands downstream to Buenos Aires 100 mts./year. It has hundreds of rivers and canals, and more than 3500 islets with abundant vegetation. The only way to move along the Delta is via fluvial, by boat. The 60% of the 350 rivers are navigable. Kirbus (1980).
Stilt architecture is the dominant architectural feature of the Parana River Delta, developed to survive the permanent threat of the flooding of rivers which in a few hours can leave the islands under water. Colours of the houses already belong to the cultural patrimony of the region.

1. ABOUT ITS HISTORY

The earliest inhabitants of the islands were indigenous groups called guaranies. Since long before the Spanish arrived on the banks of the Rio de la Plata in the early sixteenth century, the current land of Tigre was sparsely populated. On the islands several burial mounds of indigenous peoples Guarani canoeists have been found. They lived by hunting, fishing and of small palm coconuts and some of them growing corn, peanuts and beans. The arrival of the Spaniards caused the flight of the indigenous peoples who abandoned their secular habitat. Ruiz Moreno (2004). The area was first settled after the second founding of the city of Buenos Aires by Juan de Garay. Documents from 1580 indicate the lands had been distributed to Spanish colonizers and also to indigenous encouraging sedentary. Dominant house type was the hut made of mud and straw. Sastre (1940)

Tree centuries later, when Domingo Faustino Sarmiento (1811-1883) inspected the area while fulfilling his role as chief of the Department of Schools, the area was sparsely populated. Sarmiento fell in love with the Delta and constructed the first of the typical wooden houses (1) now seen throughout the delta.

As President of Argentina (1878-1872) he was instrumental in the development of the area.

He fought for the right of settlers to own the land they were working on and encourage residents of Buenos Aires to purchase land and construct homes in the Delta. Sarmiento (2011).The aristocracy of Buenos Aires followed Sarmiento's lead and purchased entire islands and built homes for weekend getaways or investment. The

encouragement given by Sarmiento coincided with the beginning of the significant immigration process, newly arrived European immigrants, Ukrainians, Hungarians, Poles, Italians, Spanish, French, Russian, Basque, which in the last third of the nineteenth century doubled the population of Argentina. Debenedetti (1977). The islands became economically important and part of those immigrants settled there. Cultivation of wicker, osier, flax, fruits and it products became very important. During the second half of the 19th century the area became not only economically but also socially more important. In 1865 the railway line arrived to Tigre, the continental part of the region, from which the boats depart to the Delta. The train eased trade in Delta products, allows the visits by city dwellers, favored the setting up of recreational camps, places to spend a journey on the islands and aroused the interest in rowing. Giesso (1999).
As the only way to move along the Delta is via fluvial, the post, warehouses, library, the bank and even the Catholic chapel (up to 1952) use motorboats.

2. DWELLINGS IN THE DELTA

Construction materials for the dwelling were adobe, straw and wood. The simple huts were made from adobe, a very low cost building material made of sun-dried earth and sticks or straw. Adobe structures are extremely durable, and account for some of the oldest existing buildings in the world. Lenclos (1999). Whitewash is especially effective on adobe. It offers significant advantages because when absorbed, hardens the material and has antibacterial properties.
These materials were followed by houses made entirely in wood. Sarmiento promoted the import of prefabricated wooden houses in the style of the pioneers of North America. The house, on stilts, develops on the upper floor. A footpath leads to the wooden pier.
These houses were in white, creamy colors and that of natural wood. Colour was also use for the roof, structural details and the pie.
In plastered brick houses most white, color was often used for decorative details. Houses with the features of the British, French or Italian picturesque architecture (2, 3) was well adapted to the houses of Tigre and Delta, with more complex designs, import technologies, prefabricated pinnacles. Beautiful examples are the buildings for rowing clubs.(4). Ruiz Moreno (2004)
Many of the beautiful nineteenth century houses no longer exist. Once the houses deserted and without preserving the coastline from the strength of the river, the houses collapsed.
Sail in the Delta is to penetrate in a very special atmosphere which is not limited to water and trees. Time seems to stand still in the old wooden houses on stilts.(5) There are still some typical houses with galleries immersed in lush parkland with aspen, pine, ceiba trees, pines, willows, and eucalyptus and palm trees.

2. COLOUR TO OUR DAYS

Towards mid-twentieth century “chalets” in brickwork or plastered brick began to appear in the Delta first section. (6)

After the strong 1940 flood there was an unquestionable change in the demographic trend of the islands; the stable population decreased while the weekend visitors increased.
At the beginning of the 90's a remarkable increasing of temporary population led to the construction of new houses, because of the electricity and telecommunications diffusion. In the last twenty years a remarkable process began to show: the increasing of temporary population and at the same time, the use of color in houses exterior. The use of color in home exteriors also increased as results of paint manufactures campaigns.
In 1962 Sherwin Williams becomes the first paint company in our country that launches the revolutionary Colormeter tinting system of his invention, (the kem colormeter, the store mixing system,used in USA since 1959) without success. In 1990 arrived in Argentina the Tintometric Color System and was introduced to the market in 1991 by Alba. This system affords the possibility of preparing an extensive range of colors in a simple way. It is very useful when real artisan painters disappears to leave place to people that know about technical aspects but not too much about colour. The "paint boutiques," were equipped with terminals which enabled customers to look at the house exterior they wanted to paint and experiment with colours based on the company's multicolor system.
This was a real motivator of the the use of color in houses exterior. This process was accompanied by others actions that improved the knowledge and use of colour. Foreign companies began to propose special colour charts for Argentina, settled after the discussion with argentine specialists, and also information about colour meaning and trends.
The impact of all this actions is evident. Colour takes a cultural dimension, also social and economic.
The colour palette of architecture is closely linked to the vegetation of the environment.
The natural elements such as lighting, seasons, vegetation, water levels and their reflections, sky, bring a colour animation to architectural landscape. Lenclos (1999). Dialogue between nature and houses in the Delta is now extremely rich. Yellow first (7), followed by pink (8) are very often seen, but orange (9), green, blue (10), lilac and even violet won now the facades. Large houses, when painted, continue to be mostly in white (11) or creamy (12) and very light colors but small houses appear as colored jewels in the greenery surroundings. The possibilities of changes permitted by painting give rise to unexpected innovations that can testify the resident's desire for a real individualism. Lenclos (1999). Colors made by the creativity of the architect or owner's own fantasy already belong to the cultural patrimony of the region.
The 16th annual assembly from UNESCO international Coordination Congress in Paris in September of 2000 declared the second and third section of islands Biosphere Reserve for the conservation of genetic diversity. It covers more than 90.000 has. with an additional growing of lands formed by alluvial deposits.
The establishment of the Biosphere Reserve aims at revitalizing the economy of the region at the same time as conserving the natural and cultural values of the area and support the investigation and study of the ecosystem with the possibilities of investments in projects of sustainable growth of organic cultivation and varied ways of land-forest production with certification of ecological quality.

LIST OF BIBLIOGRAPHICAL REFERENCES

Borodowski E.D. y Suárez R.O.. 2004. *El cultivo de álamos y sauces: su historia en el Delta Paraná*. SAGPyA Forestal, 32: 5-13. ISSN 0328-971

Debenedetti, E.,1977. *Islas del Delta del Parana-Poblacion-Bosquejo demografico*,1855-1895, Buenos Aires, Academia Nacional de la Historia.

Giesso, F, Mezzera,R., 1997 *Nuestras casas de Tigre*, Buenos Aires.

Kirbus F, 1980, *La primera de las tres Buenos Aires*. Buenos Aires

Lenclos J.P., Lenclos,D. 1999, *Couleurs du Monde, Geographie de la couleur*, Paris: Le Moniteur, ISBN 2-281-19116-

Sastre, M.,1940. *El Tempe Argentino*. Buenos Aires: Ed.Sopena (first edition 1939)

Sarmiento, D.F, 2011. *El Carapachay : imagenes de las islas del Delta del Parana*. Buenos Aires:Eudeba. ISBN 978-950-23-1852-3.

Ruiz Moreno de Bunge,S., 2004. *Tigre y las verdes islas del Delta*. Buenos Aires: Camalote ISBN 987-43-8311-9

Delta Rowing, 2012. *Historia del Tigre.* www. escuela de remo.com.ar/historiadetigre.html

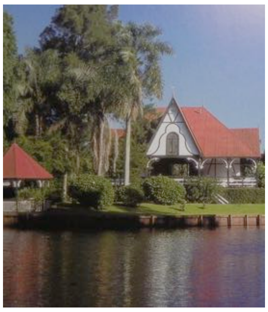
Mey, C, 2007. *Historia y Arqueología Marítima exploracion del Delta de Parana*. http://www.histarmar.com.ar/InfHistorica/IglesiaCristoRey/IglesaCristoRey-1.htm

Own regular weekly visits to the Delta since 1985.

Interviews of long time residents.

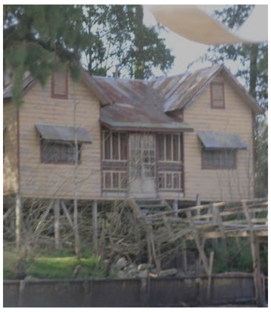
1-Sarmiento house Cream colour

2- With facade, colours in details



3- White, colour in the roof of painted sheet

4-Creamy facade, tile roof



5-Old wooden house

6-White and bricks

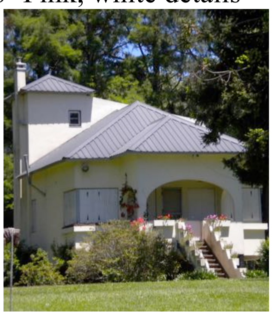
7-Yellow, white details

8- Pink, white details

9- Orange, green details

10- Light blue, white details

11- White, blue roof



12-Creamy, grey roof

oral paper

Brightness Evaluation for a Room Furnished with Various Chromatic Objects

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ABSTRACT

Although horizontal illuminance is used as a measure to represent space brightness, horizontal illuminance does not always correspond to the brightness impression of the space. For example, the room furnished with high saturated colored objects was perceived brighter than the room with achromatic, even though the horizontal illuminance was the same. We examined the effect of interior chromaticness on space brightness by brightness-matching method. Subjects were presented a couple of miniature rooms that were different in terms of chromaticness of interior decorating surfaces, but kept lightness of surfaces constant. Subjects needed less illuminance to get the equality of space brightness if the room had saturated objects. We also examined the relationship between the color effect on space brightness and photometric chromaticity distribution.

1. INTRODUCTION

It is very important for architectural design to assess space brightness quantitatively. To design a lighting environment, horizontal illuminance is generally used as the brightness measure of a room. But several studies reported that space brightness does not always match the horizontal illuminance. To resolve this discrepancy, several systems have been proposed to evaluate a perceived brightness for a lighting environment based on measuring a luminance distribution of the scene. These methods would be powerful tool to evaluate a lighting environment which is difficult to estimate the perceived brightness only by measuring a horizontal illuminance.

Ikeda et al. (1996) showed that perceived brightness of a room furnished with chromatic interior decorations was higher than a room with achromatic interior decorations, even if surface reflectance of objects were same each other. In other words, even though the luminance distribution was unchanged, space brightness was increased by the effect of chromaticness. Thus, to estimate a brightness of colored room, not only luminance distribution but also chromaticity distribution must be required. The purpose of this study is to evaluate the effectiveness of colored furniture on space brightness subjectively, and to examine the relationship between the color effect and photometric chromaticity distribution.

2. METHODS

2.1 Experimental room

The experiment was conducted with miniature room as shown in figure 1. This room was uniformly illuminated by luminous ceiling. To investigate an effect of interior chromaticness on space brightness, we conducted the experiment in four miniature rooms that were different in terms of chromaticness of interior surfaces, but kept lightness constant to maintain luminance distribution. One of the rooms, named room A, was furnished with achromatic objects. The room of L, M and H were furnished with low, middle and high saturated objects, respectively. Table 1 shows Munsell notation of interior surface.

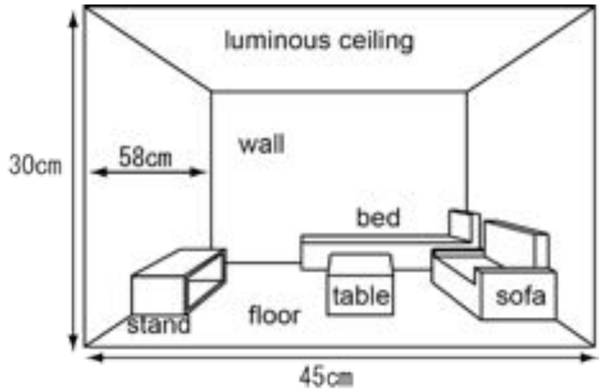

Fig. 1. Scheme of experimental room.

Table 1. Munsell notation of interior surfaces.

	Room A	Room L	Room M	Room H
wall	N7.7	N7.7	N7.7	N7.7
floor	N3.7	N3.7	N3.7	N3.7
bed	N5.0	5B 5/1	5B 5/5	5B 5/9
	N3.0	5PB 3/4	5PB 3/8	5PB 3/12
sofa	N7.0	5GY 7/4	5GY 7/8	5GY 7/12
	N4.0	5G 4/2	5G 4/6	5G 4/10
table	N8.0	5Y 8/6	5Y 8/10	5Y 8/14
	N6.0	5YR 6/5	5YR 6/9	5YR 6/13
stand	N5.0	5RP 5/6	5RP 5/10	5RP 5/14
	N4.0	5R 4/6	5R 4/10	5R 4/14

2.2 Subjective evaluation

Subjects were presented a couple of miniature rooms. One is the room A, that is reference room, and the other is one of the four rooms, that is test room. The horizontal illuminance of the test room was set at one of the three levels; 100, 300 and 1000lx. Subjects were asked to adjust the illuminance of reference room to equate the space brightness of test room. Twelve times adjustments were done for all conditions. Seven subjects participated in the experiment.

2.3 Measurement of color and luminance distribution

To obtain chromaticity and luminance distribution of the natural scene we developed a colorimetric system with CCD (DFK41AU02, IMAGINGSOURCE). This system provides us CIEXYZ distribution with visual field of 160 x 160 degrees by using fish-eye lens (FE185C046HA-1, FUJINON). This system converts from RGB value of each pixel to XYZ tristimulus value by combining images of different exposure.

3. RESULTS AND DISCUSSIONS

3.1 Results of brightness matching

The results of subjective evaluation are shown in figure 2. The abscissa represents the horizontal illuminance of the test room, and ordinate the brightness matched illuminance of the reference room. White bars indicate matched illuminance for room A, and light gray, middle gray, black bars show that for room L, M, and H, respectively. It was found that there were two types of subject: type I and type II. Subject of type I perceived test room brighter if the test room furnished saturated objects (fig.2 top). Four of seven subjects were type I. Matched illuminance of the room H and M were significantly higher than that of room A. The illuminance ratio between each test room and room A were plotted in figure 3. The abscissa shows test room conditions and ordinate illuminance ratio. The difference of symbols indicates the difference of test room illuminance. As the interior chromaticness increased, the matched illuminance also increased for all test room illuminance conditions.

On the other hand, subject of type II set illuminance of the reference room almost equal to the test room (fig.2 bottom). There were no significant differences among the matched illuminance, so these subjects perceived brightness of the test room constant regardless of whether saturated objects exist.

3.2 Relationship between matched illuminance and distribution of luminance and color

We measured luminance and color distribution for all test room conditions by using CCD colorimetric system. Averaged luminance of the entire scene is shown in Table 2. These values were measured when the test room illuminance of 300lx. Luminance of luminous ceiling is excluded for the mean calculation. Averaged luminances are equal each other because the Munsell values of objects are same.

Let us consider the Helmholtz-Kohlrausch effect for interior objects. It is well known that saturated color patch is perceived brighter than monochromatic patch even if the luminance of the patch was identical. The H-K effect is quantitatively represented by brightness to luminance ratio. There are several methods to estimate equivalent luminance of the colored patch, we used the system that was proposed by Nakano et al. (1999). Measured luminance of each pixels were converted to equivalent luminance and averaged whole of the scene. Equivalent averaged luminance and increment of averaged luminance are also shown in Table 2. Although the equivalent averaged luminance is increased with the saturation of interior objects, the difference is little. Thus, equivalent averaged luminance is not enough to explain the difference of space brightness.

I would like to focus on the chromaticity distribution. Figure 4 represent histograms of color distribution for each test room conditions. Region of existing color in the u'v' chromaticity diagram extend in order of A, L, M and H. We investigated the relationship between area of extension and space brightness in the figure 5. The abscissa indicates the ratio between the color extension area of each room conditions and that of room A. The ordinate indicates the illuminance ratio same as the figure 3. Since the illuminance ratio increases with the area ratio, the area of color extension could be useful to estimate space brightness for a room with saturated furniture. When we examined brightness of a room that equipped twice

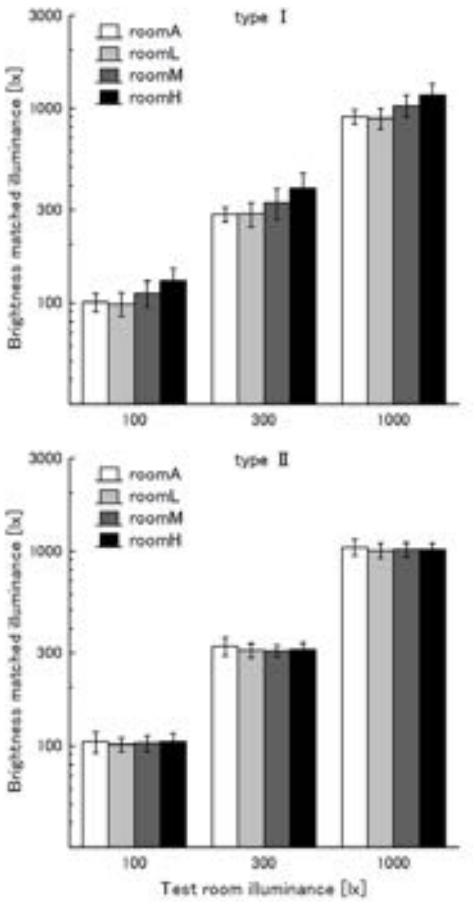

Fig. 2. Illuminance of the reference room matched with the test room brightness.

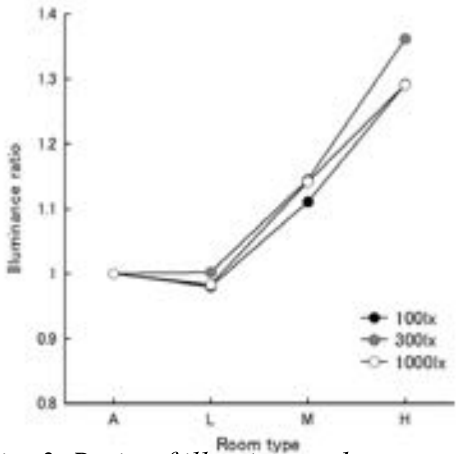

Fig. 3. Ratio of illuminance between the reference room and test room.

Table 2. Averaged luminance of entire scene measured by CCD system.

	A	L	M	H
averaged luminance	17.6	17.5	17.7	17.7 [cd/m²]
equivalent averaged luminance	17.9	17.8	18.1	18.1
difference	1.7%	1.8%	2.3%	2.5%

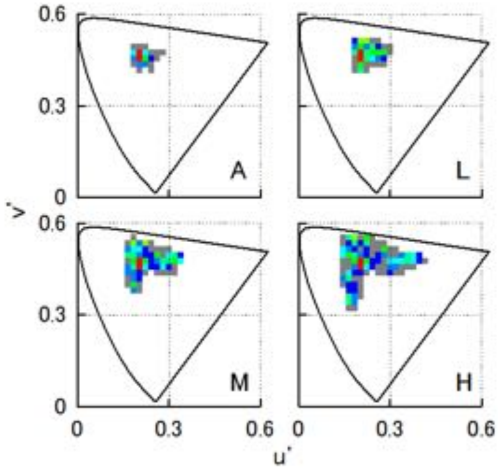

Fig. 4. Histogram of chromaticity distribution plotted in the u'v' diagram.

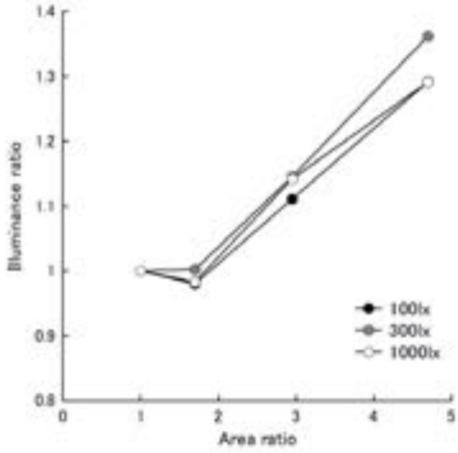

Fig. 5. Illuminance ratio plotted against the area of color distribution.

number of colored furniture, however, subjects tend to perceived the room brighter than a room with small number of furniture even though the Munsell chroma of object's surface is the same. Therefore, we could suggest brightness evaluation method using area of color distribution, but further work is needed to evaluate the effect of the configuration or number of colored furniture on space brightness.

ACKNOWLEDGEMENTS

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REFERENCES

Ikeda, M., and F. Kaneko. 1996. Effect of initial visual information on the recognized visual space of illumination –The case of lightness and saturation–. *Journal of the Illuminating Engineering Institute of Japan* 80 (5):319-323.

Nakano, Y., K. Yamada, K. Suehara, and T. Yano. 1999. A simple formula to calculate brightness equivalent luminance. In *CIE 24th Session, Proceedings.* Vienna: 33-37.

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Interaction of color and taste: Color synesthesia in the food environment

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oral paper

ABSTRACT

Synesthesia is a phenomenon by which associations between different sensory channels are produced: stimuli received through one of the senses are interpreted as other kind of sensations. Food is evaluated by the consumers on the basis of various sensorial aspects: taste, olfaction, texture, color and cesia, among others. The experience of food consumption constitutes a typical case where synesthetic associations are produced, in which it is difficult to separate or evaluate independently the different sensations, or where some of them influence the others. This proposal investigates the synesthetic associations between color and taste sensations. This paper will present the conceptual frame and some antecedents on this subject, as well as the methodology and results of an experimental survey made at the University of Buenos Aires, showing how color synesthesias work in the food environment.

INTRODUCTION

Synesthesia is a phenomenon by which stimuli received through one sensory channel trigger sensations of a different perceptual nature. The most usual associations are sight with hearing (for instance the synesthesias between color and sound), and also with taste, olfaction and touch. The visual sense is almost always present, associated with the other senses.

Neurologists usually distinguish two kinds of synesthesia: *pseudo-synesthesia*, that everyone can experience when recognizing qualitative similarities between sensations of different type; and *genuine synesthesia*, that appears as a neurological abnormality in a minority of people. In genuine synesthesia, the associations are involuntary, stable (repeated constantly along the life of a person), unidirectional (a taste can provoke a color sensation, but the reverse does not work), and projected outside the individual. In pseudo-synesthesia, instead, the associations are metaphorical, by similitude of qualities, promoting iconic relationships among sensations; they can be two-directional (if a taste evokes a color, the reverse is also true) or multi-directional (every sensation triggers any of the other kind of associated sensations), and they can also be stable (repeated constantly, not in a few individuals but in the majority of people).

Pseudo-synesthesia can be considered a normal phenomenon of association, either culturally induced or product of neurological connections. There is an hypothesis that babies' sensoriality is typically synesthetic, and that when they grow older, the sensory channels undergo a process of separation. If this is true, an adult genuine synesthete would be a person whose sensory systems remained as in the initial stage (Baron-Cohen 1996). But it seems logical that in normal people some vestiges of this initial stage could also remain.

Food is evaluated by the consumers on the basis of various sensorial aspects: taste, olfaction, texture, color and cesia, among others. The experience of food consumption constitutes a typical case where synesthetic associations are produced, in which it is difficult to separate or evaluate independently the different sensations, or where some of them influence the others. This proposal investigates the synesthetic associations between color and taste sensations.

As a frame of reference, it is known that, in the same way as the color continuum has been ordered by means of three-dimensional systems, also taste sensations have been classified and ordered in a solid model. Hans Henning proposed a volume to represent the order and variation of taste sensations, which consists in a tetrahedron with the four primary tastes —sour, sweet, bitter, salty— at the vertices. These four primary or elementary tastes have a correlate with four zones in the main organ for taste, the tongue. We recognize here a connection between the way tastes are ordered and how the involved sensory organ works. A similar situation could be depicted with color order systems and the organs of vision, although it is somehow more complex. In the first stage, at the retina, the processing is made by a trichromatic system: the three kinds of cones sensitive to long, medium, and short wavelengths. And there are color order systems that represent this: they are organized by three primary colors —red, green, and blue—, such as the systems by Helmholtz, Maxwell, CIE 1931, Villalobos, Küppers, Gerritsen, and others. It is in a further stage where the visual processing is made on the basis of four elementary color sensations, and the theory of chromatic opponency is verified. And we can see this represented in systems such as those of Hering, Hesselgren, CIELAB, and the Natural Color System, among others.

Some of the questions that we can pose are: Which are the colors more strongly associated with each of the elementary tastes? And, symmetrically, which are the tastes more strongly associated to each of the elementary colors? Is it possible that associations between elementary tastes and elementary colors result from this? Or rather the correlations would be between elementary sensations of one continuum with intermediate sensations of the other one? Finally, if there is a definite correlate between elementary sensations of both continua —color and taste—, would the correlate still work for the intermediate sensations?

SOME ANTECEDENTS

Richard Cytowic (1993) published a book that starts by reporting the encounter with a person who experienced flavors as physical shapes, and from this case introduces the reader into the world of synesthesia, including also color. Since more than one decade, Sean Day (2012) is obtaining information from genuine synesthetes, and distinguishes more than 60 types of synesthesia with the following percents of incidence: colored graphemes 64.8%, colored time units 23.0%, colored musical sounds 20.0%, colored general sounds 15.2%, colored phonemes 9.5%, colored musical notes 8.8%, colored odors 7.0%, *colored flavors 6.2%*, etc. We can see that the association taste-color is in the 8th position among all. Campen and Froger (2001, 2003) have developed the NeCoSyn method to plot the profile of a synesthete person. In our case, this method can be used as a tool to see how the taste-color association ranks, in strength, among other types of synesthesias such as word-color, music-color, odor-color, etc. The model is able to plot hue, blackness and chroma separately, to show the specific color dimensions in terms of which the correlations are made. Juan Carlos Sanz (1985: 85-86) has related taste to color using geometrical spaces to plot the relationships (a cube for tastes, an hexagon for colors), and has also devised methods to ask people about the color-taste relationship. A series of researches have studied how the flavor of food and beverages is affected by color by means of surveys and experiments involving people (DuBose et al. 1980, Roth et al. 1988, Philipsen et al. 1995). These kind of experiments are useful to scientists who study how vision interacts with the sense of taste and olfaction, and also to food companies that want to know how their products are perceived by the consumers.

In this paper we describe an experiment and survey to answer these questions: What is the color of each of the four primary taste sensations (sour, sweet, bitter, salty)? How any of the four elementary colors (yellow, red, blue, green) taste? If we understand synesthesia in a wide sense, as sensorial associations or similitude among sensations of different kind that all people can perceive (not just people with a neurological anomaly); and if the order systems for color and taste represent how humans perceive and organize these kind of sensations; then it seems plausible to find a relationship between synesthesia and the order systems. The hypothesis is that the positions of the sensations in the order system of tastes and in color order systems would exhibit a correlation. For instance, opposite or complementary colors should correlate to opposite tastes.

EXPERIMENT

A survey was made to test color-taste associations. Foods contaning components providing four tastes —sour, sweet, bitter, salty— were prepared, with three different types of consistency or texture: a colorless beverage (liquid), a colorless gelatin (jelly), and baked cookies (solid). They were identified by numbers, known only by the experimenters, and provided to a panel of 16 non-trained subjects who did not know which taste was represented by which number.

Session 1 – Elementary colors associated to elementary tastes: foods of the four tastes were administered to the subjects in random order, and had to be correlated to the four elementary colors —yellow, red, blue, green— displayed on surface cardboards. The subjects were asked to identify the tastes and the colors they were seeing. Then, they were asked to select one color for each taste.

Session 2 – Basic color names associated to elementary tastes: The observers were asked to write down a list of 12 to 20 one-word color names. From these, we selected the 12 most frequently appearing in the upper positions of the list as basic color names. They were: red, green, yellow, white, blue, violet, black, gray, skyblue (in Spanish, *celeste*), orange, brown, pink. These names were displayed in a random order and had to be related to the four preparations previously described, after tasting them.

Session 3 – Chromatic extension for each elementary taste: The four tastes were offered in random order and the atlas of the Natural Color System was shown to the subjects. They were asked to select the particular color that was more strongly associated to each taste.

For all three sessions, the experiment was repeated for the three types of consistency — liquid, jelly and solid flavors— with the same subjects in different days, except for the third session in which only jelly and solid flavors were tested. The results are shown in Tables 1-3.

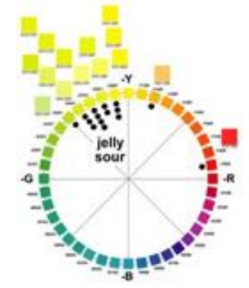
Table 1. Session 1 – Elementary colors associated to elementary tastes.

	sour-yellow	sweet-red	bitter-blue	salty-green	salty-yellow
liquid flavors	81%	81%	56%	50%	--
jelly flavors	73%	64%	60%	53%	--
solid flavors	53%	53%	43%	33%	40%

Table 2. Session 2 – Basic color names associated to elementary tastes.

liquid flavors			jelly flavors			solid flavors		
sour-	-yellow	81%	sour-	-yellow	67%	sour-	-yellow	40%
sweet-	-red	31%	sweet-	-pink	50%	sweet-	-pink -red	33% 27%
bitter-	-violet	19%	bitter-	-violet	27%	bitter-	-green	21%
salty-	-green	38%	salty-	-green -skyblue	20% 20%	salty-	-green -yellow	27% 20%

Table 3. Session 3 – Chromatic extension for each elementary taste (jelly and solid flavors).

			
jelly-sour, around yellow	jelly-sweet, around red	jelly-bitter, around violet	jelly-salty, around blue
			
solid-sour, around yellow	solid-sweet, around red	solid-bitter, around violet	solid-salty, around yellow

CONCLUSIONS

Making a synthesis of the results, we can see that: a sour taste was very highly associated to yellow; a sweet taste was highly associated to red (also to pink and orange, to some degree, i.e. a whitish red or a yellowish red); a bitter taste is equally associated to blue and violet (also to green, in a lesser degree); and finally, a salty taste is mainly associated to green or turquoise (i.e., around bluish green), and also to yellow in some degree. Figure 1 shows a general scheme with the most frequent correlations.

Figure 1. Most frequent taste-color associations.

REFERENCES

Baron-Cohen, S. 1996. "Is there a normal phase of synaesthesia in development?". *Psyche* 2 (27). In www.daysyn.com/baroncohen1996.pdf. Access: July 2012.

Campen, C. van, and C. Froger . 2001. "Assessing the strength of color synesthesia in words, music, taste and odor perception". In www.synesthesie.nl/pub/necosynreport.htm. Access: July 2012.

——. 2003. "Personal profiles of color synesthesia". *Leonardo* 36 (4): 291-294.

Cytowic, R. 1993. *The man who tasted shapes*. New York: Putnam.

Day, S. 2012. "There are more than 65 different types of synesthesia". In www.daysyn.com/Types-of-Syn.html. Access: July 2012.

DuBose, C., et al. 1980. "Effects of colorants and flavorants on identification, perceived flavor intensity, and hedonic quality of fruit-flavored beverages and cake". *Journal of Food Science* 45 (5): 1393-1399.

Philipsen, D., et al. 1995. "Consumer age affects response to sensory characteristics of a cherry flavored beverage". *Journal of Food Science* 60 (2): 364-368.

Roth, H., et al. 1988. "Psychophysical relationships between perceived sweetness and color in lemon- and lime-flavored drinks". *Journal of Food Science* 53 (4): 1116-1119.

Sanz, J. C. 1985. *El lenguaje del color*. Madrid: Hermann Blume.

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An fMRI study on the perception of the harmony of color and fragrance

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ABSTRACT

Nine healthy subjects aged from 20- to 27-yrs participated in the fMRI study. The stimuli were 6 colors projected onto the screen; Red (255, 0, 0), Yellow (255, 255, 0), Green (0, 255, 0), Blue (0, 0, 255), Purple (255, 0, 255) and Gray (125,125,125) and the most preferred fragrance for each subject which he/she had selected among 120 various fragrances before the experiment started. Brain scanning was done in a 1.5T Magnetom Vision fMRI scanner. Color stimuli were back-projected onto a screen viewed through an angled mirror. Subjects were presented 2 sets of 60 blocks (one session contained 6 colors with/without fragrance for 5 times) in the scanner and were asked to give a rating on the basis of how well they were perceived to match with a 9-grade evaluation system. The activation of the orbito-frontal cortex (OFC) and insula indicated a harmonized combination of color and fragrance. Moreover, the activation of the midbrain with harmonized pairs indicated that the perception of harmony might be closely related to the autonomic nerve system.

1. INTRODUCTION

Neurological perspectives on crossmodal perception or multi-sensory perception (or integration) has recently become a subject of current interest, especially to researchers in the fields of psychology and neuroscience. Among the studies which explore the crossmodal interactions on the basis of neurophysiology, Skrandies & Reuther (2008) showed that color and food words affected the human brain differently and induced electrical activity when paired with matching or non matching combinations of odor or taste words. Österbauer, Matthews, Jenkinson, Beckmann, Hansen, and Calvert (2005) have studied the neurophysiological correlation of visual influences on olfactory perception by using functional magnetic resonance imaging (fMRI). Subjects were scanned while exposed either to odors or colors alone, or to both simultaneously. In the presentation of color-odor combinations, they were asked to rate on the basis of how well they were perceived to match. Activity in caudal regions of the orbito-frontal cortex which has been well known to be engaged during the perception of rewarding stimuli and in the insular cortex increased progressively with the perceived congruency of the color-odor pairs. In this study, the congruent color-odor combinations such as yellow-lemon, strawberry-red, spearmint-turquoise and caramel-brown parings were used as well as the less congruent pairings and the subjects were asked to rate the degree of match of the congruency. The question still remains whether such activities of the orbito-frontal cortex and insula are factors which influenced the results which were elicited by the appropriate association (congruency) of color-odor pairs or solely by the perceived harmony.

2. OBJECTIVE

The previous study has described the brain areas which are engaged in the perceptions of congruent pairs of odor-color, however, the brain areas related with harmony are not well defined yet especially from the viewpoint of one's preference or taste for fragrances. The purpose of this study is to specify the neural areas which are activated when subjects consider the color and fragrance which he/she preferred are perceived to match.

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3. METHOD

3.1. Stimuli

Colors: The stimuli were 6 colors projected onto the screen in fMRI; colors and RGB values were Red (255, 0, 0), Yellow (255, 255, 0), Green (0, 255, 0), Blue (0, 0, 255), Purple (255, 0, 255) and Gray (125,125,125) as a control.
Fragrances: 120 fragrances which were divided into 15 groups by cluster analysis.

3.2. Subjects

Nine healthy subjects (2 males and 7 females) aged from 20- to 27-yrs (mean age 22.3 years, SD± 2.18) participated in the study.

3.3 Procedures

Subjects first selected their favorite group of fragrances among 15 clusters, then chose one favorite fragrance from the group before the experiment started. During the session, a figure of + at the beginning of the experiment and the color stimuli were back-projected onto a screen viewed through an angled mirror. Subjects were presented 2 sets of 60 blocks (one session contained 6 colors with/without fragrance for 5 times) in the scanner and were asked to give a rating on the basis of how well color-fragrance combinations were perceived to match based on a 9-grade evaluation system. Two liters of air was ventilated through a tube connected an oxygen cylinder and the subjects' oxygen mask. While in a session without fragrance (color alone) only the air was ventilated with the presentation of color in random order, while in a session with fragrance, the subject was presented his/her favorite 10ml-fragrance inserted into a tube by a 60ml syringe which was contained in absorbent cotton impregnated with 0.05ml-fragrance along with synchronous presentation of each color. (see Figure 1 and Figure 2)

3.4 Image acquisition and image analysis

Brain scanning was done in a 1.5T Magnetom Vision fMRI scanner (*Siemens,* Germany). The scans produced 4mm thick slices covering the entire cerebrum. The acquisition parameters were TR = 4s; TE= 45ms, matrix size = 64 x 64 and a flip angle of 90°.
Image analysis of the brain scanning was carried out using *MATLAB* by *MathWorks*. A cluster significance threshold of p = .005 was analyzed with the cluster size of 10.

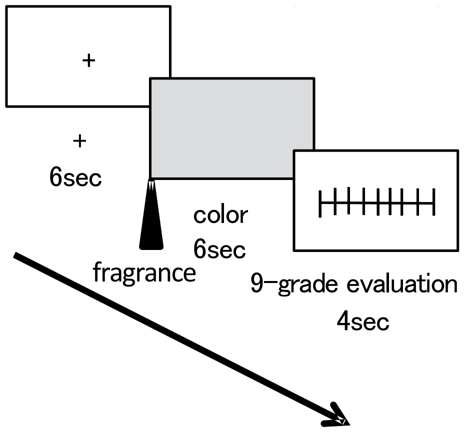

Fig.1 *Experimental protocol with fragrance*

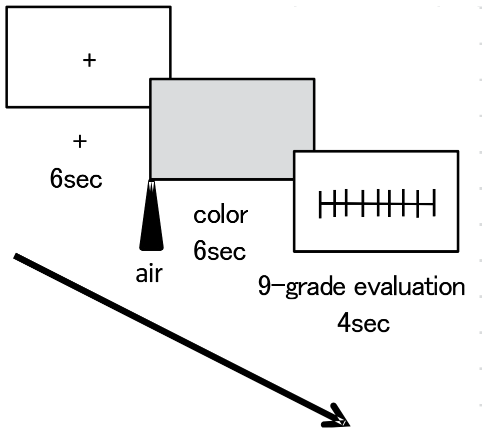

Fig.2 *Experimental protocol without fragrance*

4. RESULTS AND DISCUSSION

Figures 3 to 5 show the activated brain regions (significance threshold of p = .005) which correlated to the subjects' judgments of the degree of match between colors and a simultaneously presented fragrance during the scanning for 6 sec. In Figure 3, the group activation map shows the activation (crosshairs) in the orbio-frontal cortex (OFC; x, y, z, = -34, 24, -8) in all 3 slices orientations, as well as the main cluster of activation of the insula (x, y, z, = 30, -14, 18) which is indicated in Figure 4. The activation of the midbrain is also obtained, as shown in Figure 5 (x, y, z, = -8, -16, -4). The orbito-frontal cortex has been well known to be engaged during the perception of rewarding stimuli and the results of this study also indicated that perception of harmony stands for the rewarding stimuli. Moreover, the activation of the insular cortex in harmonized pairs indicated a close relationship with the orbito-frontal cortex. The insula is integral to the experience of emotions and it plays an important role in the anticipation or expectancy of reward value. Consequently, it was suggested that these areas seemed to be responsible for the judgments of harmony. The activation of the midbrain which is closely related with the central nerve system and the interbrain is also exhibited in this study suggesting the anticipated relationship between the perception of harmony and the autonomic nerve system.

5. CONCLUSION

Consistent with the results of neurological study conducted by Österbauer et.al. (2005), the acquisition of the activations of the orbito-frontal cortex (OFC) and the insular cortex in harmonized combinations of color and fragrance in this study suggested that the brain activity of the perception of the well "association" of congruent color-odor pairs and the regions which were engaged in the perception of the "harmony" of color-fragrance pairs were identical. Moreover, the activation of the midbrain with harmonized pairs suggested that the perception of harmony might be closely related to the autonomic nerve system.

ACKNOWLEDGEMENTS

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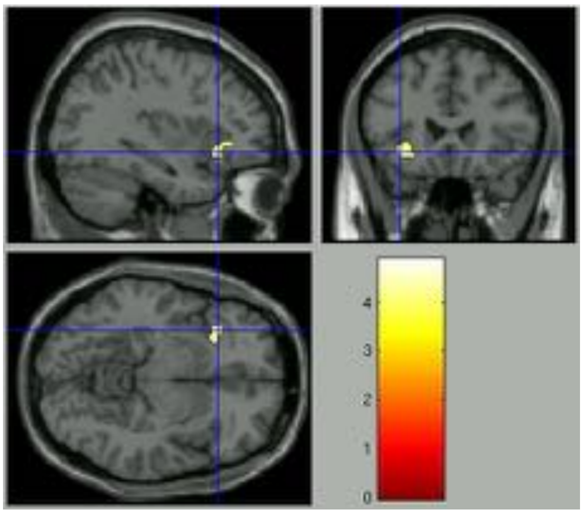

Fig.3 *Brain activation of the orbito-frontal*

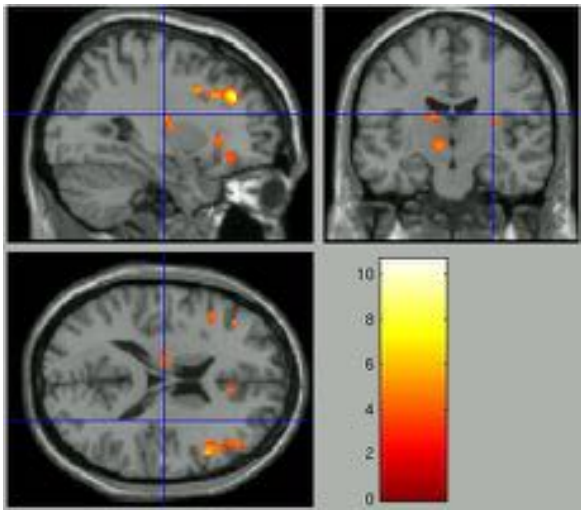

Fig.4 *Brain activation of the insula*

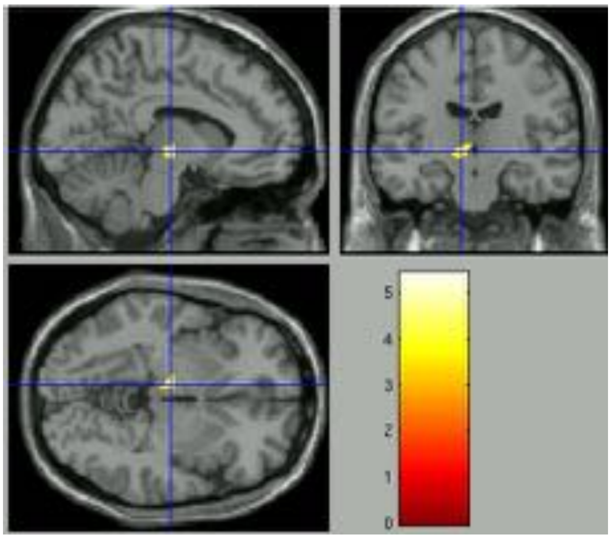

Fig.5 *Brain activation of the midbrain*

REFERENCES

Österbauer, R. A., P. M. Matthews., M. Jenkinson., C.F. Beckmann., P.C. Hansen., and G.A. Calvert. 2005. Color of scents: chromatic stimuli modulate odor responses in the human brain. *Journal of Neurophysiology* (93): 3434–3441.

Skrandies, W., and N. Reuther. 2008 Match and mismatch of taste, odor, and color is reflected by electrical activity in the human brain. *Journal of Psychophysiology* 22(4): 175-184.

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As pink as an orange blossom odor: a Lebanese-French cross-cultural study

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ABSTRACT

It is well-known that culture-specific experiences with odors may influence basic aspects of odor perception such as intensity, pleasantness or edibility. Differences in terms of odor-color association might therefore be expected depending upon the culture in which people grew up. To further investigate the influence of experience on odor-color correspondences, the responses of 155 French and 96 Lebanese subjects to the same 16 odorants were compared. Our results confirm the existence of robust odor-color correspondences among both populations and raise important questions about the representation of odors. This underlines the need for further studies to understand the mechanisms underlying these cross-modal correspondences and the influence of cultural background and experience on them.

1. INTRODUCTION

Many cross-modal correspondences involving colors have been documented in non-synesthetes. Among these cross-modal associations, a small number of studies have attempted to investigate the relationship between odors and colors (see Gilbert et al., 1996; Schifferstein and Tanudjaja, 2004; Demattè et al., 2006). Consistent associations between specific colors and odors mainly related to food have been confirmed recently (Maric and Jacquot, 2012). These findings replicated those reported previously and extended them to a population of French participants. Besides, Maric and Jacquot (2012) demonstrated that similar odors led to significantly different color associations. Their results also confirmed that there is a significant relationship between the selected color (lightness and saturation) and the pleasantness of the odor, which corroborates the findings of Schifferstein and Tanudjaja (2004). Nevertheless, the colors which people chose as corresponding to an odor, if based exclusively on odor pleasantness, would not have been consistent across subjects. Cognitions or categorizations produced by smelling an odor could therefore explain such consistent associations. The perceived edibility of odors had indeed an impact on the mean hue of selected colors. The more an odor was judged as edible, the more the hue tended to yellow-red colours. On the contrary, less edible odors were preferentially matched with blue hues, which are less often encountered in food.

In the present study, we investigated possible cultural differences in odor-color associations, since the perception of olfactory stimuli changes between different geographical zones or populations (Ayabe-Kanamura et al., 1998).

2. EXPERIMENT

Participants: 155 French participants (mean age: 27 years old) and 96 Lebanese (mean age: 26 years old) participants were recruited in both countries. Subjects were either students or University personnel. All subjects were naïve with regard to the stimuli and the purpose of the study. We only tested participants who reported having a normal sense of smell with no olfactory dysfunction. Participants were also screened for color vision anomalies using the Ishihara test. Subjects whose color vision was anomalous were dropped from analysis.

Olfactory stimuli: 15 food and floral natural aromas (Laboratoires Mathé, Maxéville, France) were selected as olfactory stimuli: caramel, cucumber, lavender, lemon, lime, mint chlorophyll, mirabelle plum, orange blossom, peppermint, rose, pineapple, shallot, smoked, violet, and wild strawberry. Fourteen odors had the same aromatic intensity. We decided to present the same odor of mirabelle plum (a small yellow plum, specialty of the French region of Lorraine) twice; that is to say with two different aromatic intensities (at low and high intensity). 16 olfactory stimuli were thus presented. The samples were prepared by injecting 1mL of each odorant into a small piece of carded cotton that was previously placed into a small opaque glass bottle. No salient visual cues were therefore available to participants.

Color samples: 24 different color patches (4cm in diameter) were presented in a color chart. This color chart consisted of a white A3 size page containing twenty-one color patches arranged in circle from red to purple, and three achromatic colors (white, grey, black) presented separately in the lower left corner. Each color patch was identified by a code (one capital letter and one figure). Color charts were printed on coated paper. The print was calibrated to ensure consistent colors between participants. L*a*b coordinates were measured for each color chip by means of a Datacolor system (Pantone® ColorVision™ Spyder Master Suite Spectro), and converted in L*C*H* (Lightness, Chroma, Hue) coordinates, to get the exact position in the CIELAB color space.

Task location and procedure: In each country, sessions were conducted in sensory testing facilities with separated booths. Each testing booth had white walls and standardized white light source (D65). After completing the Ishihara Color Vision test, each subject was presented with the sixteen olfactory stimuli in a random order, and with the color chart. For each olfactory stimulus, participants were asked to open the glass bottle and smell its content orthonasally. Afterwards, participants were instructed to select from among the 24 color patches one color that they felt closely matched the odor. After having made their choice, they rated the difficulty of odor-color association and the odor perceived intensity, familiarity, pleasantness, and edibility. Participants were not required to name the odors they smelled.

3. RESULTS

Odor-color associations: Both populations matched olfactory stimuli with colors in a non-random manner ($X^2(345) = 4122.53$, $p < 0.0001$, in France; $X^2(345) = 2233.21$, $p < 0.0001$, in Lebanon). Indeed, significant color characterizations were found for all tested odors in both countries.

For 12 olfactory stimuli (cucumber, lavender, lemon, lime, mint chlorophyll, mirabelle plum - high and low intensity -, pineapple, shallot, smoked, violet, and wild strawberry), no significant differences were found between French and Lebanese subjects in all the matched colors. For 3 odors (caramel, rose, and peppermint), no differences were found in the mainly associated color between the two populations. Somewhat unexpectedly, significant differences in colors association were only found for one odorant: *orange blossom* (Figure 1).

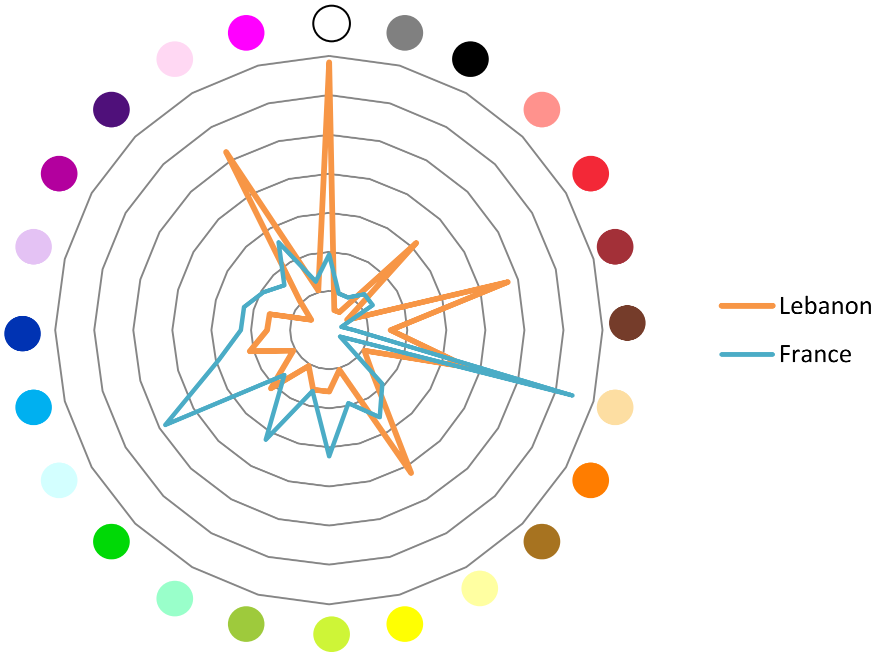

Figure 1. Orange blossom odor: choice of colors as a function of populations

Odor ratings: Regarding the orange blossom odor, no significant differences were found in intensity, familiarity or pleasantness ratings. Actually, a significant difference ($p<0.0001$) was only found between the two populations in edibility ratings for this odor (% responses "yes" = 0.53 in Lebanon; % responses "yes" = 0.13 in France; Figure 2). The difference in odor-color association could therefore arise from cultural differences in the odor function. Indeed, orange blossom is more used in Lebanese food (especially in pastries) than in French food. Actually, orange blossom odor is mainly encountered in hygiene products in France.

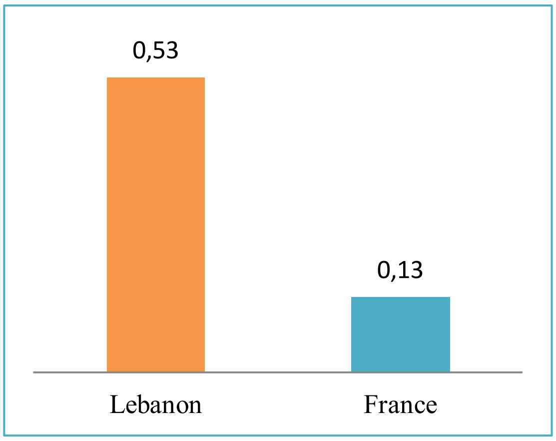

Figure 2. Edibility judgment (%) for orange blossom odor: France vs Lebanon

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4. CONCLUSIONS

Our results confirm the existence of robust odor-color correspondences among both populations and raise important questions about the representation and categorization of odors. Indeed, odors might have a common representation with boundaries which might be more culturally dependent (which accords well with findings of Chrea et al. in 2004). Further research is thus needed to investigate more in depth the influence of cultural background and experience on them. In order to do so, we are establishing an international collaborative research network on this issue to repeat the experiment among other populations. Thanks to the AIC 2012 Meeting Organizing Committee (Prof. Tien-rein Lee) and Dr Vincent Sun (Department of Mass Communication, Chinese Culture University, Taiwan), we will carry out the same experiment in collaboration with CCU on the week after the meeting. This experience will be a great opportunity to compare at a more global level our previous results with correspondences made by people who grew up in an Asian culture. A forthcoming experiment is also scheduled in UK (Oxford University, Crossmodal Research Laboratory, in collaboration with Prof. Charles Spence) and we are of course open to any suggestion or proposition of further collaborations at a global level.

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REFERENCES

Ayabe-Kanamura, S., I. Schicker, M. Laska, R. Hudson, H. Distel, T. Kobayakawa, and S. Saito. 1998. Differences in perception of everyday odors: a Japanese-German cross-cultural study. *Chemical Senses* 23: 31-38.

Chrea, C., D. Valentin, C. Sulmont-Rossé, D. Hoang Nguyen, and H. Abdi. 2005. Semantic, typicality and odor representation. *Chemical Senses* 30: 37-49.

Demattè, M. L., D. Sanabria, and C. Spence. 2006. Cross-modal associations between odors and colors. *Chemical Senses* 31: 531-538.

Gilbert, A. N., R. Martin, and S.E. Kemp. 1996. Cross-modal correspondence between vision and olfaction: the color of smells. *American Journal of Psychology* 109: 335-35.

Maric, Y., and M. Jacquot. 2012. Contribution to understanding odour-colour associations. *Food Quality and Preference*. Available online: http://dx.doi.org/10.1016/j.foodqual.2012.05.001.

Schifferstein, H. N. J., & I. Tanudjaja. 2004. Visualising fragrances through colours: the mediating role of emotions. *Perception* 33: 1249-1266.

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oral paper

Prototyping Experiences with Food Color

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ABSTRACT

The main goal of this article is to show that color is a fundamental value in gastronomy, as a perception index of the food consumed. At the same time, it proposes a methodology in the shape of a pedagogic exercise to demonstrate the perceptive experience of color. In this exercise, we implemented —as a tool for the elaboration of creative processes of innovation— an interactive learning model in which color theories and their design applications are introduced.

The course dynamics respond to the questions that are considered a key to understand the perceptive and cognitive processes that intervene in designing with colors. The questions are: Why the color of some food is not a like to people? Why do people refuse elements with non-conventional colors? Which composites provide color to food?

We have designed pedagogic dynamics that allow the students —after experimenting, experiencing, and confirming— to reinforce their knowledge of the effects of color, its interactions, applications, perception and meanings.

Pedagogic innovation —through conceptual exercises and interactive learning— arouses curiosity and creativity among the students. That is the reason why we have created a practice focused on the emotive experiences, made evident through changes in the usual color of food.

1. INTRODUCTION

Food comes through the eyes. .... This is a popular saying in Colombia and is the starting point of experimentation on the relationship between color perception and food taste. which take place in Bogota, an applied exercise called *"Colorful Food, Experience and Sensation"* was proposed and it has allowed us to experiment, prototype and iterate using food color and guests. In the "*Color, color and more color"* course included in the University Courses of Integral Education by Los Andes University

They say that the more intense and varied menu colors are, the healthier and more nutritious is food; however, what happens when food color changes? When its presentation is different from the common presentation we are used to in our brains? -A color other than its natural color?- Food color provides us with a great amount of information, colors in food send us messages about composition, ripeness and quality of food, which are factors to determine their degree of acceptance.

Ramachandran, E. 2003. Hubbord, *Escuchar colores, saborear formas.* Investigación y Ciencia 322 Rev. 34 Pág. 25-29.

Consequently, this practice occurs as a prototyping of emotive experiences through a change of food color and presentation with regard to their composition and combination

The first appreciation and meaning we give to food in our exercise is visual experience. We refer to eating through our eyes, but while experimenting with color in food, all senses –i.e. sight, smell, taste- activate and get involve evoking perceptive memories and flavors.
Color in food can change certain behavioral patterns that may affect and alter the mood and emotional state of a person; generating in that person a sensation of pleasure or rejection, positive and/or negative emotions, which can be observed through salivation, body posture, expressions of joy, disgust, repulsion or rejection, among other emotions expressed instantaneously and unconsciously.

Everything is the result of experimenting with the design of prototyping performed jointly by students and guests invited to participate in the staging with food.

2. PROTOTYPING WITH FOOD

The suggested exercise explores the psychological impact of color on food and new perceptive answers generated by guests. For this purpose, an applied experimental methodology was developed by using empirical verification through prototyping, in which the person faces acquired knowledge and live experiences, thus producing perceptive answers to new stimuli.

The making of prototypes with food becomes a key activity to understand, explore and communicate based on the perception of multiple sensorial features of a proposal interpreted through filters previously established by students in the staging they develop.

Prototyping an experience with food is based on the observation of participants, on how they see, feel, taste and express themselves by gestures and verbally while eating new proposals of food presentations. This experience is beyond "sensory concrete".

Fulton Suri, J. 2000. *Experience prototyping*. San Francisco IDEO. http://portal.acm.org/citation.cfm?id=347802 Accessed: Junio 8, 2011.

It is reinforced with structured questions and open interviews that register impressions and reactions generated by the proposals of color application.

2.1 Exploring the Concept (Raw Prototyping)

The project starts by making work groups, which create a series of questions, select a sensation or feature or emotional state that leads to generate a concept that is prototyped through outlining (raw prototyping) in order to determine the starting points of staging.

- Once the color was chosen, the staging was designed in a composition made up of the food, plates and other accessories that are part of the eating experience in our culture. The chosen color had to prevail in the staging, although other complementary colors could be used in small quantities —always justifying their use.

- The final presentation of this exercise was a public exhibition in which all the groups took part.

2.2 Public Presentation

The exercise is based on highly elaborated appearance features to achieve the proposed goals –elaborated prototyping-. Staging involves involves several experiences and combines variables such as: Characterization, shape and composition, food quality, taste, creativity and atmosphere.
The result of this experience is information about the extent to which the color influences the decision to consume certain food.
The activity allowed people to experience and perceive directly the influence and reactions produced by the changed color of the foods, and understanding that many gastronomic elements can be used to produce different perceptive feelings in people.

Figure 1. Prototyping of experience with food color
(Pictures of Amparo and Samira Quijano Kadamani)

2.3 Activity Results

The way a person watches, smells and tastes certain food is linked to color. This was evident in guests' spontaneous reactions in the activity, where they established an association to a specific flavor commonly related to color, got confused, showed pleasure or disgust.
Some evidence includes the following:

- Black color in food is not an appealing color to taste; it is associated to stale food. However, they got surprised in the exercise when tasting the proposed food; a pleasant flavor despite of the color.
- Similarly, blue color in food is not very enticing for guests. It is a sickly color in food related to something artificial and sweet that generates curiosity in spectators.
- Beige color is associated to serenity. Despite of the fact that the activity included only one sweet piece of food, it was acknowledged as a predominant flavor due to its complementary colors (pink, green, orange, etc.).
- Brown color, explored in cakes decorated with several colors, evidences that persons prefer yellow, red and orange decoration and avoid blue and green decoration even in the same cake. The former generate a higher contrast, which makes the product more provocative. Guests associated shiny brown color to sweetness and warm temperature, while opaque brown color was associated to less calories and a lower temperature.

- Grey color in food generates expectations, but also distrust and rejection. Users were afraid of getting sick because this color is perceived as dirty and/or stale.
- Expressions such as "not provocative", "I thought it would have no taste" respond to the preconception about white food having insipid flavor.
- The concept of sweet was associated to yellow; it gets the guest's attention as "looking tasty"

Finally, in response to a stimulus (through color, composition and table decoration), guests were able to generate an association among food color, concepts and flavor.

3. CONCLUSIONS

The developed exercise and scheduled activity reassured that color is essential when sitting at the table. It is worth mentioning that several color shades have subjective meanings derived from the individual's personal experiences, culture and socialization in his environment. Likewise, it was evident that colors communicate meanings, feelings and emotions consistently and unconsciously based on a particular language that ranges from expressing simple gestures to the construction of dialectical discourses that determine a meaning and social relationship. Mankind is able to consolidate minimum basic parameters during its social journey by means of its interdependence with its natural environment. These minimum parameters can be translated into dialectical, cultural and social creations that determine the uncertainty of the meaning of color in the different means it may be used.

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REFERENCES

ZELANSKY, P. Fisher M. 2001. *Color* Edit Blume 1999 cap 4, 50-57.
DAMASIO A. and DAMASIO, H. 1992. *Cerebro y Lenguaje,* Investigación y Ciencias 194.
EDWARD, M. 2003. *Escuchar colores, saborear formas.* Investigación y Ciencia 322.
GAGE, J. 2001. *Color y Cultura* Edit. Siruela. Percepción construida Goethe Cap. 5, 112-134.
HELLER, E. 2004. *Psicología del color*. Edit. GG Cap.
ORTIZ, G. 2001. *El significado de los colores Los contrarios psicológicos* Edit. Trillas. 35-36.
MOGGRIDGE, B. 2006. Working with people. *Designing Interactions*. Cambridge, Massachussetts: MIT Press.
BUXTON, B. 2007. *Sketching User Experiences*. San Francisco: Morgan Kaufmann Publishers.
Ramachandran, E. 2003. Hubbord*, Escuchar colores, saborear formas.* Investigación y Ciencia 322 Rev. 34 Pág.

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oral paper

Effects of Personal Background on Residential Wall Color Preference

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ABSTRACT

In this research, we clearly identify and investigate some of the factors influencing color preference. We have taken social environment as a primary focus and the influence of a person's residential, regional, educational and personal background have been examined. A questionnaire, 2 drawings (one of a bedroom and another of the exterior of a few houses) and 24 color pencils were prepared. In total, 319 data were gathered with 301 applicable data. One of the questions was the respondent's favorite color. The results showed that 97.98% of the respondents have used their favorite color in the drawings. Among other things observed was the bigger influence of education ($P<0.01$). Furthermore, it was observed that the students who had parents with art backgrounds had more color varieties in the drawings rather than the ones with parents with no art background ($P<0.05$).

1. BACKGROUND OF RESEARCH

In a previous research[1], we did a cross cultural study regarding interior color preference and concluded that there is not much color variety when Japanese people are choosing colors for their bedroom walls and they are all focused on white more so than other respondents. Furthermore, Professor Miho Saito has done a cross cultural study[2], and concluded that Japanese people like white (more so than others).

2. PURPOSE OF RESEARCH

In this research, through comparing different social and architectural contexts and experiments, we clearly identify and investigate some of the factors influencing color preference.

3. METHOD OF RESEARCH

We have taken social environment as primary focus and the influences of a person's residential, regional, educational and personal backgrounds have been examined. This was done between August and November 2011 in Iran and Japan with university students between the ages of 20 to 30. (Table 1)

Table 1. Number of Gathered Data (Applicable Data)

Iranians Living in Iran	Japanese	Foreigners Living in Japan	Total
101(94)	122(115)	96(92)	315(301)

In the beginning, each respondent was given 2 drawings (Figure 1) and 24 color pencils and they were asked to paint the drawings according to their preference. Then, they were handed a questionnaire regarding their personal background which was divided into regional, educational and residential sections.

Figure 1. Sample of interior and exterior drawings

4. DATA AND ANALYSIS

The data was analyzed by comparing the regional, educational, residential and personal sections in the questionnaire and the number of the color varieties and the colors used in both of the drawings. Not only the number of color varieties and the colors used were considered, but also we verified if they have used any patterns on the walls, thus, to see the creativity, this method – drawings with the color pencils – was the most appropriate.

4-1. Usage of Respondents' Favorite Colors in the Drawings

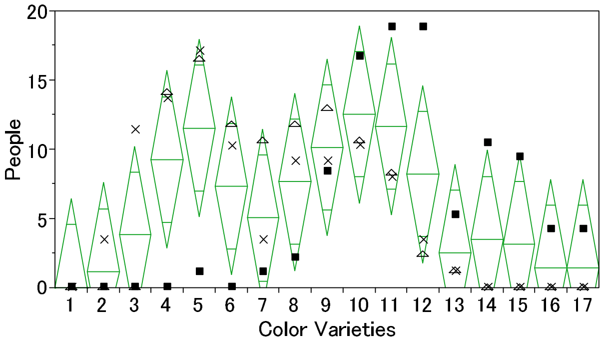
One of the questions was the respondent's favorite color. It was observed that 97.98% of the respondents used their favorite colors in the drawings. (Table 2) One respondent didn't use her favorite color (gray) in the drawings for the reason of not finding the gray she was looking for in the color pencils.

Table 2. Distribution of favorite colors in the drawings

Yes	**Interior**			**Exterior**
	Wall	Bed	Other Objects	
97.98%	43.43%	35.01%	77.78%	85.52%

4-2. Educational and Regional Cases

The respondents were asked to give the number of art hours of classes they had per week from kindergarten throughout high school. It was observed that with more hours of art, they had used more number of color varieties in their drawings (P<0.01) (Figure 2). Furthermore, in the regional section, it was concluded that people living in Coastal areas have used more blue hues in their drawings (P<0.05) (Figure 3).



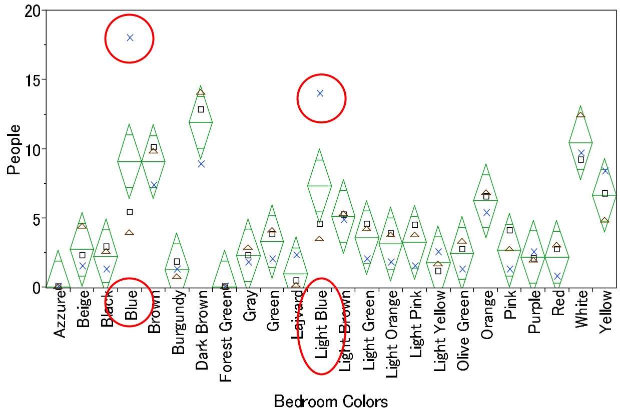
X: Less than 4 hours of Art

△Between 5 to 7 hours of Art

■ More than 8 Hours of Art

σ Average σ
Means Diamond in the Graphs

Figure 2. Art Hours and Number of Colors



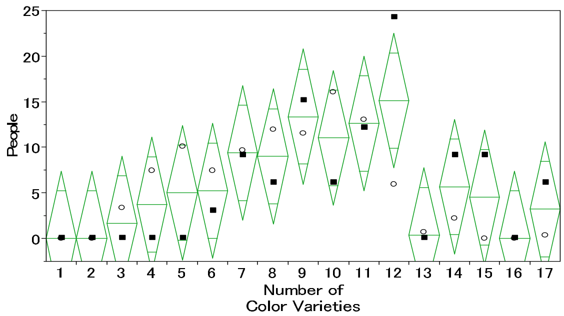
X: People living in Coastal Areas

△ Mountainous ☐Metropolitan

Figure 3. Regional and Colors Used

4-3. Respondents' Parents' Background and Number of Color Varieties

The respondents were also asked if their parents had any art background or not. It was observed that students who had parents with art background had used more number of color varieties rather than those who didn't (P<0.05) (Figure 4).



■Parents with Art BG ○Parents with no Art BG

Figure 4. Respondent's Parents and No. of Varieties

4-4. Nationalities and Number of Color Varieties

This paper has been focused on the data as a whole, but this section focuses on the 3 different categories (Iranians, Japanese and Foreigners). Figure 5 shows the distribution of

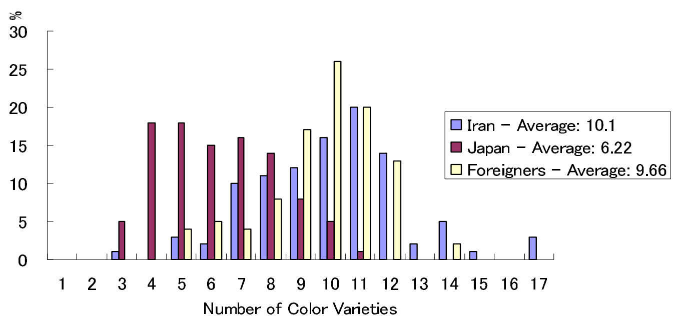


Figure 5. Number of Colors for the 3 Categories

number of color varieties, and it is concluded that in total, foreigners (including Iranians) have used more number of color varieties rather than the Japanese respondents. Table 3 shows the patterns the respondents had used in the bedroom wall drawing. It is observed that Iranians living in Iran have used more patterns in the drawings compared to the other foreigners or Japanese.

Table 3. Patterns used in the Bedroom Wall Drawing

	Plain	Patterned	Striped	Mixed Shades	Florish	Starish	Curved Lines	Circled
Iran	77 (81.91%)	17 (18.09%) *	1 (1.07%)	9 (9.57%) **	3 (3.19%)	0	2(2.13%)	2 (2.13%)
Japan	108(93.92%)	7 (6.08%)	0	5 (4.34%)	1 (0.87%)	0	1(0.87%)	0
Foreigners	85 (92.39%)	7 (7.61%)	0	0	3 (3.27%)	2 (2.17%)	0	2 (2.17%)

* p<.05, **p<.01

DISCUSSIONS AND CONCLUSIONS

In this paper, the influence of personal background on color preference was studied using drawings. Not only the colors used and the number of color varieties were analyzed, but also the patterns the respondents have used in the drawings. From the analysis, it was concluded that education had the most influence on the number of color varieties ($P<0.01$). The respondents, whom had attended more hours of art throughout their education, had used more color varieties in the drawings. Furthermore, 97.98% of the respondents had used their favorite colors in both drawings. It was also observed that people living in Coastal areas have used more blue hues in both their interior and exterior drawings ($P<0.05$). This test was done among Japanese and Foreign students (foreign students living in Japan and Iranian students living in Iran) and in total, Japanese respondents had used less number of color varieties compared to the Iranians and Foreigners.

REFERENCES

1) Mahshid Baniani and Hiroya Igarashi: How Different People with Different Life-Styles Think towards Interior Design, In *AIC Color 2009*, Sydney, p. 124
2) Miho Saito: Preference for White in Japan and its Background – “A Comparative Study in Asian Areas”, *Journal of the Color Science Association of Japan*, Volume 23, No. 3, pp 158-337, 1999

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Contextual associations affect warm and cold colours

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ABSTRACT

All people perceive colours as warm or cold, and this is one of the most common synaesthetic experiences involving visual and tactile senses. It is well known that context can considerably modify how colours appear and in this work modifications in colour appearance were investigated by associating a colour sample to images whose semantic content was expected to increase or decrease its warm/cold aspect. Three kinds of images were used, whose subject was provoking warm, neutral and cold impressions. The effect was tested by a group of 12 referees. The task of the participants was to evaluate how much cold-warm appeared each of the five studied colour after observing the associated inducing image. Results show a strong inducing effect which significantly modifies the perceived temperature of all colours as a function of their semantic characteristic.

1. INTRODUCTION

The characterization of a colour as being warm or cold can nowadays be conceived as a synaesthetic trait because it assigns a tactile property to a visual content of our perception. On the other side linguistic studies testify that always colours have been considered warm or cold: in the poorest languages having only two terms for colours (Berlin and Kay, 1969) white and black, light and dark, and warm and cool were almost synonyms. Nevertheless colour science, with few exceptions (Sivik and Taft, 1992), set this topic apart while it became diffusely dealt by artists (Garau 1993). Only recently some experimental studies have been performed to identify which colours are effectively warm or cold (Ou et al. 2004; Xin et al. 2004; da Pos and Valenti 2007).

Results were widely agreeing, but contextual effects, like simultaneous and successive contrast, were not studied, although of large interest in art and design. For contrast we mean the enhancement of the differences when two colours differing in an aspect (lightness, chroma, temperature, and so on) are put close together. In this work we study a new contextual effect due to the semantic induction of an image on the warm-cold appearance of an associated colour.

2. MATERIALS AND METHODS

The colours we used to study their warm-cold appearance as a function of the semantic induction by the associated images were yellow, red, green, blue, and purple, described in Table 1 and Figure 1.

As our aim was to test if and how much the meaning of an image can change the warm-cold appearance of an associated colour, we chose a number of images which were eliciting either a warm, or a cold or a neutral impression. Therefore we selected three images for each of the three kinds of inducing effects and coloured them with the five experimental colours (in total 45 images, exemplified in Figure 2) and asked a group of 12 referees, with normal colour vision, to state which impression each of them was provoking and to which extent in a 0-12 scale (0 very cold, 12 very hot).

Results of this inquiry are shown in Figure 2, where the difference between the warm and the cold inducing images appears quite large, but also the in-between group of neutral images is significantly different from the other two.

Table 1. *CIELAB specifications of the colours used in the experiment.*

	L*	a*	b*
Red	51.65	65.88	53.31
Yellow	90.32	3.61	76.42
Green	62.04	-47.94	47.14
Blue	40.74	7.75	-72.55
Purple	55.91	41.22	-53.60
Bianco	97.65	-0.06	0.86

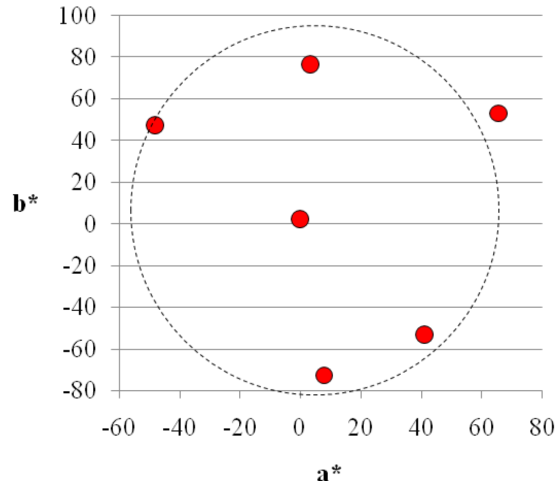

Figure 1. Representation of the five colours and the achromatic point used in the experiment in a CIELAB diagram

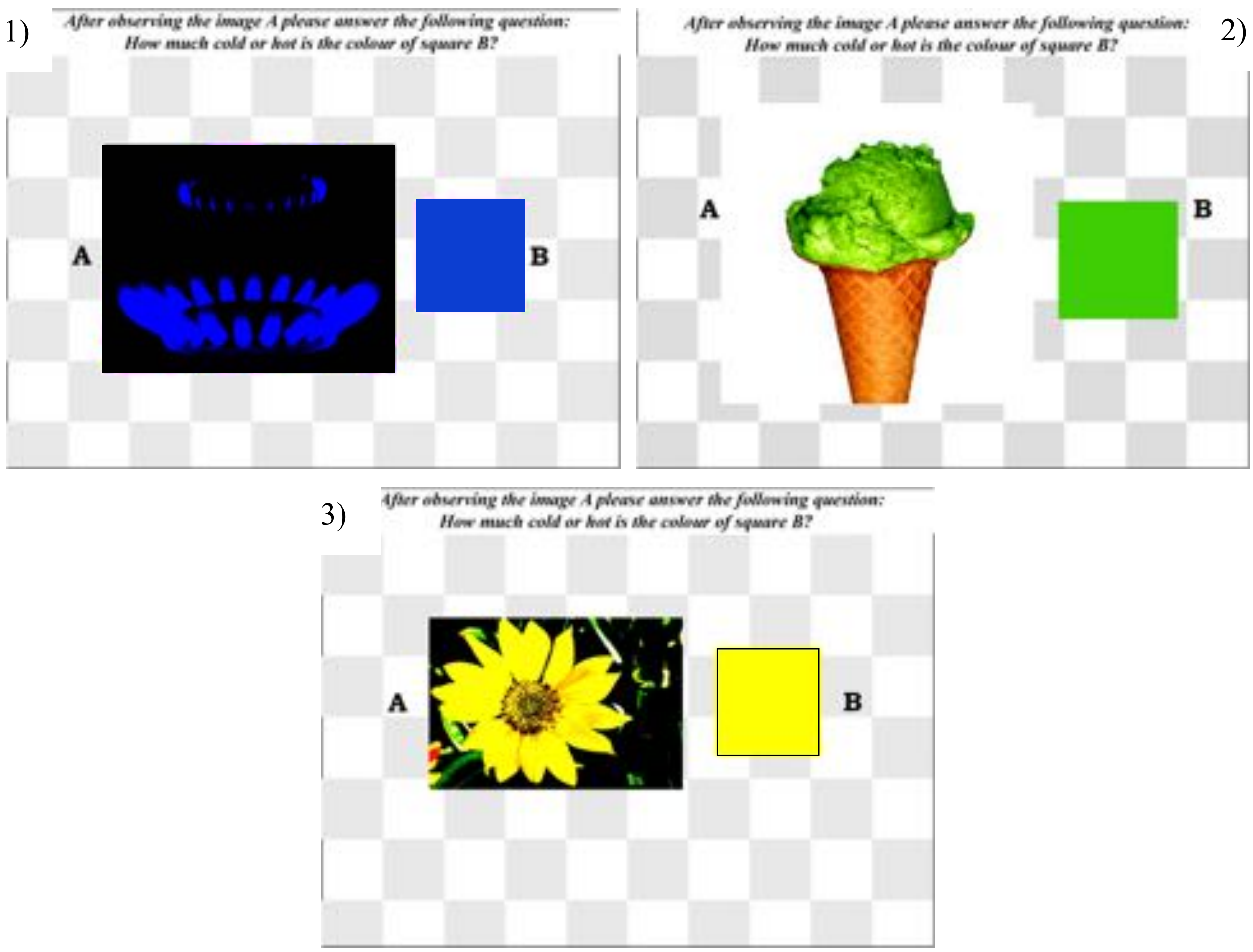

Figure 2. Examples of the stimuli presented to the observers: (1) an image(A) inducing warm impression in the associated colour(B); (2) an image inducing cold impression in the associated colour and (3) an image inducing neutral impression in the associated colour.

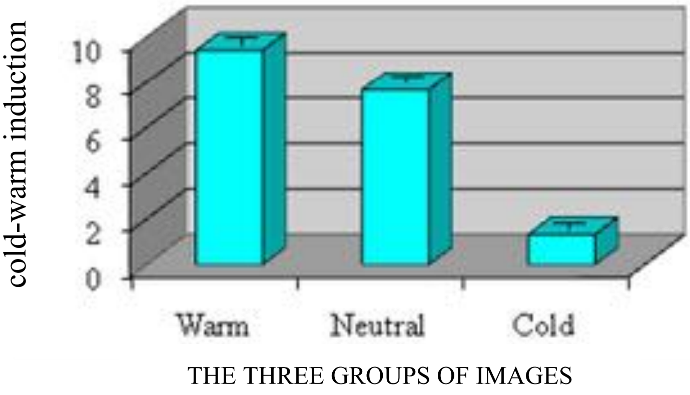

Figure 3. Mean evaluations and SE bars of warm induction given by the referees to the three groups of images.

A group of 43 participants, all with normal colour vision, took part in the experiment. Stimuli were presented on a calibrated LCD monitor in a dimly-lit room; ambient reflections were avoided by putting a black curtain behind the observer, sitting at about 50 cm far from the screen. Each presentation was followed by a light and dark gray chessboard to cut colour after-effects. The task was to carefully observe the inducing image and then to evaluate how much warm appeared the associated colour placed at its side. Evaluations were performed by putting a stroke on a segment whose ends corresponded to the maximum cold and maximum warm, respectively, so that the distance of the stroke from the two ends corresponded to the degree of perceived colour temperature.

2. RESULTS AND CONCLUSIONS

Global results, shown in Figure 4, indicate that all colours which were associated with one of the three types of images significantly differed from the others in perceived temperature as a function of the inducing characteristic ($F_{2,34} = 39.09$, $p < 1.0E-12$).

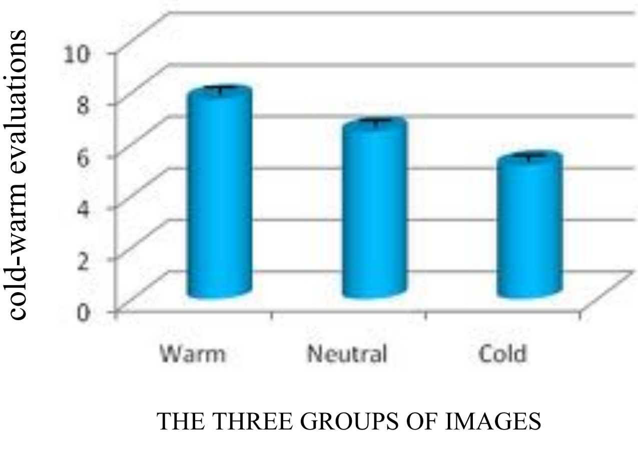

Figure 4. Mean evaluation and SE bars of temperature given by the observers to all colours associated with the three types of images.

Moreover each single colour was differently evaluated in temperature as a function of the inducing images to which was associated (Figure 5) ($F_{8,336}$ = 15.93, p < 1.0E-12). Lastly all colours-image combinations appeared significantly different from the others, except the green associated with cold inducing image and the blue associated with warm inducing image, which were evaluated of the same warmth. Results therefore show a significant and strong effect of the temperature induction produced by the associated images, induction not due to a colour interaction but to the semantic property of the images.

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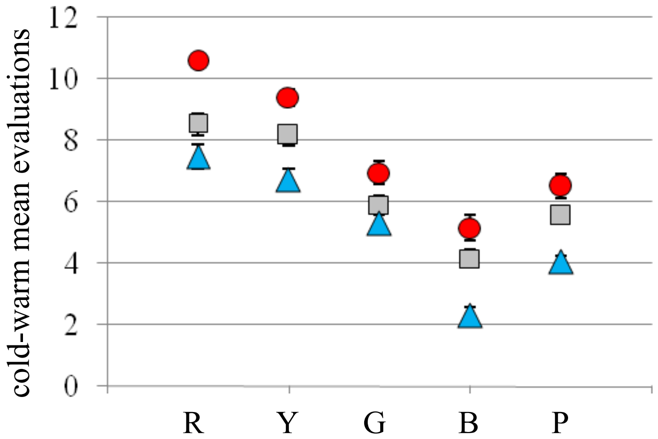

Figure 5. Mean evaluations and SE bars of the cold-warm appearance of the colours under induction by the three types of images. Circles: colour affected by warm inducing images; Squares: colour affected by neutral inducing images; Triangles: colour affected by cold inducing images; RYGBP: the five experimental colours.

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REFERENCES

Berlin, B., Kay, P. 1969 *Basic Color Terms: Their Universality and Evolution* Berkeley and Los Angeles, California: University of California Press

Da Pos, O., Valenti, V. 2007 *Warm and cold colours*. In *AIC2007 Colour Science for Industry*, Guanrong YE, Haisong XU (Eds.), Proceedings of the AIC 2007 Midterm Meeting, Color Association of China, Hangzhou, pp. 41-44

Garau, A. 1993. *Color harmonies*. Chicago: The University of Chicago Press.

Ou, L.C., Luo, M.R., Woodcock, A., Wright, A. 2004 A study of colour emotion and colour preference. Part I: Colour emotions for single colours. *Color Research and Application*, **29**, pp. 232-240

Sivik, L., Taft ,C., 1992 Colour combination ad associated meanings – Semantic dimensions and colour Chords, *Göteborg Psychological Reports, Univ. of Göteborg, Sweden, 22(1),* 1-23

Xin J.H., Cheng, K.M., Taylor, G., Sato, T., Hansuebsai, A., 2004 Cross-regional comparison of colour emotions Part I: Quantitative analysis. *Color Research and Application*, **29**, pp.451-457

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oral paper

Age effects on visual comfort as a function of lightness difference between text and background

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ABSTRACT

A psychophysical experiment was performed using two groups of observers: 21 young observers and 20 older observers. The paired comparison method was used in this study, with 12 document layouts as the stimuli generated by all possible text-background combinations of 4 achromatic colours. The experimental results suggest that an extremely high luminance contrast for text and background can result in a decline in visual comfort, which was found to be more significant on a dark background than on a light background.

1. INTRODUCTION

Luminance contrast for text and background on a display has been extensively studied (e.g. Taptagaporn and Saito, 1990; Buchner and Baumgartner, 2007) regarding its impact on visual performance and comfort. A consensus seems to be reached that the higher the luminance contrast was, the better the visual comfort was. Looking closely at the individual findings, however, one may notice some significant disagreement between the studies. For instance, despite the majority of papers showing the advantage of a high luminance contrast over a lower one, studies by Zhu and Wu (1990) and by Roufs and Boschman (1997) reported that visual comfort was highest for the moderate luminance contrast, with less comfort for both extremely low and extremely high contrast levels. It is interesting to note that the values of maximum luminance used in the majority of studies were normally under 300 cd/m^2, a value far lower than those used in studies by Zhu and Wu (633 cd/m^2) and by Roufs and Boschman (400 cd/m^2). While it is yet to be established whether luminance has a direct impact on visual comfort, a high luminance display does tend to create a higher contrast ratio than a screen with lower maximum luminance.

The issue is more essential in the area of aging research thanks to the increasing popularity of e-reading and web applications for older people. Considering potential impacts of text-background contrast on visual comfort for older people, the present study aims to establish whether the existing findings regarding text-background contrast still hold true for a display with an extremely high contrast ratio.

2. METHODS

A psychophysical experiment was carried out to investigate the effect of text-background luminance contrast, defined as the CIE lightness difference in this study, on visual comfort for young and older observers. Forty-one Taiwanese, including 21 young observers (11 male and 10 female) and 20 older observers (10 male and 10 female), participated in the study. The young observers ranged in age from 22 to 29 years (m = 25.2); the older observers ranged from 60 to 78 years (m = 66.8). The observers have all passed Ishihara's test for colour deficiency.

During the experiment, each observer was presented with 132 comparisons of two document layouts, and was asked to pick one of the two layouts, of which the observer felt more comfortable to read the text. Each document layout presented the same text, the only difference being the luminance values of the text and of the background for the two document layouts. Figure 1 shows an example of the comparisons.

Figure 1. An example of the screen layout

The text and background colours were based on four achromatic colour samples. Table 1 shows colorimetric measurement data for the four colours including luminance and the CIE values. Based on the four achromatic colours, 12 text-background combinations were generated, considering both positive and negative polarity conditions. This resulted in 66 paired comparisons. Each of the 66 combinations was repeated once, meaning 132 comparisons in total were made by each observer. During the experiment, the sequence of the 132 comparisons was randomised; the right/left positions of the two document layouts for each comparison were also randomised.

The experiment was performed using a Samsung 46-inch LCD (C7000). The display was situated in a darkened room, with an illuminance level of less than 3 lux if the display was turned off. The display peak white had a luminance value of 551.77 cd/m^2, with CIE chromaticity (x, y) = (0.2679, 0.2867). The high luminance of peak white enabled a wide range of luminance contrast levels for text-background combinations used in the experiment. The viewing distance was 1500mm for each observer.

Table 1. Measured CIE colorimetric data of the 4 colour stimuli

Luminance (cd/m^2)	**Lightness (L*)**	**x**	**y**
551.77	100.00	0.2679	0.2867
170.48	62.42	0.2742	0.2887
41.16	32.83	0.2809	0.2995
0.02	0.03	0.2315	0.2322

3. RESULTS

To see how closely the data from the two age groups correlate with each other, the scale values of the two groups were compared. High correlation (r = 0.90) was found between the two groups, suggesting there was little age effect on visual comfort response in this study.

To see whether and how lightness difference between text and background might affect the observer response, the averaged scale values of both observer groups were plotted against the lightness difference value, as illustrated in Figure 2. The graph shows a somewhat interaction effect between the lightness difference and the background luminance, indicating that the darker the background colour is, the higher the slope of the data lines tends to become, i.e. increasing lightness difference tends to enhance visual comfort, the enhancement being more significant on a dark background than on a light background. The graph also shows that the darker the background colour, the curvier the shape that the data lines seem to form. This suggests that continuing to increase lightness difference may result in a decline in visual comfort, which seems to be more likely on a dark background than on a light background.

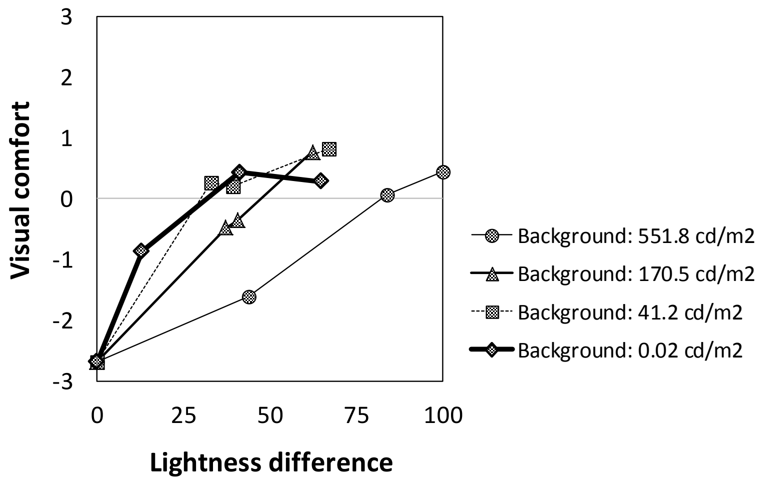

Figure 2. Perceived visual comfort (the average of all observers) plotted against the lightness difference between text and background

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4. CONCLUSION

The experimental results show high correlation (r = 0.90) between the two age groups, suggesting little difference between the young and older observers regarding the effect of lightness difference on perceived visual comfort. The results also show that continuing to increase lightness difference resulted in a decline in visual comfort, which was found more significant on a dark background than on a light background. Some previous studies (e.g. Taptagaporn and Saito, 1990) have reported that visual comfort tended to be higher for positive polarity than for negative polarity. According to the present study, however, there was no clear, simple relationship between visual comfort and screen polarity.

5. ACKNOWLEDGEMENT

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REFERENCES

Buchner, A. and N. Baumgartner. 2007. Text-background polarity affects performance irrespective of ambient illumination and colour contrast. *Ergonomics* 50: 1036-1063.

Roufs, J.A.J. and M.C. Boschman. 1997. Text quality metrics for visual display units: I. Methodological aspects. *Displays* 18: 37-43.

Taptagaporn, S. and S. Saito. 1990. How screen polarity and lighting condition affect the pupil size of VDT operators. *Ergonomics* 33: 201-208.

Zhu, Z. and J. Wu. 1990. On the standardization of VDT's proper and optimal contrast range. *Ergonomics* 33: 925-932.

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Color Emotions of Cubes and Square Patches

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ABSTRACT

The color emotion evoked by a cube shaped object was compared with those by eleven squre color patches generated using the local and average surface colors of the cube. The experiment was conducted for three different colors i.e. red, green and blue. For each color stimulus, "warm-cool", "heavy-light", "active-passive", and "soft-hard" emotions were evaluated by 24 observers in a dark room using sRGB LCD monitor. Then the representative color of a cube was calculated by analyzing the relationship between color emotion and CIELAB L*, C* and h values of square color patches. The results showed that in the case of green and blue colors, there was little representative color changes by color emotions while red color show relatively larger variation. Color distance map, representing the color difference between each pixel's color on the cube and the representative color, suggests that the representative color area on the cube must be related with the area gets most attention from the observers. This study suggests that color emotion data of square patches can be used to describe color emotion of three-dimensional space.

1. INTRODUCTION

Conventionally, color emotion studies are based on the experiments using square color patches. However a real world object painted with single color have three-dimensional shape showing various tones and shades on the surfaces depending on the position and strength of light sources. In spite of various color tones on a surface, we tends to perceive one unique color emotion from the object. The aim of this study is to investigate whether the color emotion of a three-dimensional object can be judged by one representative color on a surface. If color emotion of three-dimensional object can be described using one representative color of an object, color emotion data of square patches can be used to describe color emotion of three-dimensional space. In this research, the color emotions of cubes and square color stimulus are collected and compared.

2. EXPERIMENTS

The 24-inch sRGB LCD monitor (ColorEdge CG242W) was used to show the three sets (red, green and blue) of color stimuli, which consisted of one color cube and 11 suqare color patches extracted from each color cube. In total, 3 cubes and 33 square patches were used in the experiment. Each color was measured using the Minolta CS-2000 tele-spectroradiometer. Figure 1 shows the screen shots of cube and square patch stimulus and color distributions of color stimuli in CIELAB space.

Twenty four observers with normal color vision including 14 males and 10 females with an average age of 23.1 years participated the experiment. The observers were asked to report the perceived “warm-cool”, “heavy-light”, “active-passive”, and “soft-hard” of each stimulus using a 7-step categorical judgment method. All the experiments were conducted in a dark room and all the stimuli were shown in random order. The observers’ data were converted to have +3 to -3 range and averaged.

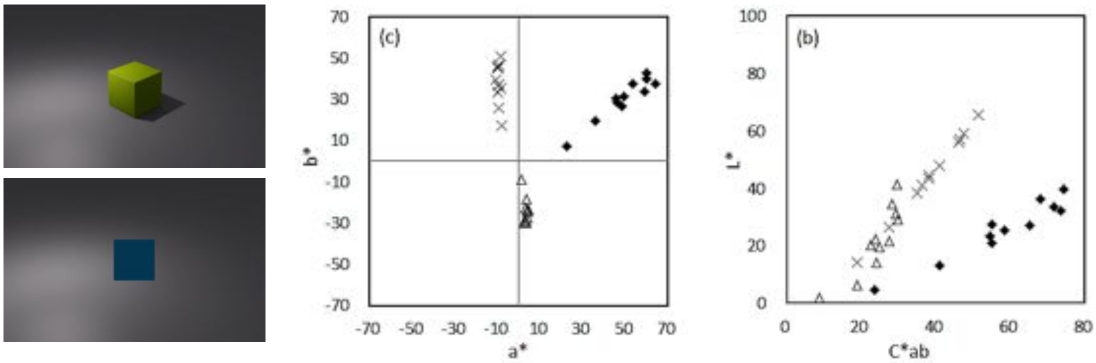

Figure 1. Example of Color Stimulus Images and Color Distributions in CIELAB space

3. EXPERIMENTAL RESULTS

Figure 2 shows the relationship between color emotion and CIELAB values of square color patches. It is notable that “warm-cool” emotion is affected by hue only while in the case of “heavy-light”, “active-passive”, and “soft-hard” emotions, as CIELAB L* and CIELAB C* values increase together, colors tend to be perceived as lighter, more active and softer.

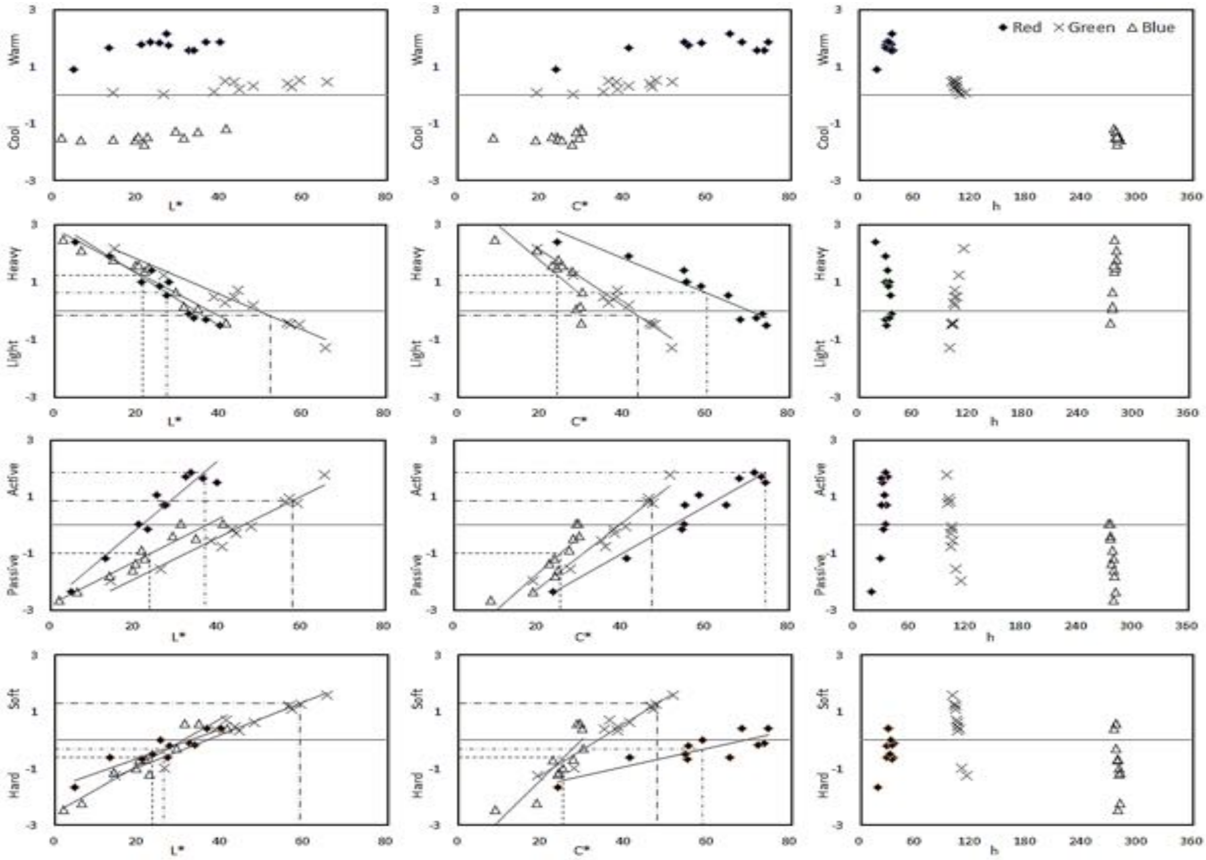

Figure 2. The relationship between color emotion scales and CIELAB values

The representative color of cubes were estimated by calculating corresponding CIELAB values of color emotions of cube images as shown in Figure 2 with the dotted lines. Table 1 summarizes the resulting average CIELAB values and standard deviations of four color emotions. Since there is little CIELAB hue difference between color patches, average hue angle is used as representative CIELAB h. Red color cube shows largest representative color variations between color emotions while Green and Blue colors' represenatitive colors are fairly consistant regaredless of the color emotions.

Table 1. CIELAB values of representative colors of 3D cube images

3D cube color	L*	C*	h
Red	29.94 ± 5.97	64.38 ± 8.82	31.84
Green	56.25 ± 3.64	46.07 ± 2.34	103.66
Blue	22.76 ± 1.43	24.77 ± 0.85	277.80

The representative color points on 3D cube surfaces are visualzed using color difference map as shown in Figure 3. This figure suggests that people may determine their color emotion of an object by looking at certain area on the surface, where gets most attention from the observers.

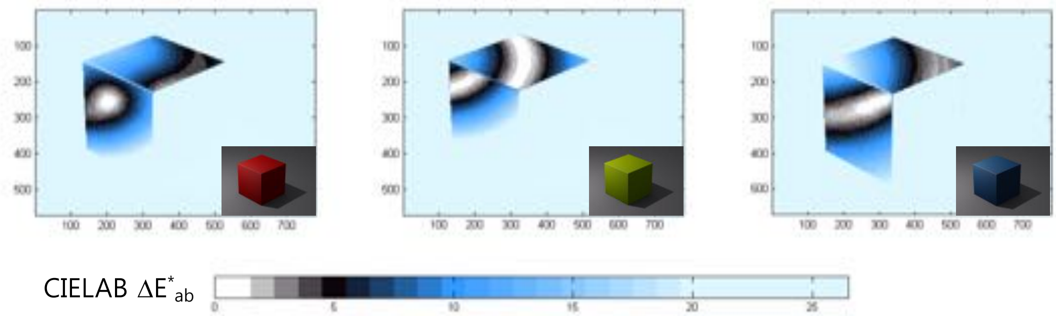

Figure 3. Color distance map from representative colors

4. PERFORMANCE TESTS OF COLOR EMOTION MODELS

Four color emotion models were evaluated using the newly collected data, which are models developed by Ou et al. (2009), Lucassen et al. (2011), Sato et al. (2000) and Xin and Cheng (2000). Figure 4 show the relationship between the predicted data and the experimental data.

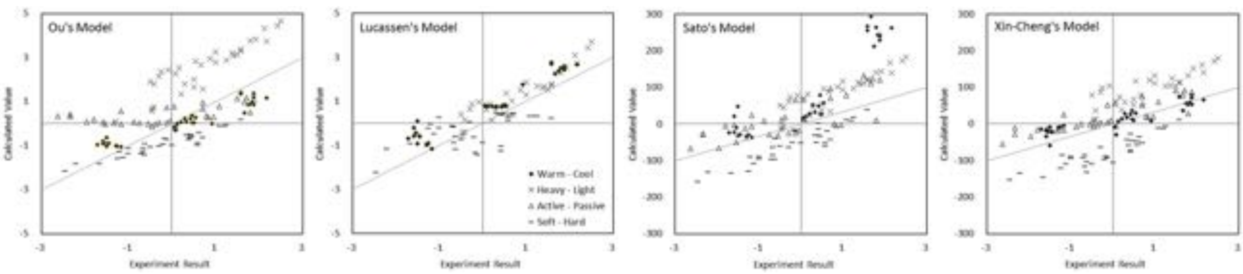

Figure 4. Performance of four color emotion models

Except active-passive scale, most of them show good linearity but have shifted predicted emotion toward heavy and hard direction.

4. CONCLUSIONS

The color emotion evoked by cube shaped object was compared with those by eleven squre color patches generated using the local and average surface colors of cube. The experiment was conducted for three different colors i.e. red, green and blue. For each color stimulus, "warm-cool", "heavy-light", "active-passive", and "soft-hard" emotions were evaluated by 24 observers in a dark room using LCD monitor. Then the representative color of a cube was calculated by analyzing the relationship between color emotion and CIELAB L*, C* and h values of square color patches.

The results showed that as CIELAB L* and C* increase together, square color patches tend to be perceived as lighter, more active and softer, while warm-cool emotion is affected by hue attribute only. Using the color emotion-CIELAB relationship of squre patches, the representative color of cube is defined as corresponding CIELAB L*, C* and h values of color emotion of cubes. In the case of green and blue colors, there was little representative color changes by color emotions while red color show relatively larger variation. Color distance map, representing the color difference between each pixel's color on the cube and the representative color, suggests that the representative color area on the cube must be related with the area gets most attention from the observers. The performance test results of four color emotion models demonstrates that current color emotions are not good enough to be universally accepted.

Since current research finding are based on the limited number of color stimuls, further intentive color emotion studies are required to generalize the results. However, it is believed that this study suggests high possiblity that color emotion of three dimensional space can be predicted using color emotion models developed from simplified squre color patch experiment.

ACKNOWLEDGEMENTS

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REFERENCES

Lucassen, M. P., T. Gevers, and A. Gijsenij. 2011. Texture affects color emotion. *Color Research and Application* 36 (6): 426-436.

Ou, L., M. R. Luo, A. Woodcock, and A. Wright. 2004. A study of colour emotion and colour preference. Part I: Colour emotions for single colours. *Color Research and Application* 29 (3): 232-240.

Sato, T., K. Kajiwara, H. Hoshino, and T. Nakamura. 2000. Quantitative evaluation and categorising of human emotion induced by colour. *Advances in Colour Science and Technology* 3: 53-59.

Xin, J., and K. Cheng. Quantitative evaluation of colour emotion. *JSPS Fund Meeting* 2000;71– 86.

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Intensity Independent RGB-to-XYZ Colour Camera Calibration

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ABSTRACT

In order for a digital colour camera to represent the colours in the environment accurately, it is necessary to calibrate the camera RGB outputs in terms of a colorimetric space such as CIE XYZ or sRGB (Wyszecki 1976). Assuming that the camera response is a linear function of scene luminance, the main step in the calibration is to determine a 3×3 linear transformation matrix M mapping data from linear camera RGB to XYZ. Determining M is usually done by photographing a calibrated target, often a colour checker, and then performing a least-squares regression on the difference between the camera's RGB digital counts from each colour checker patch and their corresponding true XYZ values. In order to measure accurately the XYZ coordinates for each patch, either a completely uniform lighting field is required, which can be hard to accomplish, or the illuminant power spectrum incident on each patch must be measured. In this paper we present an optimization method for camera colour calibration that does not necessitate constant radiance across the scene, yet still determines an accurate colour correction matrix.

1. INTRODUCTION

Due to the fact that the spectral sensitivity functions of most cameras do not correspond to that of the human eye, cameras often need to be calibrated in order to produce outputs that are consistent with standard colour spaces, such as sRGB or CIE XYZ. Assuming for the moment that the camera response is a linear function of scene luminance, the main step in the calibration is to determine a 3×3 linear transformation matrix M mapping data from (linear) uncalibrated camera RGB to XYZ. Non-linear "gamma correction" is then added as a second step.

Determining M is often done by photographing a calibrated target such as the X-Rite Digital ColorChecker SG and then performing a least-squares regression on the difference between the camera's RGB digital counts from each colour checker patch and their corresponding true XYZ values. One difficulty with this method is that it is hard to create an environment in which the lighting is completely uniform. If there is a single light source, then we can assume that the *relative* spectral power distribution of the light is constant; however, its irradiance is likely to vary across the colour checker and this will affect the RGB digital counts. If the amount of variation in the irradiance is unknown, then the "true" XYZ values will not correctly model the scene and so the colour correction matrix (CCM) M computed from them will also be incorrect. A difference in irradiance on a patch changes its luminance and hence results in a scaling of the associated RGB intensities (i.e., digital counts). In other words, treating RGB as a vector, its length changes, but not its direction. In traditional least-squares, the difference between transformed RGBs and XYZs is what is minimized.

One way to account for illumination variation is to measure the irradiance at each patch, but this extra step can be quite time consuming. It would certainly be preferable to measure the illuminant spectrum at only one location and have a method for deriving matrix M that works even when the irradiance is non-uniform. Just such an illuminant-independent method is presented here.

The proposed method deals with illumination variation by minimizing the angle between transformed RGBs and XYZs. Unlike the traditional least-squares method, which takes into account both the direction and magnitude of RGB vectors, and thus is affected by any irradiance-induced scaling; the proposed method seeks the 3×3 linear transform that best aligns the vectors from RGB space with those in XYZ space, without regard to their magnitude. As a result, the effect of irradiance is eliminated from the minimization.

2. BACKGROUND

The camera colour calibration process involves imaging a target with a camera. Let A represent the $3\times N$ matrix of camera responses for N patches. Similarly, let B represent the $3\times N$matrix of the corresponding tristimulus values computed using the measured SPD of the illuminant, the spectral reflectance functions of each patch, and the CIE colour matching functions. Conventional least-squares regression minimizes $E(M) = |MA - B|_2$. It is well known that the best mapping is given by the Moore-Penrose pseudo-inverse

$$M = MA^T(AA^T)^{-1}.$$

As is clear from the above equation, both the direction and magnitude of RGB vectors represented in A affect the regression results. We next propose a magnitude-independent regression technique that is especially useful for camera calibration under circumstances where the irradiance cannot be guaranteed to be uniform across the target.

3. INTENSITY-INDEPENDENT REGRESSION

Consider a set of camera RGBs, $\{\vec{a}\}_{i=1}^N$, captured from N patches and their corresponding XYZ values, $\{\hat{b}_i\}_{i=1}^N$. The proposed technique finds a 3×3 linear transform M mapping RGB to XYZ by minimizing

$$E(M) = \sum_{i=1}^{N} \cos^{-1}\left(\frac{M\vec{a}_i \cdot \vec{b}_i}{|\, M\,\vec{a}_i|\,|\,\hat{b}_i|}\right)$$

This minimization takes into account only the angles between pairs of vectors. We used the Nelder-Mead (Nelder 1965) nonlinear optimization method to solve for the M. However, since the minimization is performed without regard to the overall vector magnitudes, the resulting transformation matrix M can be arbitrarily large or small in magnitude. To correct for the overall magnitude of M, the matrix is rescaled so that the sum of all its elements is 3 in sRGB space. This constraint ensures that the transformation does not alter the overall image brightness. We next show the results of performing camera calibration using synthesized data by applying least-squares and our proposed intensity-independent regression.

4. EXPERIMENTS

We performed two sets of experiments to study the effectiveness of our proposed method in camera calibration. In the first experiment, we synthesized an image of the interior patches of the X-Rite Digital ColorChecker SG under a non-uniform illuminant (Figure 1a) with irradiance-induced image intensity variation as shown in Figure 1b. The XYZ coordinates of each patch are calculated assuming constant radiance across the scene in both cases.

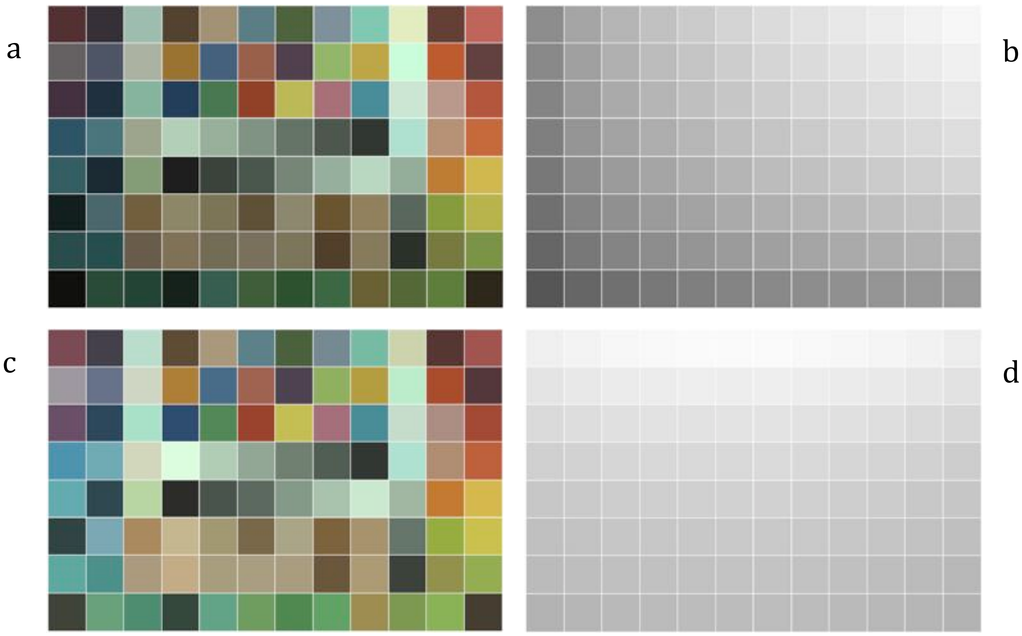

Figure 1: *a) synthesized image of the interior patches of the color checker under non-uniform lighting b) intensity variation in the synthesized image c) captured RGB values of the color checker patches in the light booth d) intensity variation in the captured image. The images here have been modified for visualization. The actual image data is linear.*

If we compute the CCM mapping camera RGB to XYZ space using conventional least-squares minimization, we obtain the following two matrices M_1 and M_2 for the images synthesized under uniform and non-uniform lighting, respectively:

$$M_1 = \begin{pmatrix} 0.6915 & 0.4720 & -0.0126 \\ 0.2476 & 1.0363 & -0.2559 \\ 0.1031 & -0.2840 & 1.5388 \end{pmatrix} \qquad M_2 = \begin{pmatrix} 0.2020 & 0.3539 & -0.1059 \\ 0.0612 & 0.5435 & -0.1913 \\ 0.0279 & -0.1356 & 0.7056 \end{pmatrix}$$

The relative difference between the two matrices, measured using the Frobenius norm, is $2\frac{|M_1 - M_2|_F}{|M_1 + M_2|_F} = 0.893$, indicating that the calibration results are impacted significantly by the irradiance variation. However, using our proposed technique, the camera calibration results are unaffected by the variation in the scene irradiance, and the two CCMs obtained for scenes 1 and 2 are identical:

$$M_1 = M_2 = \begin{pmatrix} 0.5428 & 0.3956 & 0.0232 \\ 0.1765 & 0.9293 & -0.2574 \\ 0.0234 & -0.0727 & 1.1288 \end{pmatrix}.$$

Of course, it is not sufficient for the transform simply to be intensity independent; we are also interested in seeing how well the transform maps colours from camera RGB to XYZ.

For this purpose, we compute the CCM based on the shaded image and measure the error on the uniformly lit image using CIEDE2000. We repeat this process for both methods. The results in Table 1 under "synthesized data" column show that our proposed calibration technique has better colour correction properties than the least-squares method under non-uniform lighting due to the fact that it is not affected by the irradiance variation across the scene.

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	Synthesized Image Data		Captured Image Data	
	mean ΔE^*_{ab}	max ΔE^*_{ab}	mean ΔE^*_{ab}	max ΔE^*_{ab}
Least-Squares	8.00	12.41	4.25	7.91
Intensity Independent	3.19	8.86	2.81	7.49

Table 1: ΔE^*_{ab} *statistics based on calibrating the camera using an image of the X-Rite Digital ColorChecker SG under non-uniform lighting and testing it on a uniformly lit image.*

In addition to using synthesized images, we used a camera to acquire images and then computed the CCM based on the captured image data. To reduce the effects of noise, the camera RGB values for each patch were determined by averaging the values over the whole patch. The resulting values are displayed as the image shown in Figure 1c. To measure the irradiance variation across the colour checker, we replaced it with a grey surface in the same location and captured a second image. The average RGBs from each patch location are shown in Figure 1d. As before we calibrated the camera using the original (non-uniformly lit) image and also an image in which the intensity was adjusted to be uniform using the background irradiance variation map. As expected, the results showed that while the two CCMs computed by the least-squares method based on the original versus intensity-corrected images differed significantly (Frobenius norm of 0.10), our intensity-independent regression resulted in an identical CCM in both cases. The "captured data" column of Table 1 also shows that the proposed method has better correction error than the standard least-squares method.

5. CONCLUSION

We proposed a color calibration technique that does not require uniform irradiance across the calibration target. While conventional methods, such as least-squares regression, take into account both the magnitude and direction of color vectors in mapping uncalibrated camera RGB output to XYZ coordinates, our method eliminates the dependence on the scene irradiance and resulting image intensities by considering only vector directions. The method's effectiveness was demonstrated on a non-uniformly lit calibration target.

ACKNOWLEDGEMENT

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REFERENCES

Wyszecki, G., and W. S. Stiles. 1967. *Color science, concepts and methods, quantitative data and formulas*. New York: John Wiley and Sons.

J.A. Nelder, R. Mead, A simplex method for function minimization. Comp. Journal 7, pp. 308-313, 1965

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Gamut Comparison Index: A metric for comparing colour gamuts

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ABSTRACT

It is often necessary to be able to compare two or more colour gamuts, in order to determine how similar they are. For example, if a colour image is to be re-targeted to a different medium, we may wish to know whether the second medium has a sufficiently similar gamut to make an acceptable reproduction a possibility. The gamut volume alone enables a comparison of the size of the gamut, but not whether the gamuts intersect sufficiently to meet the reproduction aims. This can be achieved by visual comparison of the two gamut volumes in a pseudo-3D rendering, but it would be useful to have a single-number value which enables this comparison to be computed from the gamut boundary description of the two gamuts. A new metric – gamut comparison index – is proposed to quantify the similarity between gamuts. A number of test cases for the index were computed. The results indicate that the gamut comparison index gave a consistent prediction of how well the two gamuts compared. Use of the resulting gamut comparison index value would enable users to select the transform or device that best matched the reproduction aim.

1. INTRODUCTION

A gamut of a printing system is typically found by using a numerical model to predict co-ordinates on the gamut surface. This can be done by printing a set of colour patches, measuring them, deriving a model and using this to calculate the 3D gamut boundary in a uniform colour space such as CIELAB, as described by Morovic (2000). Alternatively, the gamut can be sampled directly using a suitable test chart (Green, 2001).

Conventionally, gamut volume is used to compare two gamuts. In many cases, it is desired to match one gamut to another; for example, simulating a conventional printing process on digital proofing system. In this case, two gamuts can be compared visually and a difference between gamut volumes can be calculated. But, gamut volume cannot tell how closely the source gamut matches to the target gamut. For example, both gamuts could have the same volume, but they might not coincide in CIELAB colour space. To address this issue, a new metric called 'Gamut Comparison Index' is proposed here.

2. METHOD

Suppose we have two colour devices, x and y. If their gamut volumes are V_x and V_y respectively, then a gamut comparison index between these two devices can be calculated as follows:

$$GCI = \left(\frac{V_i}{V_x}\right)\left(\frac{V_i}{V_y}\right)$$

$$GCI = \frac{V_i^2}{V_x V_y}$$

... Eq.1

where V_i is the volume of intersection of the two gamuts ($V_i = Vx \cap V_y$). The term (V_i / V_x) quantifies how much of the gamut *x* is outside the intersection of gamuts; the term (V_i / V_y) determines how much of the gamut *y* is outside the gamut intersection.

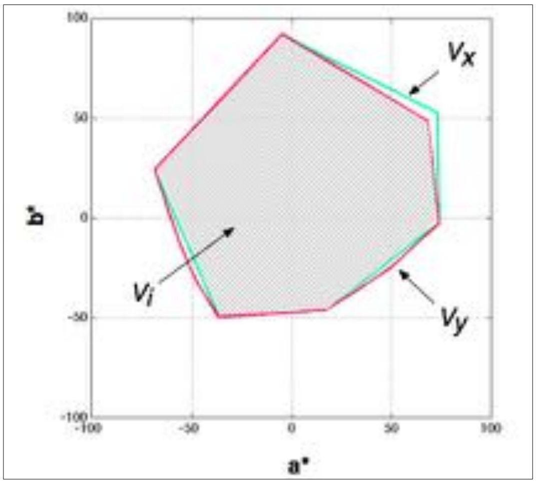

Figure1 Comparison of two gamuts x and y

GCI between two gamuts indicates how closely they match. The value of *GCI* ranges from 0 for no match to 1 for exact match. A higher value of gamut index indicates better accuracy. For a perfectly predicted gamut, $V_x = V_y = V_i$ and the value of gamut index equals 1. If these two gamuts have the same volume ($V_x = V_y$), but they don't intersect fully with each other, then the value of *GCI* will be less than 1. If two gamuts do not intersect at all ($V_i = 0$), then *GCI* = 0. Where gamut V_x completely encloses gamut V_y, then $V_i = V_y$.

For this test, the gamut was taken to be the convex hull (i.e. the smallest convex set that contains all the co-ordinates of the colour reproduction system), and the convex hull volume was computed on CIELAB co-ordinates from the Delaunay triangulation in Matlab using the Qhull algorithm. The convex hull provides an approximation of a gamut solid, but it has been noted elsewhere (Guyler, 2000, Cholewo, 1999, Morovic, 2008) that it has limited accuracy as it does not represent the curvature of a gamut and any concave regions. Better estimations of gamut volume can be computed using a curved-face model (Guyler, 2000) or by summing the volumes of all the tetrahedra belonging to the alpha shape of the gamut (Cholewo, 1999). Computing the gamut volume in a more perceptually uniform co-ordinate system is also likely to yield a better correlation between computed and perceived gamut volume (Morovic, 2008).

To test this metric, gamuts of different printing conditions were used. ISO DIS 15339-1 defines characterisation data sets for different reference printing conditions (RPCs). There are 7 reference printing conditions as follows: RPC1 Coldset Newspaper, RPC2 Heatset Newspaper, RPC3 Premium Uncoated paper, RPC4 Super-calendared paper, RPC5 Publication coated paper, RPC6 Premium coated paper, RPC7 Extra large gamut. Colour gamuts of these reference printing conditions were derived using a convex hull method.

Gamut comparison index were calculated for each pair among all reference printing conditions. The aim was to check if *GCI* values correlate well with the gamuts.

Another use-case considered was simulating a standard offset printing process on digital proofing. A characterisation data-set from FOGRA39L (2007) was used as a standard offset printing process. Two proofing devices – proofer A and B – were calibrated and characterised using Semimatte 250gsm paper to simulate FOGRA39L data-set. Test chart IT8.7/4 was printed on both proofers. Printed test charts were measured using X-Rite EyeOne spectrophotometer according to ISO 13655 (2009) measurement condition M0. Colour gamuts of both proofers were derived using convex hull algorithm in Matlab. *GCI* between FOGRA39L and each of the two proofers were calculated.

3. RESULTS

Figure 2 shows the *GCI* between RPC-7 and each of the remaining RPCs. As expected, the gamut indices agree with the 2D gamut plots in *a** - *b** plane shown in Figure 2.

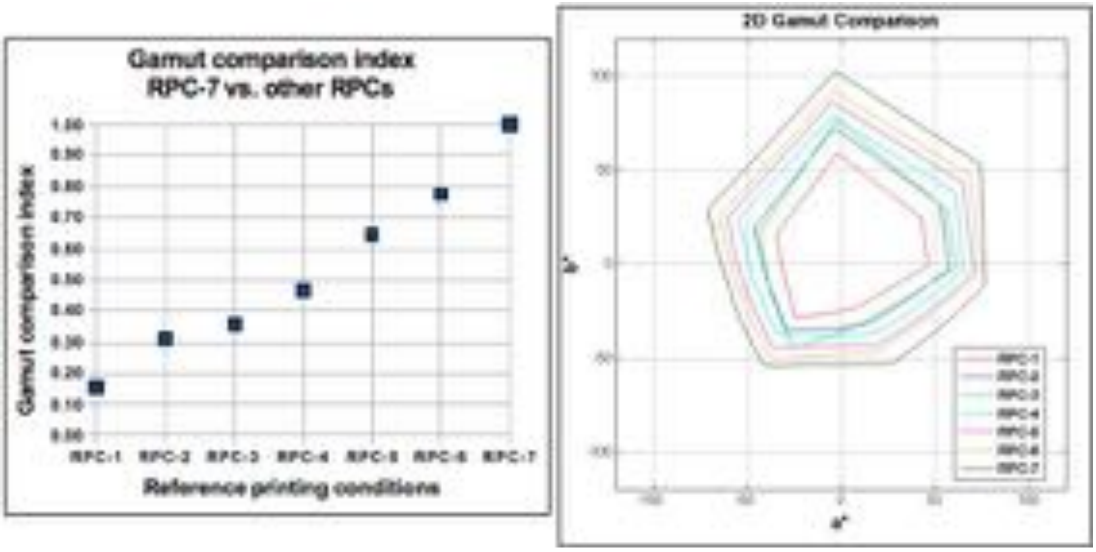

Fig.2 GCI between RPC-7 and each of the reference printing conditions and 2D gamut comparison of all reference printing conditions in a - b* plane*

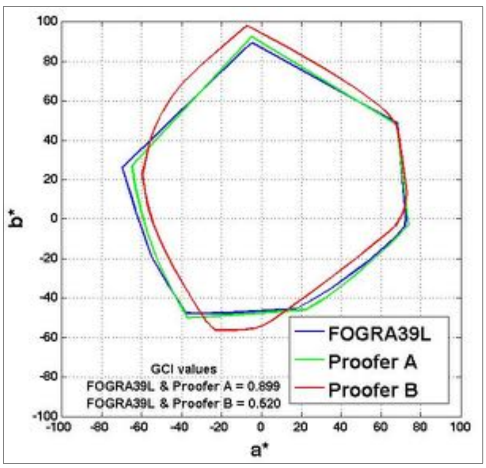

Figure 3 GCI values for Proofer A and B against FOGRA39L gamut

Comparison between two proofing systems indicates that the gamut of proofer A matches the FOGRA39 printing condition more closely than that of proofer B, and is therefore likely to be able to generate proofs which simulate the final prints with greater accuracy. This was confirmed by *GCI* values. GCI between FOGRA39L and Proofer A was 0.899, whereas *GCI* between FOGRA39L and Proofer B was 0.520 (Figure 3).

4. CONCLUSION

The gamut comparison index provides a single objective metric to compare two colour gamuts and quantify the difference between them. Range of gamut comparison index value is from 0 to 1; higher the index value better is the match between two colour gamuts. For a perfectly matching pair of colour gamuts, the gamut index is 1.

Once gamut volumes and their intersection are calculated, the gamut comparison index can be calculated with a simple mathematical formula, making it easier to implement within colour management applications and workflows.

Although this index doesn't provide any information about a specific colour region, it can be used in various scenarios. For example, comparing the press-gamut simulated by proofing device to actual press-gamut; comparing the model-predicted gamut to real gamut of the printing system and comparing press-gamut to the standard printing conditions FOGRA39L.

REFERENCES

Cholewo, Tomasz J., and Shaun Love. 1999. Gamut boundary determination using alpha-shapes. In *IS&T/SID 7th Color Imaging Conference*: pp. 200-204.

FOGRA39L. 2007. Characterisation data for standardised printing conditions. http://www.fogra.org/index_icc_en.html

Green, P. J. 2001. A test target for defining media gamut boundaries. In *Proc. SPIE* Vol 4300 105-113

Guyler, Karl, 2000. 'Visualization of Expanded Printing Gamuts Using 3-Dimensional Convex Hulls. In *Proc. TAGA 2000*

ISO 13655. 2009. *Graphic technology – Spectral measurement and colorimetric computation for graphic arts images*.

ISO DIS 15339-1. 2012 Graphic technology — Printing from digital data across multiple technologies — Part 1: Principles and characterized reference printing conditions

Morovic, Jan. 2008. *Color Gamut Mapping*, Barcelona: Wiley.

Morovic, J. and Luo, M. R. 2000. Calculating medium and image gamut boundaries for gamut mapping, *Col. Res. App.* 25 394-401

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Investigation of colour and appearance for human skin

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ABSTRACT

In this study, colour measurements were conducted in three countries for over 400 subjects in 9 body areas using a spectrophotometer. Based on their skin colours, a skin colour database was established based on CIE XYZ tristimulus values. Skin colour appearance was predicted by using CIECAM02 and skin colour appearance differences between ethnics groups were investigated. Then, skin colour gamuts for three ethnics groups were determined. Results demonstrated that, in general, there was a clear trend for Chinese and Arabs skin to be darker and significantly more yellowish when compared to Caucasian skin. However, for individuals, skin colour cannot be distinguished easily between these three ethnics groups since the colour gamuts overlap. It was also found that compared to other ethnic groups, Caucasians has the largest variation in skin tones, whereas Chinese have the least skin colour variation.

INTRODUCTION

Interest in the colour of human skin has been greatly stimulated by the increased need in its application within multidisciplinary teams in various industries including, skin colour measurement for the diagnosis of cutaneous disease[1], skin colour segmentation for face detection and recognition[2], skin colour reproduction for graphic arts[3] and skin colour matching for body and maxillofacial soft tissue prostheses[4]. Recently, new technology has allowed for unique and innovative methods of 3D data capture, storage and the manufacture of a body's geometry and colour data to produce replacements as either images or physical objects (hard or soft). For these applications, a comprehensive knowledge of the range of skin shades that represent individuals, an understanding of how skin colour varies and how people perceive these differences in a wide range of viewing conditions, has become highly desirable.

The aim of this study was to generate a comprehensive skin colour database, to further identify their colour appearance and colour gamut, and analyse factors that may affect the skin colour appearance.

MATRIALS AND METHODS

In this study, a Minolta CM-2600d spectrophotometer using SpectraMagic NX Colour Data Software was employed to take skin colour measurements in CIE XYZ tristimulus values with a 2 degree standard observer[5]. The illuminant was set to the CIE standard D65 to simulate skin colour in day light conditions. During the measurement, a viewing geometry of d/8 (diffuse illumination, 8-degree viewing), was used with the specular component included and the aperture size was set to 3mm. Skin colour measurement was conducted for each subject at a total of nine body areas - forehead, tip of nose, cheek, ear lobe, chin, back of hand, palm, outer forearm and inner forearm (Figure 1). CIE XYZ tristimulus values were recorded for each of measurement. After measurement, each subject also provided further information including age group, gender and ethnics group. All colour measurements were conducted in either the UK, Iraq or China.

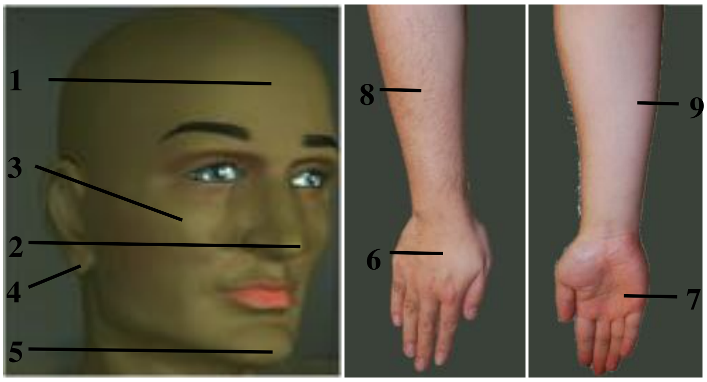

Figure 1. Body Areas for skin measurements (1. Forehead, 2. Tip of Nose, 3. Cheek, 4. Ear Lobe, 5. Chin, 6. Back of hand, 7. Palm, 8. Forearm Outer, 9. Forearm Inner)

The CIECAM02 colour appearance model was adopted to predict skin colour appearance in term of three human perceptual attributes - lightness (J), chroma (C), hue composition (H), respectively[6]. Hue composition is a 400-step hue scale that is used to describe perceived hue in terms of percentages of two of unique hue from which the test hue is composed. For instance, hue composition of 60 represents 60% of unique yellow and 40% unique red. By using the colour appearance from whole skin colour database, the skin colour gamut was achieved in CIECAM02 colour appearance attributes. Skin colour variation indicates the extent to which the skin colour of an individual subject matches with the average skin colour from those individuals assessed, and it is a basic measure of how skin colour varies within a population. In this study, the skin colour variation for each ethnic group was investigated and was undertaken by calculating the colour difference between those colours measured from each individual subject to the mean skin colour from within each ethnic group. The CIELAB colour difference formula was then employed to measure skin colour difference.

RESULTS AND ANALYSIS

To date, 437 volunteers covering five different ethnics groups participated in this study. Most individuals were collage students aged between 20-40 years old.

Table 1. Skin colour data for different ethnics groups

	Caucasian	Chinese	Arab	Asians	African
No. of Subject	73	202	146	6	2

A Skin Colour Database was established and based upon 3933 (437 subjects x 9 body areas) skin colour data in terms of CIE XYZ Tristimulus values. Based on these data, skin colour appearance, skin colour gamut and skin colour variation were also investigated. Skin colour appearance between different ethnics groups were also analysed by using Caucasian, Chinese and Arab skin colour data. Further data collection is required to establish the skin colour and appearance for other ethnic groups.

Colour appearance

By inputting the XYZ tristimulus values of the each skin colour samples into CIECAM02, values for the three corresponding colour appearance attributes were obtained. Note that the average surround was selected for the input parameters for CIECAM02 in order to simulate skin colours viewed under normal lighting conditions. The mean and standard deviation of skin colour for each ethnic groupsin each perceptual attribute was calculated and the results is provided in Table 2.

Table 2. Skin colour appearance for different ethnics groups

CIECAM02	Lightness (J)	Chroma (C)	Hue (H)
Caucasian	51.2 ± 4.8	17.8 ± 4.1	33.4 ± 15.1
Chinese	49.3 ± 4.2	17.5 ± 2.3	43.1 ± 10.4
Arab	48.1 ± 5.4	17.9 ± 2.6	42.2 ± 11.7

From Table 2, firstly it can be seen that in general, Caucasians have a lightest skin, whereas Arabs have a darkest skin. Secondly, compared to Chinese and Arabs skin shade, Caucasian skin appears to be more reddish. Finally, there is little difference in the chroma attributes for those three ethnic groups.

Colour Gamut

In order to further investigate skin colour variations between different ethnic groups, skin colour gamuts were plotted in CIECAM02 colour space (Figure 2). All data are illustrated in both ac-bc chromatic diagrams (Figures 2a) and in J-C diagrams (Figures 2b). Skin gamuts for Caucasians, Chinese and Arabs were plotted in left, middle and right sub-figure and denoted as sub-figures1, 2, 3, respectively.

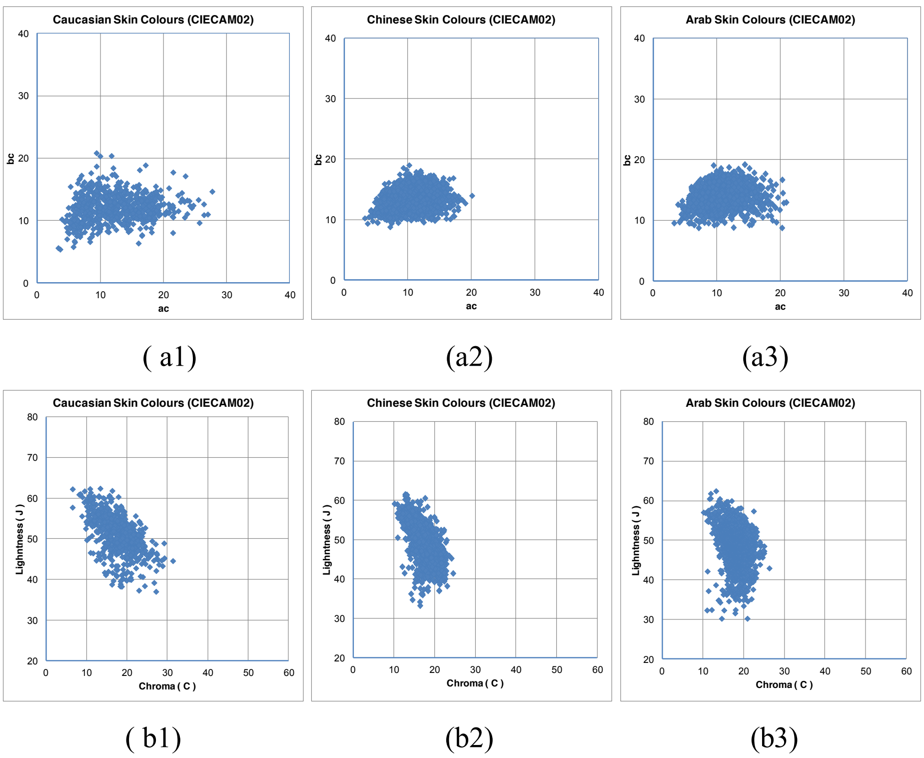

Figure 2. Skin colour gamut for three ethnics groups

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It can be seen that the skin colour gamuts from all three ethnic groups are in a hue range between 0^o to 90^o and within a lightness range of 20 to 70 in CIECAM02. The Arab skin colour gamut is very similar to that of the Chinese. The Caucasian skin colour gamut appear to be slightly different when compared to either the Chinese or the Arab skin colour gamut, where the colour appear to be more reddish and lighter. However, most of the skin colours between Caucasians and Chinese (or Arabs) overlap to a large extent such that differentiation according to ethnic groups is not possible.

Skin colour variations

For each ethnic group, skin colour variation in term of lightness-, chroma-, hue- and colour difference was calculated using CIELAB and the results are given in Table 3. It can be seen that Caucasians have a largest skin colour variation, whereas the Chinese skin colour has a least colour variation.

Table 3. Skin colour variation for three ethnic groups

Colour Variation	ΔL*	ΔC*	ΔH	ΔE*ab
Caucasian	3.6 ± 2.8	3.1 ± 2.3	3.2 ± 2.1	6.4 ± 3.0
Chinese	3.2 ± 2.6	2.0 ± 1.4	2.3 ± 1.4	4.9 ± 2.4
Arab	3.8 ± 3.8	1.5 ± 1.2	2.9 ± 1.2	5.6 ± 3.1

CONCLUSIONS

A skin colour database for Caucasian, Chinese and Arab individuals was achieved by colour measurement for 437 subjects in three different countries. For each ethnic group, skin colour appearances were predicted in CIECAM02 and their skin colour gamuts were developed. It was found in general Caucasian skin colour appears to be more reddish and lighter than either Chinese or Arabs. However, for a large proportion of individuals, the overlap in skin colour between the three ethnic groups is significant. Finally, the skin colour variations within the groups demonstrated that Caucasians skin has the largest variation.

REFERENCE

1. E Edwards, S Duntley. The pigment and color living human skin. Am J Anat 1939; 65: 1–33.
2. A. Nasrabadi, J. Haddadnia, Skin Color Segmentation by Fuzzy Filter. International Journal of Computer and Electrical Engineering 2010; 2:1039-1042.
3. H Chen, T Wang, S Chen, J Liu. , Skin-color correction method based on hue template mapping for wide color gamut liquid crystal display devices. Color Research & Application 2011, 36.
4. R.D. Paravina, G. Majkic, M.D.M Perez, S. Kiat-amnuay, Color Difference Thresholds of Maxillofacial Skin Replications, Journal of Prosthodontics 2009; 18: 618-625.
5. CIE. Colorimetry, 3rd edition. Publication CIE 15:2004, ISBN 3-901-906-33-9. Vienna, Austria: Commission Internationale De L'eclairage; 2004.
6. CIE Publication 159:2004. A Color Appearance Model for Color Management Systems. Vienna, Austria: Commission Internationale De L'eclairage; 2004.

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Understanding the color of polymers in their lighting environment - Application to color-changing materials in interior design

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ABSTRACT

This paper aims at understanding the origin of color of filled polymers in different artificial white lighting environments, mainly halogen and LED lights with a variable incidence angle. Besides, the purpose is to design a material which interacts with light to convey an impression of changing its color and contributes to create harmony and welfare in inner spaces.

Transparent mineral fillers are dispersed in two types of calendered and then embossed transparent polymers: low-density polyethylene and PVC. The influences of volume and surface contributions of the materials are considered separately throughout the colorimetric analysis.

L*a*b* colorimetry shows above all that the color strongly depends on the type and concentration of fillers, their size, and the type of polymer. Spectral measurements are then done in front-scattered light on materials showing different roughness. Based on geometric optics, these variations in color, mainly due to L*, are correlated with topographical data.

Finally, the absorption of materials is enhanced by the use of colored organic pigments. Under different illumination, the materials change their spectral response: these variations are measured both with a camera in an achromatic white box with different positions of the two illuminants and with a gonio-spectrophotometer connected with optical fibers to the sources.

1. INTRODUCTION

The actual trend towards fewer energy-guzzling appliances and especially halogen lights entices governments and industries into promoting LED lights. Such a change is thus likely to modify the appearance of objects and surfaces in inner spaces.

This study focuses on the color in different lighting environments of two massively-used polymers, PVC and low-density polyethylene (LDPE) filled with different types of transparent and colored particles. The influences of the type of pigments, polymers, surface roughness and illuminant on the perceived color are discussed in order to design a color-changing material that is likely to enhance harmony and welfare in interior design.

Supported by colorimetric analysis of calendered filled polymer films (thickness = 300 µm), the purpose is to better understand to what extent the volume (composition) and the surface (process) of the material interacts with light and the viewing angle. The effect of changing the light source should then be investigated: a current halogen light source has been used as a reference, and a cold-white high-power LED has been chosen in comparison.

The bias in our design process toward the switch to LED lights was rather to use it as an asset in order to create color-changing materials than to study only its undesirable metameric side effects: harmony between pattern and colors has been considered essential.

2. COLOR CHANGE IN THE VOLUME

Low-absorbing mineral fillers are homogeneously dispersed into the polymers at the same volumetric concentration before calendering. The refractive indices of unfilled polymers were measured with an Abbe refractometer using α-bromo-naphtalene: n_{LDPE} = 1.502 +/-0.002, n_{PVC} = 1.530 +/-0.001.

The L*a*b* color of calendered polymer films (thickness = 300 µm) sandwiched between two glass slides containing immersion oil (excluding topographical differences) is analyzed with a diffuse xenon-light colorimeter (Minolta CR-201b). L*a*b* colorimetry reveals that the increase in filler concentration by 13% vol. (higher than 20% wt.) leads to different color variations depending on the type of filler. However the color slightly changes for these low-absorbing fillers. A global variation of the color coordinates toward the yellow area (higher b*) can be noticed for example in the case of kaolin (Figure 1), whose refractive index is 1.56 (Bass. 1994).

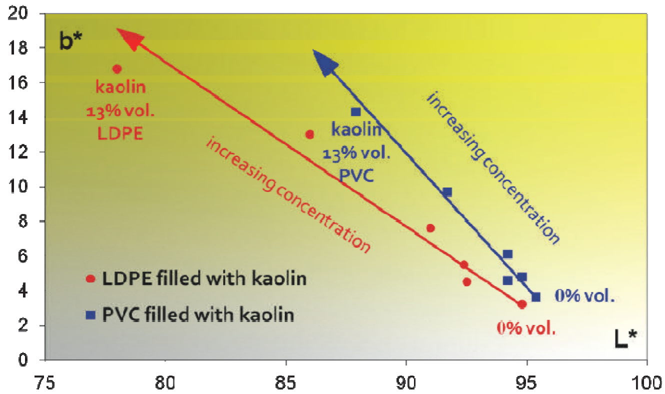


*Figure 1: Color (a*b*) of filled polymers depending on the concentration of fillers*

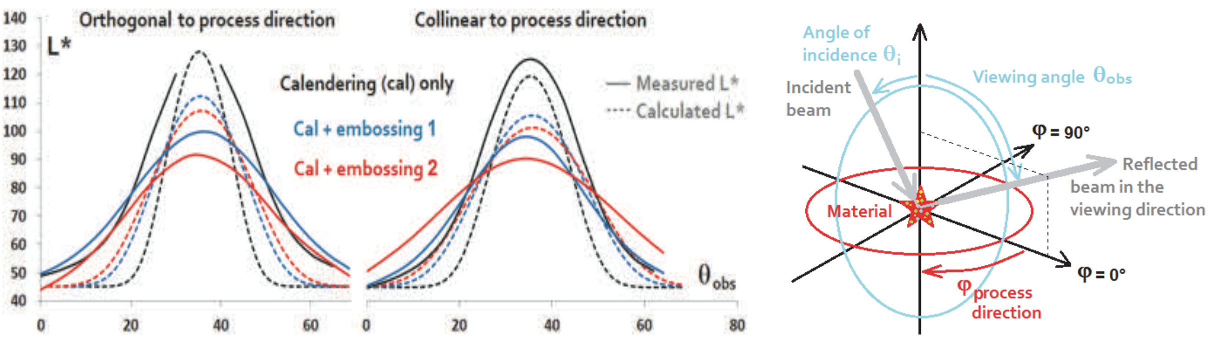
What's more, at the same concentration, the color change is higher for LDPE than PVC. This can be explained by the higher refractive index difference between LDPE and kaolin than the one between PVC and kaolin: light is more refracted at each LDPE/filler interface, which leads to stronger color change, brought forth by higher scattering in the LDPE volume.

3. COLOR CHANGE DUE TO SURFACE TOPOGRAPHY

Since the largest color change is obtained with kaolin, both polymers filled with 13% vol. kaolin have been mechanically embossed by two different cylinders: one side of the film has had the cylinder's roughness transferred and the other side remains unchanged with the topography due to calendering. Non-destructive optical surface roughness measurements have been made on 4 mm² square areas with a confocal scanning system (Stil), and then computed to find out micro-roughness data (high-frequency signals only) for the 3 different surface states.

The analysis of micro-roughness of our embossed materials aims at determining the angular distribution of the local slopes, from the RMS (root-mean-squared) height of the surface S_q and the correlation lengths (dominating structural wavelength at a given sampling size) along the x-and-y-axis (Whitehouse et al. 1970). The angular distribution of the slopes fits to a normal probability density law for each sample in both orientations (orthogonal and collinear to the calendering direction). We establish then a relationship in geometric optics (no diffraction is allowed under these assumptions) between the light reflected by the first air/polymer interface and spectral color measurements on highly filled polymers.

In parallel, gonioscopic spectral measurements are made in the specular plane on the same samples (Figure 2b) in both process directions: the angular range goes from 0° to 70° for the sensor (at a viewing angle θ_{obs}) and the halogen light source. The calibration of the spectrocolorimeter is made on a standard diffuse white, but the frequency is increased to measure color near the specular reflection. Finally, we calculate L*a*b* coordinates under our halogen illuminant spectrum, and compare L* measurements with L* data from the model (Figure 2a), as very slight change due to embossing can be noticed in a* and b* results.



(a) (b)

Figure 2: (a), Comparison of measured and calculated L ; (b) Gonioscopic device diagram*

Whatever the angle of incidence is, diffuse reflection stems from stronger micro-slopes which cut down the specular reflection (max $_{\text{red curve}}$ < max $_{\text{black curve}}$). In addition, we showed that calendering brings the material to a little increase by 5% in brightness L* which is removed when embossing: the material looks then similar in any viewing directions around it when observed at a fixed viewing angle with a fixed angle of incidence.

4. COLOR CHANGE WITH WHITE LIGHTS

The role of absorption, as the imaginary part of the refraction index presented in Section 2, is now dramatically increased by introducing colored organic pigments. The purpose is to understand the chromatic variations of the samples created by changing the illuminant (Figure 3) from halogen (100W-3200K) to LED (22W-5500K) white light and to control these variations to design a material that interacts with its lighting environment.

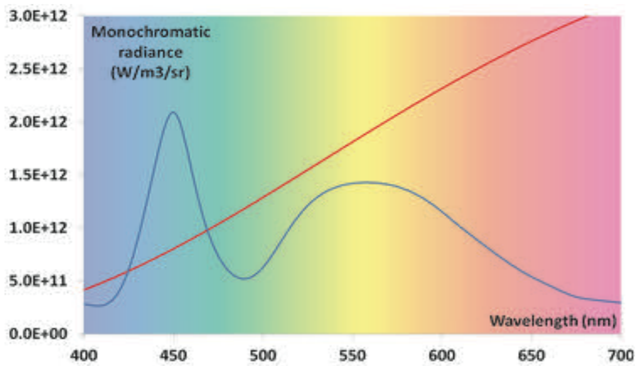
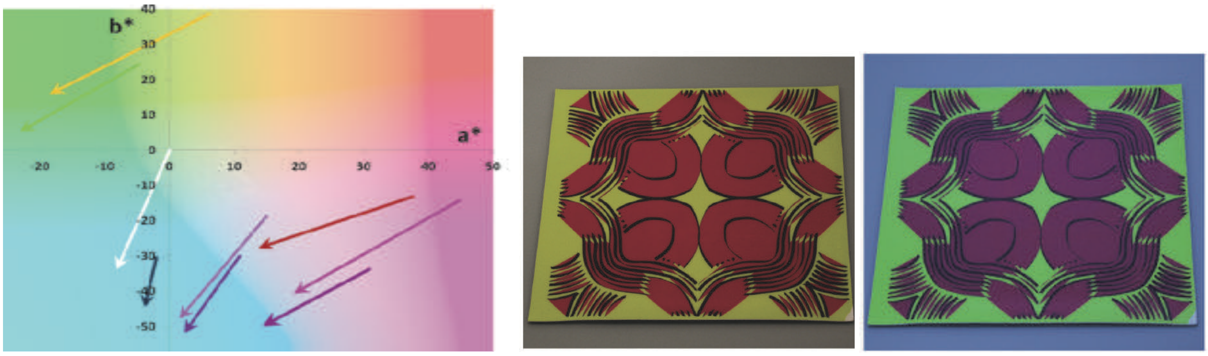


Figure 3: Visible spectra of our illuminants Halogen (red) and white LED (blue)

The refractive indices n of the organic pigments we used are between 1.65 and 1.8, which means that these pigments are visible within the polymers and are likely to make them opaque in addition to giving them a specific color (absorption). Natural colors rarely show more than two absorption peaks (Elias and Lafait. 2006). Therefore, we simulate the influence of variable Gaussian bi-modal reflectance spectra of virtual materials on the color change ΔC* due to the switch of illuminant, where $\Delta C^* = C^*_{LED} - C^*_{halogen}$ and $C^* = \sqrt{(a^{*2}+b^{*2})}$. It stems from the simulation that color change is strongly due to an accurate matching between both spectral distributions of light and material. Indeed, the maximum for ΔC* was found for a reflectance spectra with both peaks at the same wavelength (highly saturated blue) that matches exactly with the LED excitation peak and the maximum of the $\underline{z}$ CIE color matching function (maximum response of S-cones for the standard observer).

The influence of switching from halogen to LED light was investigated experimentally on 40 organic pigments with our gonio-spectrocolorimeter in back-scattering conditions (45°/45°): only the most significant color changes are presented (Figure 4a). The arrows stand for the color change ΔC* of the materials observed from halogen to LED light (end of the arrow) for each type of pigment. Excellent correlation is noticed between ΔC* and ΔE*. Hence better color changes are obtained with lighter samples (yellow, fushia, white).



(a) *(b)*

Figure 4: (a), Color change (a,b*) of 8 organic pigments and white balance under halogen ; (b), Example of one of our color-changing materials (halogen: left ; white LED: right)*

Finally, in order to meet user's expectations, these color-changing materials have also been characterized in a human-scaled environment (2m*2m*2.4m box) with different positions of the two illuminants. It is built with achromatic white extruded PVC sheets, lights up the samples with direct and indirect beams, and the results are provided both qualitatively by a panel and quantitatively by a camera (Figure 4b : direct normal lighting with white balance of the camera under halogen). Outstanding color changes with lighting have been noticed as observed.

5. DISCUSSION AND CONCLUSIONS

The results of this study suggest that a proper choice of the refraction properties of polymers and pigments leads to significant color change of homogeneous materials especially when the pigment absorption is increased. Besides, we demonstrated that embossing the surface with strong micro-slopes reduces specular reflection and thus lightens (desaturates) the color of the materials: as a result, such embossing enhanced the color change due to light switching.

What stands out of the color change simulation is the need for an accurate matching between both spectral distributions of light and materials. The role played by the LED excitation peak demonstrates that different chromatic variations may be obtained within a broad range of existing LED lights. In addition, as observed in the test-box, this color change is both surprising and attractive since the perceived ambient lighting remains white to the observer. In our design process, we chose to illustrate the hide/unveil concept: specific patterns containing at least two pigments reveal some hidden details when illuminated by LED light. The choice of colors has been made in accordance with the character embodied by the pattern.

REFERENCES

Bass, M. 1994. *Handbook of Optics, Devices, Measurements, and Properties. Vol. 2, 2nd edition*. New York: McGraw-Hill

Elias, M., J. Lafait. 2006. *La couleur: Lumière, vision et matériaux.* Paris: Belin.

Whitehouse, D.J., J.F. Archard. 1970. The properties of random surfaces of significance in their contact. In *Proceedings of the Royal Society A*. London. 316 (1524), pp. 97–121

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The Influence of Background on Colour Harmony

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ABSTRACT

This paper challenges the notion in art theory that colour harmony can be characterised by invariant hue relationships between colours. In fact colour is always perceived relative to surrounding colours, to the illumination, and to the observer's state of adaptation. By adapting to the background colour, the harmonic relationships between hues may be radically changed.

1. BACKGROUND

Experimental colour studies where observers make judgements almost invariably present the colour samples against a neutral background, typically Munsell value 5. But in seeking to simplify the configuration and reduce the number of experimental variables, researchers ignore one of the principal determinants of perceived colour. Sivik and Hård (1994) observed: "Moreover, a colour cannot exist alone. When a single colour surface is presented it must have a surround, which also has a colour; and it is, thus, this pair of colours that is seen and experienced, even if one consciously tries to perceive only one of them."

In the study of colour harmony the influence of the background has rarely been considered. This is surprising because the background, extended to fill the visual field, determines the state of adaptation of the human visual system, and therefore anchors visual perception. All colours are judged against the average background, especially in terms of lightness. Changing the background changes the way colours are judged, and therefore changes the perceived harmony between colours in the scene. Gurura *et al* (2004), presenting observers with paper samples against a large coloured card, showed that changing the background colour could result in a formerly harmonious colour combination being judged as disharmonious, and vice versa.

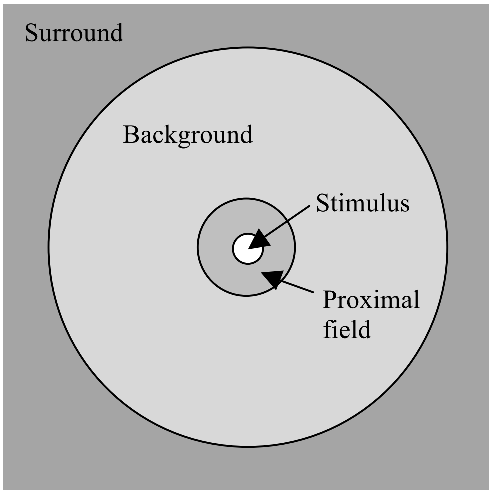

Figure 1. Concentric components of the viewing field, with stimulus at the centre (Fairchild, 2005).

In the context of colour appearance, Fairchild (2005) defined four concentric regions in the viewing field (Fig. 1). In the practical situation of viewing an image on a display, one small coloured element of the image could be considered as the stimulus, the adjacent parts of the image as the proximal field, the full area of the display screen as the background, and the wall or room behind as the surround. The proximal field is associated with simultaneous contrast, causing chromatic induction, where the colour immediately surrounding a stimulus causes it to be perceived as tinged with the opponent of the surround. Thus a grey sample surrounded by blue is perceived as yellowish and vice versa; a grey sample when surrounded by red is perceived as tinged with green and vice versa. Albers (1963) showed how surround could be employed to make the same colour look different, or make different colours look the same. The effect of simultaneous contrast has been demonstrated in each of the independent perceptual dimensions of lightness, hue and colourfulness (Luo *et al*, 1995).

2. EFFECTS OF THE VIEWING ENVIRONMENT

In any given viewing situation three factors are important: the spectrum of the illumination, the adaptation of the observer, and the colour of the background. The colour of a surface depends strongly on the incident illumination, because the radiation reaching the eye of the observer is the product at each wavelength of irradiance and reflectance factor. This is the basis of all colorimetry, yet it is often overlooked in the theoretical treatment of colour harmony, supposing that if two colours are in harmony under one source of illumination then they will be in harmony under any other source. In reality, metamerism leads to changes in the relativity of colour.

The human visual system adapts to the colour of the prevailing light, in such a way that surface colours are seen as relatively unchanged, a phenomenon known as colour constancy. It is obvious that this cannot hold under all possible light sources: under a near-monochromatic source such as a low-pressure sodium vapour lamp (for example in older suburban street lights) colours are seen only as lighter or darker shades of orange. Hunt (1998) noted the significance of chromatic adaptation, causing observers to make perceptual allowance for the colour of the prevailing illumination, referred to as ‘discounting the illuminant’.

Helson and Lansford (1970) showed that background plays a significant role in the judgement of colour harmony. They asked 10 observers to rate the pleasantness of 122 Munsell colour chips in a light booth against 25 backgrounds under five different sources: tungsten, filtered tungsten and three fluorescent lamps. They found that background exerts a greater effect on pleasantness than spectral energy of the source. They also found, surprisingly, that there was no correlation between the colour rendering index (R_a) of the light source and the pleasantness of the colours.

3. COMPUTATIONAL EXAMPLE

An image of a painting by Van Gogh (Fig. 2) was selected for analysis. The colours of the painting are used here to show the effects of changes in the illumination spectrum and the background colour. The pixels of the image were assumed to be encoded in sRGB, and were converted to CIE $L^*a^*b^*$ under D65 with the CIE 10° observer. The average colour, taken as a mean over all pixels, is L^*,a^*,b^* = 73.3,-7.7,8.5, i.e. a medium-light weak yellow-green. Plotting a randomly-selected sample of 10,000 pixels in the a^*–b^* plane shows that they fall into three clusters: yellow (hue angle ~90°), yellow-green (hue angle ~130°), and mauve-blue (hue angle ~300°). In the language of colour harmony theory, this constitutes a ‘split complementary’ colour scheme, in which the warm analogous hues between yellow and yellow-green in the lower half of the picture are opposed to the cool mauve-blue in the upper half.

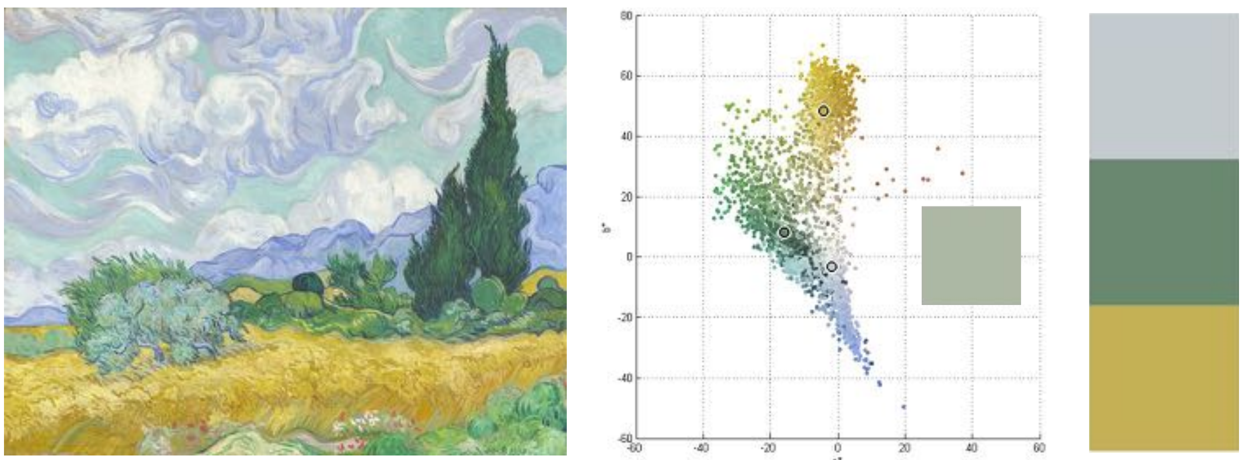

Figure 2. (left) ‘A Cornfield, with Cypresses’, Vincent Van Gogh, 1889, National Gallery London NG3861; (centre) 10,000 pixels from image plotted on CIE a–b* plane, with average colour inset; (right) centroid colours of clusters.*

oral paper

Table 1. CIE L,a*,b* values of centroid colours and NCS samples under D65.*

Sample	Centroid	NCS	D65
Blue	81.1, -1.7, -3.3	2005-R80B	79.1, -1.1, -2.4
Green	54.0, -16.9, 9.9	4030-G10Y	54.1, -18.1, 11.5
Yellow	72.1, -4.2, 48.4	2050-G80Y	70.3, -4.1, 47.5

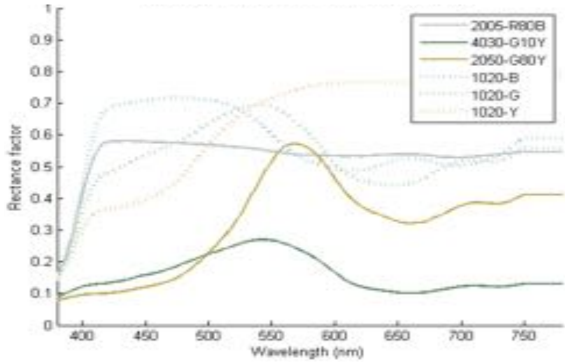

Figure 3. Spectral reflectance of three NCS samples and background colours.

Using k-means cluster analysis with the city-block distance metric identified three cluster centroids. The nearest (minimum ΔE^*_{ab}) samples were found in the NCS 1950-colour atlas (matte, d8 measurement geometry, D65, 10° observer), with corresponding reflectance spectra in Fig. 3. Table 1 shows the CIELAB values of the three NCS samples under standard daylight (D65).

The influence of the background colour on the patch colours is clear in the top row of Fig. 4, where the chromatic induction caused by simultaneous contrast is particularly strong for the blue patch. The backgrounds are arbitrarily taken to have the NCS focal hues of blue (1020-B), green (1020-G) and yellow (1020-Y), with reflectance spectra also plotted in Fig. 3 (dotted lines). If the observer could adapt completely to the colour of the background, so that it appeared white, then the patches would appear under D65 as shown in the second row of Fig. 4. The adapted colours differ substantially in appearance from both the original colours on a neutral background (Fig. 2) and also from the induced colours with the respective coloured backgrounds.

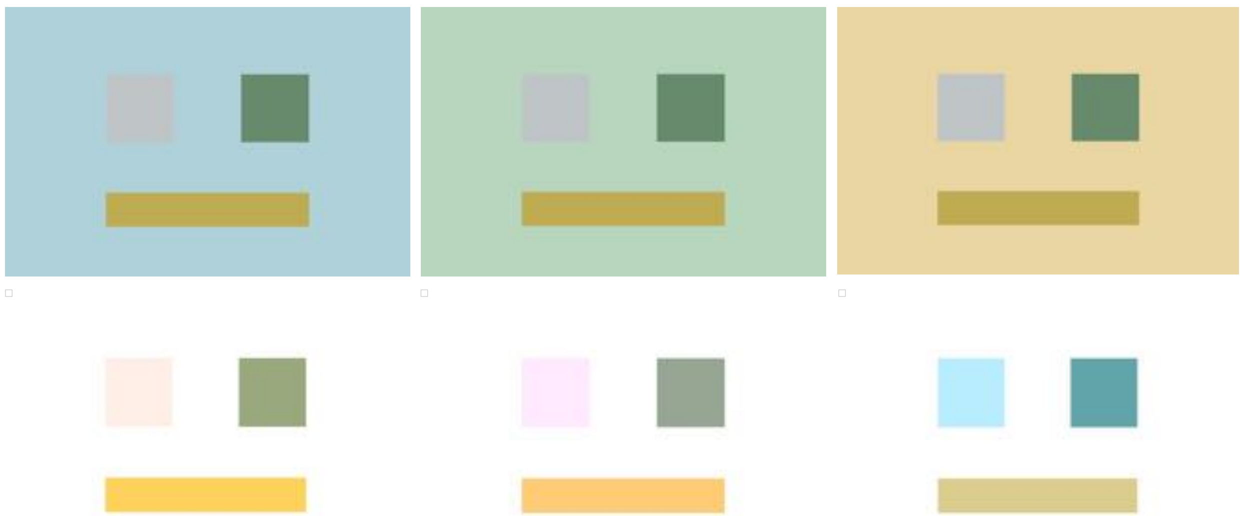

Figure 4. (top row) Patch colours on blue, green and yellow backgrounds under D65 illumination; (below) appearance of the same three layouts after complete adaptation of the observer to the background colour under D65 illumination.

4. DISCUSSION

The example above shows clearly the effect of background on colour appearance if the observer is able to adapt to the prevailing illumination. The question is then whether the colour harmony relationship of the original colours is preserved under the changing background. If the criterion is based only on relative hues, then the colour sets can be characterised by the polar hue diagrams in Fig. 5, assuming complete adaptation to the background. It is evident that the configurations of hues, and the corresponding harmonic relationships, differ greatly.

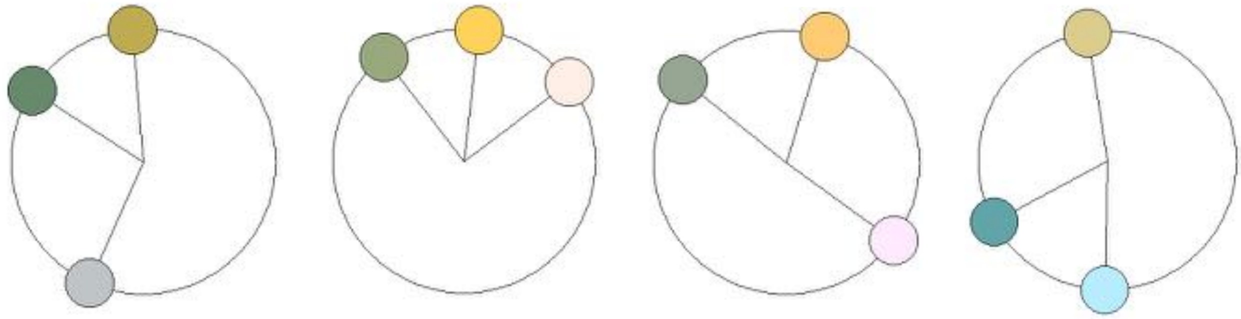

Figure 5. Hue relationships of the three patch colours under D65 illumination under complete adaptation to the background for (left to right) white, blue, green and yellow backgrounds.

The reason for the change of hue relationships with adaptation to background can be seen by plotting the sample coordinates in the CIE *a*–b** plane (Fig. 6). The Von Kries scaling of the tristimulus values has the effect of translating the background colour to the origin (i.e. neutral) while preserving the relative hue angle of each colour patch. Thus the unadapted colour 1 in Fig. 6a becomes the adapted colour B1 in Fig. 6b when the observer is adapted to the B background. This has a hue completely different from the original (pink instead of blue) but its hue relationship to the background is preserved. Other chromatic adaptation transformations, such as the Bradford transform in CIECAM02, might produce minor differences in hue for each sample, but the overall influence on colour harmony of adaptation to the background is indisputable.

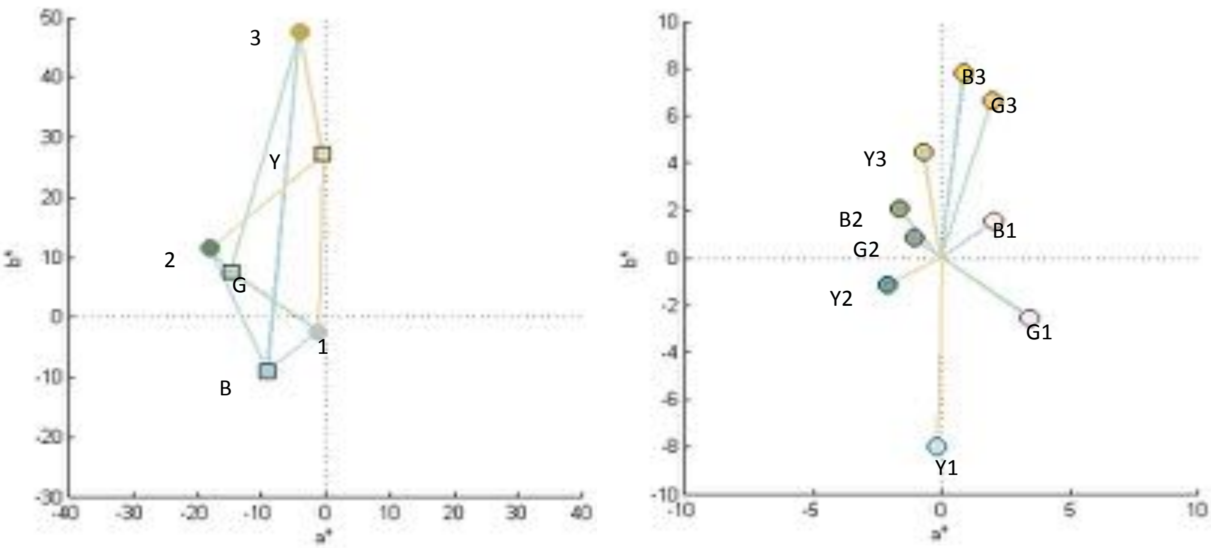

Figure 6. (left) CIE a,b* coordinates of NCS samples 1,2,3 (circles) and backgrounds B,G,Y (squares) under D65; (right) a*,b* after adaptation to blue, green and yellow backgrounds.*

REFERENCES

Albers J (1963) *Interaction of Color*, Yale University Press, New Haven CT.

Fairchild, M (2005) *Color Appearance Models*, 2nd Ed., John Wiley, Chichester, pp.134-138.

Gurura H, MacDonald LW and Dalke H (2004) Background: An essential factor in colour harmony, *Proc. AIC 2004 Conf. on Color and Paints*, Brazil, pp.239-242.

Helson H and Lansford T (1970) The role of spectral energy of source and background in the pleasantness of object colors, *Applied Optics*, **9**(7):1513-1552.

Hunt RWG (1998) *Measuring Colour*, 3rd Ed, Fountain Press, Kinston-upon-Thames, pp.208-247.

Luo MR, Gao XW and Scrivener SAR (1995) Quantifying colour appearance. Part V: Simultaneous contrast, *Color Research & Application*, **20**(1):18-28.

Sivik L and Hård A (1994) Some reflections on studying colour combinations, *Color Research & Application*, **19**(4): 286–295.

Readability of Colored Text on a Colored Background under LED Lighting and Fluorescent Lighting

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ABSTRACT

Since the Great East Japan Earthquake, general shops and stores in Japan have chosen LED lighting to promote electricity conservation. Light source changes may cause colors to appear differently under such lighting, possibly affecting the readability of text printed in various colors on packages on display in stores. The present study is a comparison of fluorescent lamp and LED lighting in readability of text likely to be printed on packages. Since it was expected that text readability would depend greatly on aging among other human vision characteristics, a test was conducted to check whether or not age-related variations in text readability differ with light sources. Test results showed that the lightness difference of colored text varied under different lighting and affected its readability on packages. Moreover, for elderly people, different lighting produced differences in text readability, which could not be explained in terms of lightness difference. The test results revealed that influential factors on differences in text readability included wavelength dependence of age-related decline in visual sensitivity.

1. INTRODUCTION

Inside general shops and stores, to provide sufficient readability of text on packages is one of important lighting quality factor. Text on commodity packages is printed in various colors on various surface colors. Thus it is necessary to analyze the readability of different combinations of text and background colors. Regarding text readability, it is necessary to take elderly people into consideration since their visual sensitivity decreases with age. Therefore, we conducted a test to examine differences of text readability using several color combinations of text and background under different lighting conditions, with elderly people as subjects. Furthermore, we tested the effects of aging on text readability through a comparison between elderly and young people.

2. EXPERIMENT

2.1 Effects of light sources on text visibility for elderly people

2.1.1 Light sources

Straight-type LED and fluorescent lamps commonly used in shops and stores were employed as light sources in the test. Figure 1 shows their spectral radiant distribution. Correlated color temperatures of the LED light and fluorescent lamp were 5920 K and

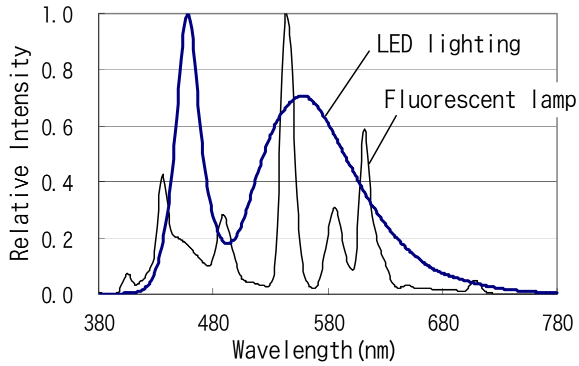

Figure 1. Spectral radiant distribution

5350 K, respectively. Average color rendering indices (: Ra) were 65 for the LED light and 73 for the fluorescent lamp. In a darkroom, two boxes with lighting installed were placed for subjects to rate. Inside each box, illuminance on the desk was adjusted to average of 900 [lx].

2.1.2 Test sheet

The notation of test sheet described efficacy like a drug package. Colors that would be difficult for elderly people to read were selected as text colors to be combined with the selected background colors. Twenty combinations of text and background colors were selected according to low readability for people with cataracts. Table 1 shows 20 color combinations of text and background.

Table 1. Twenty text-background color combinations used for test

Background	Text (Circled numbers denote the combinations)				
Reddish	① White	② Navy Blue	③ Dark Green	④ Aqua	⑤ Greenish Yellow
Yellowish	⑥ White	⑦ Ultramarine	⑧ Indigo	⑨ Black	⑩ Brown
Bluish	⑪ White	⑫ Oxblood	⑬ Lemon yellow	⑭ Cream Yellow	⑮ Cobalt Blue
Greenish	⑯ White	⑰ Orchid	⑱ Cobalt Blue	⑲ Aqua	⑳ Cobalt Green

2.1.3 Subjects

Twenty-eight subjects participated in the test, their age ranging from 61 to 85 years. They had undergone no eye surgery, was determined to be free from any color vision disorder as examined by Ishihara charts. The subjects corrected their visual acuity by wearing their glasses or contact lenses that they use when they read books or newspapers in daily life.

2.1.4 Methods

The subjects adapted themselves to the lighting for approximately two minutes under each type of lighting before starting the test. The lighting used for the first test was changed on a subject-by-subject basis. To avoid order effect, 20 text-background color combinations were randomly presented to the subjects, and different presentation order was employed for different subject. Subjects rated text readability on a scale of five.

2.1.5 Results and discussion

Since lightness differences between text and background could have some effect on the readability of 20 color combinations, as suggested by Hara et al. (2004), rating results of readability obtained under each lighting condition were plotted against lightness differences (ΔL*) between text and background of the test sheets, which are shown in Figure 2. Strong correlation is observed regardless of the type of light source. However, the readability of color combination No.12 (Oxblood text on the bluish background) is low for the relatively middle value of ΔL*. Statistically significant

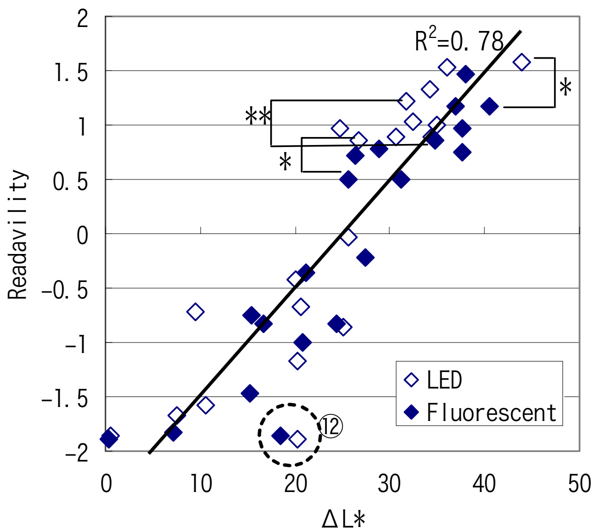

Figure 2. Relations between text-background lightness differences and rating results

differences between the results under the fluorescent lamp and LED light are observed for several color combination. Combinations with "** "and "* "shown in the *Figure 2*, indicate significant differences of $p < 0.01$ and $p < 0.05$, respectively, by the t-test. These color combinations are white or bluish text and are reddish or yellowish background.

2.2 Age-related differences in text visibility

A comparative test between elderly and young people was conducted. A decline in sensitivity in the short-wavelength range is an indication of wavelength dependence of age-related changes in color vision. So, we prepared the test sheets that either the text or background is red or blue color. A test was conducted similarly as in section 2.1, with subjects being both young and elderly people. The same test light sources as in sections 2.1.1 were used.

2.2.1 Test sheet

Text-background color combinations used in this test were 9 combinations among four colors of red, blue, white and black, as shown in Table 2.

Table 2. Nine text-background color combinations used for test

Combination No.	Background	Text
①	White	Black
②	White	Red
③	Red	White
④	Red	Black
⑤	Black	Red
⑥	White	Blue
⑦	Blue	White
⑧	Blue	Black
⑨	Black	Blue

2.2.2 Subjects

Fifty-two young subjects, ranging in age from 18 to 23 years, participated in the test. For elderly subjects, 34 subjects, ranging in age from 61 to 80 years, participated in the test. The subjects corrected their visual acuity by wearing their glasses or contact lenses that they use when they read books or newspapers in daily life.

2.2.3 Methods

Experimental procedure was similar to that described in 2.1.4 except the rating range is -3 to 3 here.

2.2.4 Results and discussion

Figure 3 shows rating results of the young subjects. No distinguished difference is found between the results under the fluorescent lamp and LED light in general. However, statistically significant differences were found for the No.3 (*: $p< 0.05$), and No.5 (**: $p < 0.01$). Possible reason for the No.5 result is that since the luminance of red color is lower under the LED light

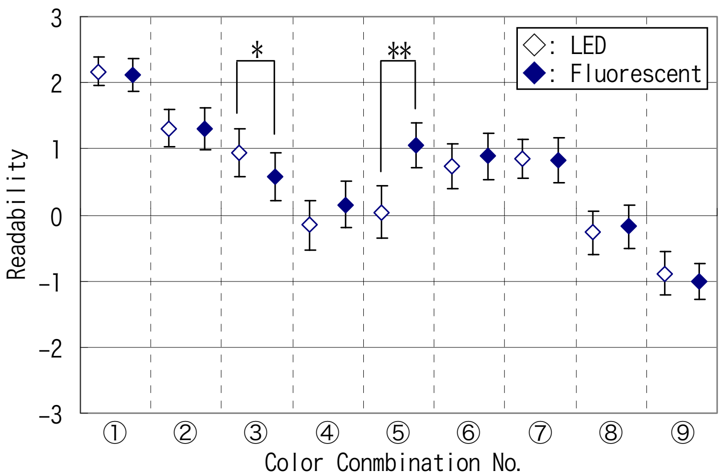

Figure 3. Rating results by young subjects

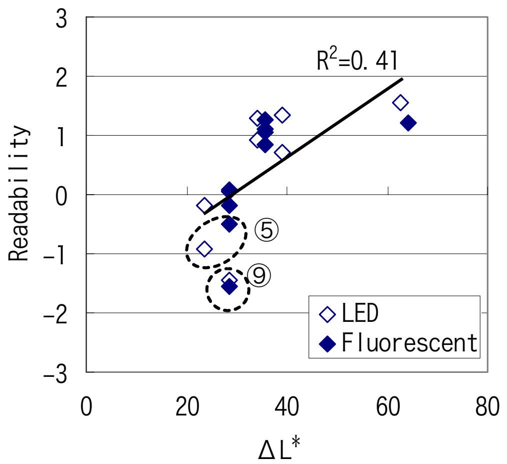

Figure 4. Correlation between ΔL and the rating by young subjects*

than the fluorescent lamp, and thus the lightness contrast becomes lower resulting low readability. In *Figure 4*, rating results are plotted against ΔL*, and relatively strong correlation is found. Rating result of No.9 (blue text on black background) is the lowest. This might reflect the retinal cone structure. As Ahnelt et al. (1987) found, the S cone cells that are sensitive to blue light are very sparsely distributed in the foveal region of the human eye. Consequently, combinations of blue text and black background like No.9 appear to result in low text readability due to low resolution for the text color with short wavelength dominancy.

In result of the elderly people, no distinguished difference is found between the results under the two lights. The correlation between readability and ΔL* was low, as shown in Figure 5. Low readability of No.9 is also similar to the young results, while the rating of No.5 is markedly lower than the young results. This might be due to the reduced sensitivity to lightness in elderly subjects not only in short wavelength region but also in long wavelength region reported by Sagawa et al. The readability of color combinations with black background, No.5 and No. 9, is low compared with other combinations with similar value of ΔL*.

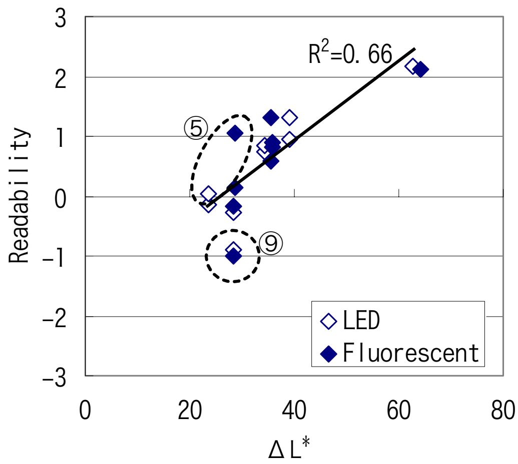

Figure 5. Correlation between ΔL and the rating by elderly subjects*

3. CONCLUSION

The present study showed that difference in spectral radiant distribution of lighting, fluorescent lamp and LED light both in the same range of CCT, does not severely affect the readability of various text-background color combinations for both young and elderly subjects. However, significant differences were found for some of color combinations for young subjects. Text readability for young subjects can be accounted for by lightness difference, while, it t does not explain text readability for elderly subjects, probably due to age-related changes in vision characteristics. When lighting is replaced in a store, light source should ideally be selected based on the quality of light and readability of texts on commodities is one of the important factors to be taken into consideration.

REFERENCES

Hara, N., T. Noguchi. 2004. Influence of Lightness, Chroma and Hue of Chromatic Letters on Readability and Equivalent Luminance Contrast under the Achromatic Background. *Journal of the Illuminating Engineering Institute of Japan* 88(11): 866-873.

Ahnelt, P. K., H. Kolb. and R. Pflug. 1987. Identification of a Subtype of Cone Photoreceptor, Likely to be Blue Sensitive, in the Human Retina. *Journal of Comparative Neurology*.255: 18-34.

Sagawa, K., Y. Takahashi. 2001. Spectral luminous efficiency as a function of age, *Journal of the Optical Society of America*, A, 18(11): 2659-2667.

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Psychological evaluation of the interior color scheme among ages

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ABSTRACT

The purpose of this study is to analyze the impression evaluation of interior colors, which changed in door and floor colors, and develop an interior evaluation map based on the results. The study shows the effect of evaluation differs among ages. We conducted an impression evaluation experiment on 288 subjects using 15 adjectives by the Semantic Differential method. The interior colors were based on actual colors used in interior space, and we produced 31 interior color patterns using computer graphics. According to cluster analysis based on these impression evaluation scores, 31 interior color patterns were classified into six clusters as follows: (a) "*white floor*"; (b) "*brown*"; (c) "*brown contrast*"; (d) "*black*"; (e) "*dark brown*"; and (f) "*unique*". The "*white floor"*, "*brown"*, "*brown contrast"* groups were assigned bright and light spacious impressions. The *"black"* and *"dark brown"* groups were assigned deep and dark impressions. Furthermore, using factor analysis, we extracted the following factors: (a) *evaluation*; (b) *light and brightness*; and (c) *familiarity*. The results of impression evaluation indicated the effect of *evaluation* varies more widely among different ages compared with other factors. Moreover, this was particularly observed with black door and white floor combinations, and black door and black floor combinations.

1. INTRODUCTION

One of the factors that constitute the visual environment for a residential space is interior color. Colors evoke various feelings and these are called color emotions. The effect of interior spaces on color emotions has been studied in various research, in which colors were systematically selected from, for example, the Munsell color system(Acking&Kuller 1972, Hogg *et al*. 1979). While, there has been an increase in the *interior selection system*- using which purchasers can themselves select interior colors, especially for doors and floors in Japan. Considering that people often use this system when planning an interior space, researching how to make interior color schemes more realistic and pragmatic is important. Therefore, we analyzed the evaluation of impressions of interior colors, in which various door and floor colors were presented using actual interior color sheets.

2. OBJECTIVES

The purpose of this study is to analyze the evaluation of impressions of the different patterns of interior colors, which varied in door and floor colors, and develop an interior evaluation map on the basis of the results. Furthermore, this study also demonstrates that evaluations differ among different ages.

3. METHOD

3.1. Stimuli

The interior colors were based on actual color sheets used in interior spaces. We selected eight colors and these were 2 brightnesses of light brown:ltB1,ltB2(ltB1 is brighter than ltB2);2 brightnesses of dark brown:dkB1,dkB2(dkB2 is darker than dkB1); grayish brown:gB; reddish brown:RB; white:W; and black:Bk. Using computer graphics, we used each of the eight colors on a door and floor to produce 64 different patterns of interior colors. On the basis of the results of pilot studies, in which subjects were asked to identify the inappropriate color pattern for interior spaces, we eliminated 33 of the 64 patterns and used 31 patterns for this research. This study was concerned with examination of color patterns, therefore, we selected a base design for these color sheets that was almost plain.

3.2.Procedures

The study had a total of 228 subjects of which 98 subjects were between the age of 18 and 25(average age, 21.7 years, SD=2.2), 110 subjects between the age of 26 and 40 (average age, 31.9 years, SD=4.5), and 80 subjects between the age of 41 and 55(average age,45.5 years, SD=4.0).Subjects were required to rate the psychological images using 15 adjective pairs(bright-dark,warm-cool,light-heavy, manly-feminine,like-dislike,comfortable-uncomfortable,youthful-old,ordinary-characteristic, harmonious-inharmonious,beautiful-notbeautiful,intimate-nonintimate,sophisticated-unsophisticated, simple-complex,elegant-vulgar,spacious-cramped)for the SD method (semantic differential method) while examining each computer graphic of the interior color patters. Subjects were shown the following two types of computer graphics:(a)Graphics in which the door was magnified;(b)Graphics of the room that comprised whole room images and real sheets of floor board and doors.

4. RESULTS AND DISCUSSION

4.1 Cluster analysis

We conducted cluster analysis based on impression evaluation. The 31 interior color patterns were classified into six clusters as follows: (a) a pattern consisting of an all-white floor "*white floor*"; (b) a pattern having a brown color scheme or the same brightness as that of a two-color scheme using brown "*brown*" (c) a pattern that has a high brightness of a brown or one that has a combination of white and a low brightness of brown "*brown contrast*"; (d) a pattern using a black color scheme "*black*"; (e) a pattern using a dark-brown color scheme "*dark brown*"; and (f) a pattern that contains a unique color scheme "*unique*". The *"white floor"* was assigned bright, cool, light, youthful, and spacious impressions. *"Brown"* tended to evoke a positive impression on all adjectives. "*Brown contrast*" elicited characteristics of bright, light, and spacious impressions which were similar to those of "*brown"*. "*Black"* elicited characteristics of dark, cool, heavy, manly, and characteristic impressions.. "*Dark brown"* derived similar impressions to those of "*black"*, except that "*dark brown*" gave a comfortable impression. "*Unique"* evoked neither a positive nor a negative impression on all adjectives.

4.2 Factor analysis

We conducted factor analysis(maximum likelihood estimation with Promax rotation) on the score of the impression evaluations. We extracted the following factors: (a) *evaluation*; (b) *light and brightness*; and (c) *familiarity*. To compare the factor scores of each cluster among ages, one-way analysis of variance for each factor was conducted. Several clusters were significant in all factors, in particular, *"white floor"*($F(2,285)= 11.32, p<.001$), *"brown"*($F(2,285)=9.63, p<.001$), *"black"*($F(2,285)= 13.61, p<.001$), *"dark brown"*($F(2,285)=11.63, p<.001$), *"unique"*($F(2,285)=3.26, p<.05$) showed significant differences for *evaluation* scores. Subjects between the age of 18 and 25 responded differently from those belonging to the other ages, particularly for the effect of *evaluation* when compared with the other factors.

4.3 Interior evaluation map

We developed interior evaluation maps based on the results of factor scores. Figures 1 and 2 show the interior evaluation maps averaged across all ages. The interior evaluation maps illustrated the relationship between the *evaluation* factor and the *light and brightness* factor and *familiarity* factor. Eight interior colors were displaced the number as the notation in each figure, W:1, ltB1:2, ltB2:3, dkB1:4, dkB2:5, gB:6, RB:7, Bk:8.(door color – floor color)

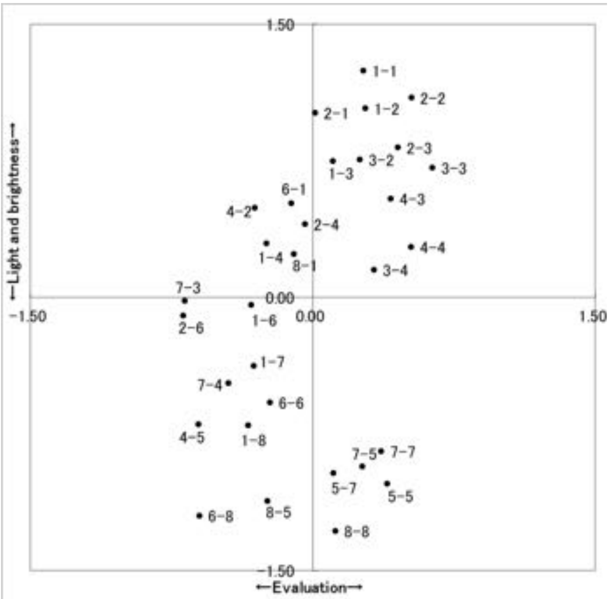

Fig.1 Evaluation and light and brightness

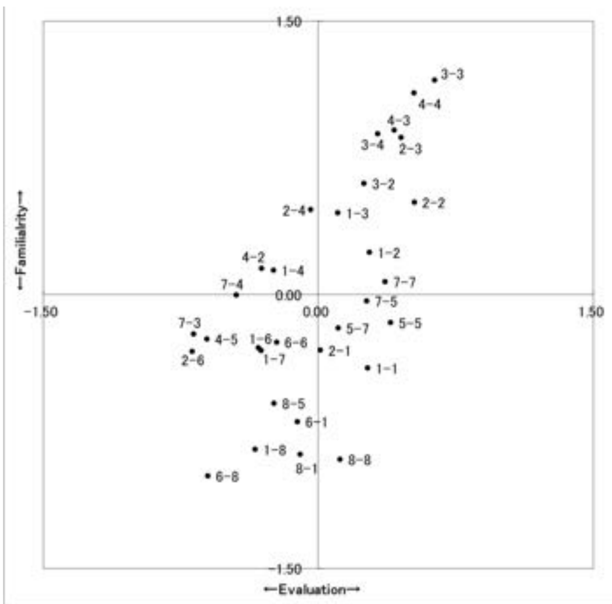

Fig.2 Evaluation and familiarity

4.3.1 Feature of clusters in each factors

Interior color schemes that had high scores for both *evaluation* and *light and brightness* were bright color schemes such as white and light brown. Color schemes that had high *light and brightness* scores but low *evaluation* scores were "*white floor"* and "*brown contrast"*. Color schemes that had high *evaluation* scores but low *light and brightness* scores were "*dark brown*" and Bk×Bk(door color×floor color) , all of which had extremely low scores. High *evaluation* scores were assigned when the same or a similar color scheme was used for the door and floor, therefore all ages mostly preferred a bright same color scheme. Color schemes that had high scores for both *evaluation* and *familiarity* were brown same color scheme and bicolor schemes with small color differences, such as "*brown*" and RB×RB. Color schemes that had high *familiarity* scores but low *evaluation* scores were "*brown contrast*". Color schemes that had high *evaluation* scores but low *familiarity* scores were "*dark brown*", "*white floor*" and part of "*black*". Same color brown schemes were considered more familiar and were preferred.

4.3.2 Features of clusters for different age groups

Bk×W, Bk×dkB2, ltB1×W, and ltB1×dkB1 were assigned high *evaluation* scores by subjects between the age of 18 and 25 and other age groups were scored low. W×ltB2, Bk×Bk , and dkB2×RB were scored low by those between 41 and 55 years, and other age groups were assigned high *evaluation* scores. Among these results, Bk×W and Bk×Bk varied more widely among different age groups. For familiarity, ltB1×ltB1, ltB1×dkB1, and dkB1×ltB1 were scored low by the oldest group. ltB2×ltB1 and W×gB were scored high and W×RB was scored low by those between 18 and 25 years.

5. CONCLUSION

According to cluster analysis based on these impression evaluation scores, 31 interior color patterns were classified into six clusters as follows: (a) "*white floor*"; (b) "*brown*"; (c) "*brown contrast*"; (d) "*black*"; (e) "*dark brown*"; and (f) "*unique*". The *"white floor"*, *"brown"*, and *"brown contrast"* groups were rated as bright, light and spacious. The *"black"* and *"dark brown"* groups were rated as deep and dark. The results of factor analysis for impression evaluation indicated that the effect of *evaluation* varies more widely among different age groups compared with that for the other factors. Moreover, this was particularly observed with black door and white floor combinations, and with black door and black floor combinations.

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REFERENCES

Acking C.A and Kuller R.1972. The perception of an interior as a function of its colour. *Ergonomics* 15:645-654.

Hogg. S. Goodman, T. Ponter, B.Mikellides and D.E. Preddy 1979. Dimensions and determinants of judgements of colour samples and a simulated interior space by architects and non-architects. *British Journal of Psychology* 70:231-242.

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oral paper

Prediction of a taste from color And its practical application

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ABSTRACT

The relationship between the attributes of color and the perceived quality of taste was investigated. A survey with 100 Korean adults was conducted, in which 120 color patches were presented to the subjects. The subjects were asked to evaluate perceived taste in terms of sweetness, sourness, bitterness, saltiness, spiciness, and nuttiness. The multiple regression analysis was performed in order to derive formulae by taking the hue(a*, b*), saturation($C=\sqrt{(a^2 + b^2)}$), and lightness(L*) of the CIE 1976 L*a*b* values as the independent variables. It was revealed that the perceived taste intensity is affected by the combination of hue, saturation, or lightness at the significant level of 0.01. Consequently, it was possible to derive equations for each taste. Among the five tastes, bitterness was most predictable (R^2= 0.24) followed by spiciness (R^2= 0.23). As an extension to a practical application, a test with six types of food—chocolate, vitamin C, capsule coffee, spam, cup ramen, and cheese—was carried out (N= 50), and each type of food had four to six variations of color. The formulae were applied to rank the colors of each food in terms of its dominant taste and the result shows that the formulae generally have enough validity in predicting the taste intensity of the food through color.

1. BACKGROUND AND PURPOSE

The relationship between food color and its taste perception has been actively studied during the past 70 years (Cardello. 1994). However, there has been a limited effort in identifying the relationship in a clear and quantifiable way such as what attributes of color have effect on the perceived taste quality. Moreover, stimuli of previous researches were limited to variation of colored-water (DuBOSE et al. 1980; Shankar et al. 2010). Hence, it is important to also explore the relationship with consideration to real industry contexts.

This study investigates and quantifies the relationship between food color and its perceived taste quality by using the CIE 1976 L*a*b* color value. As an extensive version of the empirical study, the impact of various colors of food packages on taste perception was examined.

2. EXPERIMENT I

2.1 Objective

Generally, color is the most important visual factor when people make judgments about food and therefore, one's expectation towards taste or taste intensity can vary depending on it. In experiment I, the relationship between the attributes of color and the perceived quality of taste is investigated and quantified.

2.2 Method

A group of 100 hundred Koreans, comprising of 52 male students and 48 female students, participated in the experiment with an average age of 23.03 years old and a standard deviation of 3.35 years. All participants were paid volunteers without any color vision problems. One hundred and twenty color patches taken from the Hue & Tone color system were prepared and randomly provided to the subjects under the daylight condition. Each subjects were asked to judge the perceived taste intensity in terms of sweetness, sourness, bitterness, saltiness, and spiciness when viewing the given color patch, and a Likert-Scale with range between 1(not at all) and 5(very strong) was given for the assessment.

2.3 Results and analysis

Prior to conducting statistical verification, the CIE 1976 L*a*b* values of all color patches were measured using a spectrophotometer (CM 2600d, Minolta). The CIE 1976 L*a*b* value consists of three coordinates, the lightness (L*), the position between red and green(a*; +a*: red, -a*: green), and the position between yellow and blue(b*; +b*: yellow, -b*: blue). In addition, saturation, C(Chroma) was calculated based on the a* and b* ($C=\sqrt{(a^2 + b^2)}$). Those three coordinates are independent from each other, and in particular, C was adopted since it increased of determinant coefficient(R^2) of the derived equations.

Based on the subjects' ratings, a multiple regression analysis was performed in order to derive formulae by taking the CIE 1976 L*a*b* values of a color as independent variables (see Table 1). It was revealed that bitterness (R^2= 0.24) followed by spicy taste (R^2= 0.23) were most predictable through color perception in comparison to other tastes. Moreover, as shown in Table 1, the contribution of color attributes to different taste dimensions varies. Consequently, given a color, it is possible predict its emotional aspects by putting its colors values to the equation shown in (Table 1).

Table 1. Formulae derived from the survey ratings.

Taste dimension	Formulae to predict the intensity of taste by CIE 1976 L*a*b* values of a color, unit: %	R^2	Sig.
Sweetness	-1.07 + 0.51L* + 0.29a* + 0.19C	0.15	.01
Sourness	-7.01 + 0.42L* + 0.36C	0.14	.01
Bitterness	96.58 – 0.80L* – 0.63C + 0.40b* - 0.28a*	0.27	.01
Saltiness	28.67 – 0.09L* – 0.07C + 0.06a*	0.01	.01
Spiciness	13.53 + 0.37a* + 0.31C - 0.18L*	0.23	.01
Nuttiness	24.47 + 0.35b* – 0.27C + 0.18a*	0.10	.01

3. EXPERIMENT II

3.1 Objective

In experiment II, it was purposed to verify the formulae derived in the prior experiment by applying them to real food packages.

3.2 Method

A total of 50 participants comprised of 22 male students and 28 female students with an average age of 23.26 years and a standard deviation of 3.01 years were recruited for this experiment. Six types of food package including chocolate, vitamin C, capsule coffee, spam, cup ramen, and string cheese were prepared and each package had four to six variations of colors (See Figure 1). Comparable to the previous experiment, the CIE 1976 L*a*b* values of all stimuli were measured and their expected taste intensity and rank order was calculated.

Figure 1. The six types of food and its color variations. (from left top, clockwise; chocolate, vitamin C, capsule coffee, spam, cup ramen, and string cheese)

Six types of stimuli were given in random order and participants were asked to choose all tastes that they felt represented the dominant taste of each food and rank the colors of each food based on the intensity of the taste perceived. For instance, when viewing chocolate, participants may choose both sweetness and bitterness as dominant tastes then rank the colors of chocolate covers in terms of how bitter and how sweet they felt the chocolates would taste.

3.3 Results and Analysis

Firstly, dominant tastes were identified based on participants' agreement. When more than two-thirds(> N= 33) of them agreed, the taste(s) was(were) assigned to the dominant taste of the food stimuli. For example, in case of the chocolate, sweetness and bitterness were selected as the dominant tastes, and then the Kendall's W test was performed in order to examine whether there was a satisfactory level of internal consistency between ranked ratings. The analysis yielded that the ranked ratings for both sweetness and bitterness of chocolate showed consistent tendency among participants [sweetness: N=50 agreed as dominant taste of chocolate, Kendall's W= 0.47, p= .00; bitterness: N=45 agreed as dominant taste of chocolate, Kendall's W= 0.60, p= .00]. After selecting dominant taste(s) for each food, the mean ranks of the colors were calculated using the participants' rating results.
Based on the mean ranks, a Spearman's Rank Order correlation was run to determine the relationship between rank by formula and rank by ratings. Overall, the correlation coefficient rho(ρ) ranged between 0.50 and 1.00, supporting that the distribution tendencies of both ranks were similar. As shown in Table 2, in the chocolate case, there was a strong and positive correlation between rank by formula and rank by participants' rating in terms of sweetness (ρ= .94).

5. CONCLUSION

This study attempted to quantify the relationship between the attributes of color and the perceived quality of taste. Based on the multiple regression analysis, the formulae were derived to predict the intensity of the six suggested tastes. In assigning the color attributes numerically, the hue value was profiled with both a* and b* of the CIE 1976 L*a*b* independently. The formulae presented that the color attributes were related to one's prediction of taste intensity, yet the strength varied noticeably depending on the taste type. In order to test whether the formulae drawn from the empirical study would be employed for the practice, such as food packages in real context, the second experiment was carried out. The result, in general, supported the application of formulae to predict consumers' taste perception. By adjusting and simplifying the formulae (for example, converting L*a*b* value to RGB or CMYK values), the results of this research can be easily utilized in food industries as a new way of food color marketing.

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Table 2. Comparison of Ranks by formulae and by ratings (in case of chocolate)

Stimuli	Taste	no.	Color label	L*	a*	b*	Rank by Formula	Rank by Ratings	ρ
Chocolate	Sweet	1	Vivid Red	45.72	42.99	24.29	3	3.11	.94
		2	Pale Yellow	89.50	-2.12	25.67	2	1.64	
		3	Vivid Black	24.57	-0.08	-0.56	6	5.22	
		4	Red Purple	38.65	43.31	-8.12	4	3.66	
		5	Vivid Yellow	74.82	24.80	69.31	1	2.79	
		6	Vivid Blue	43.30	9.06	-42.92	5	4.58	
	Bitter	1	Vivid Red	45.72	42.99	24.29	2	3.60	.49
		2	Pale Yellow	89.50	-2.12	25.67	4	5.76	
		3	Vivid Black	24.57	-0.08	-0.56	1	1.40	
		4	Red Purple	38.65	43.31	-8.12	3	3.44	
		5	Vivid Yellow	74.82	24.80	69.31	6	4.11	
		6	Vivid Blue	43.30	9.06	-42.92	5	2.69	

ACKNOWLEDGEMENTS

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REFERENCES

Cardello, A.V. 1994. Consumer expectations and their role in food acceptance. *Measurement of Food Preferences*, London: Blackie Academic.

DuBOSE, C.N., A.V. Cardello, O. Maller. 1980. Effects of colorants and flavorants on identification, perceived flavor intensity, and hedonic quality of fruit-flavored beverages and cake. *Journal of Food Science* 45 (5): 1393-1399.

Shankar, M.U., C. A. Levitan, C. Spence. 2010. Grape expectations: The role of cognitive influences in color–flavor interactions. *Consciousness and Cognition* 19: 380–390.

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oral paper

Visual impression of a color group characterized by a colored light source and its applicability to color design

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ABSTRACT

Our previous study(Ishida and Mori 2011) showed that a color group characterized by a colored light appeared to be harmonious. In this study, we extended our research and examined the applicability to color design. In experiment 1, we evaluated a sense of visual harmony, preference, activity, potency and warmth of color arrangements characterized by a colored light. It was found that the color arrangements gave a certain visual impression according to the characterizing colors. In experiment 2, colors selected from the characterized color group were applied to an interior space using computer graphics. Visual impressions of the space were evaluated as in the experiment 1. The results showed that the senses of harmony, preference and potency of the interior space differed somewhat from those of the color arrangements, suggesting some interactions between colors and actual contexts were involved.

1. INTRODUCTION

Color is important for design practices in any built environments and products. A systematic method producing harmonious color arrangement is worth investigating both in scientific and practical purposes. Many theories of color harmony have suggested that colors having similar visual attributes would appear harmonious(Moon and Spencer 1944; Judd 1955; Arnkil 2008; O'Connor 2010). In our previous study (Ishida and Mori, 2011), we examined one possible way to give some common visual attributes to colors. Appearances of color surfaces illuminated by a colored light will change in a similar way according to the color of light. A red light, for example, will add reddish components to each of the color surfaces and reduce their greenish components. We refer those colors as the colors characterized by a colored light. Our previous study showed that the color group characterized by the colored light appeared to be harmonious. In this study, we extended this paradigm and assessed a sense of visual harmony, preference, activity, potency and warmth of the color arrangements characterized the colored lights which were systematically selected from five hues and three saturations. In additions, the applicability of the characterized color groups to color design of an interior space was examined using computer graphic images.

2. EXPERIMENT 1: visual impression of the color arrangement characterized a colored light

2.1 Experiment 1: Methods

Figure 1 presents an experimental set-up used in the experiment 1. An arrangement of color chips was illuminated by a colored light source. A white screen board with small windows arranged in a grid placed between a subject and the color chips. The subject viewed the color arrangement through a small viewing window. Using this setting, the subject viewed the color chips as if they were placed on the white screen under the white light. That is, the colors under the colored light were presented on the white background. The sizes of color arrangements were

3x3 and 4x4. We prepared 10 color arrangements for each of two sizes by selecting colors from a large set of color chips. We set 16 lighting conditions as in table 1; 5 hues (red, yellow, green, blue and purple) and 3 saturations (low, middle and high). Since color chips were chosen randomly, the color arrangements under the white light condition expected not to give any distinct visual impressions. Our question was whether the colored light gave some common visual impressions to the color arrangement. Examples of the color arrangements were shown in Figure 2. Ten subjects from Kyoto University participated in the experiment.

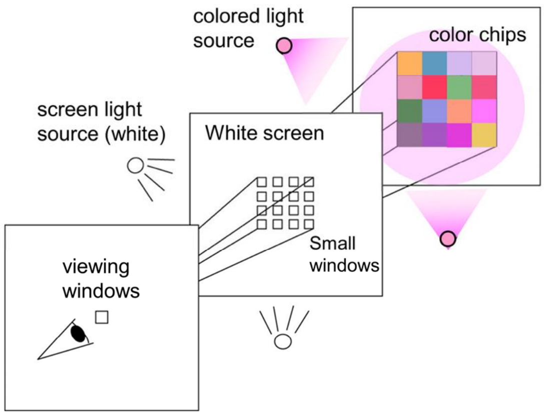

Figure 1. General method of the experiment 1.

Table 1. Specification of the colored light sources

Hue	Saturation	u'	v'	$\Delta E_{u'v'}$
W	-	0.212	0.492	0.000
R	L	0.232	0.494	0.020
R	M	0.247	0.496	0.035
R	H	0.262	0.497	0.050
Y	L	0.220	0.510	0.020
Y	M	0.226	0.524	0.035
Y	H	0.233	0.537	0.050
G	L	0.196	0.503	0.020
G	M	0.183	0.511	0.035
G	H	0.170	0.519	0.050
B	L	0.207	0.472	0.020
B	M	0.203	0.458	0.035
B	H	0.199	0.444	0.050
P	L	0.218	0.472	0.020
P	M	0.223	0.459	0.035
P	H	0.226	0.444	0.050

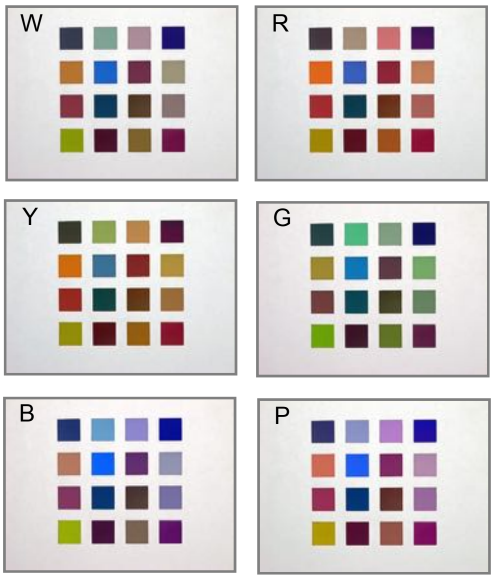

Figure 2. Examples of the color arrangements. The letters on the images show the characterizing colors.

2.2 Experiment 1: Results

Figure 3 shows the results of the experiment 1. The evaluation scores averaged over all subjects are plotted against the saturation of the characterizing colored lights expressed in the color difference between the white and the colored lights. As shown in this figure, the color arrangements characterized by the colored lights were evaluated more harmonious and preferable than those by the white light. It was also found that the colored light gave unique impressions to the color arrangement. A sense of activity was enhanced by the red light condition. The color arrangements characterized by the red and yellow lights gave much warmer impressions. In figure 4, the score differences between the color characterized and the white light conditions were plotted on the $u'v'$ chromaticity diagram. We can see from this figure that the hue of the characterizing light strongly affected on the visual impression of the color arrangements and their effects were enhanced with increasing the saturation of the characterizing lights.

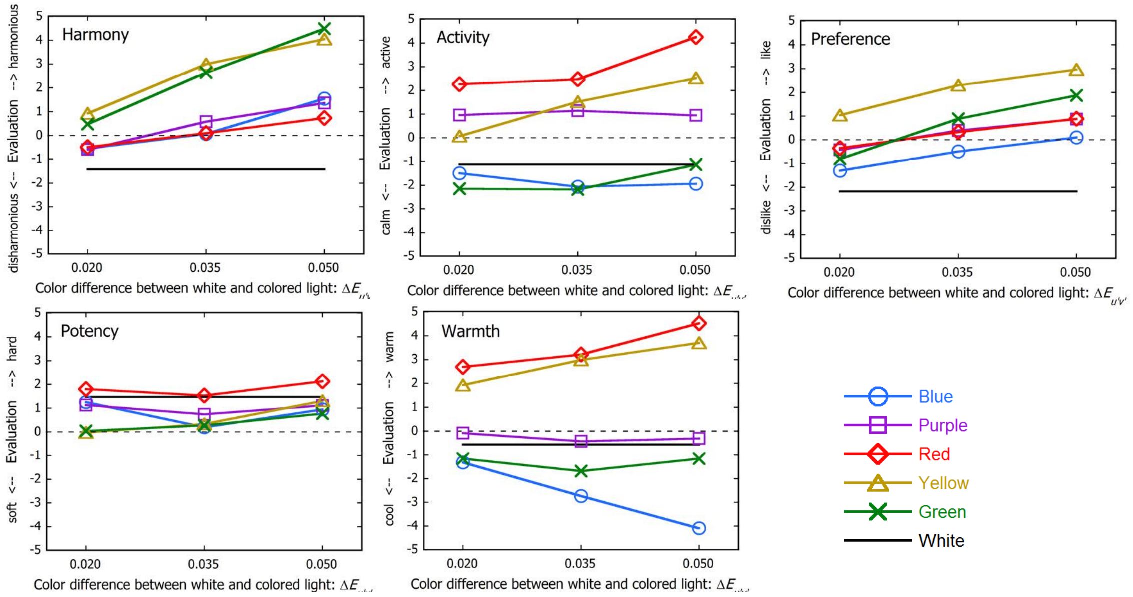

Figure 3. Results of the experiment 1.

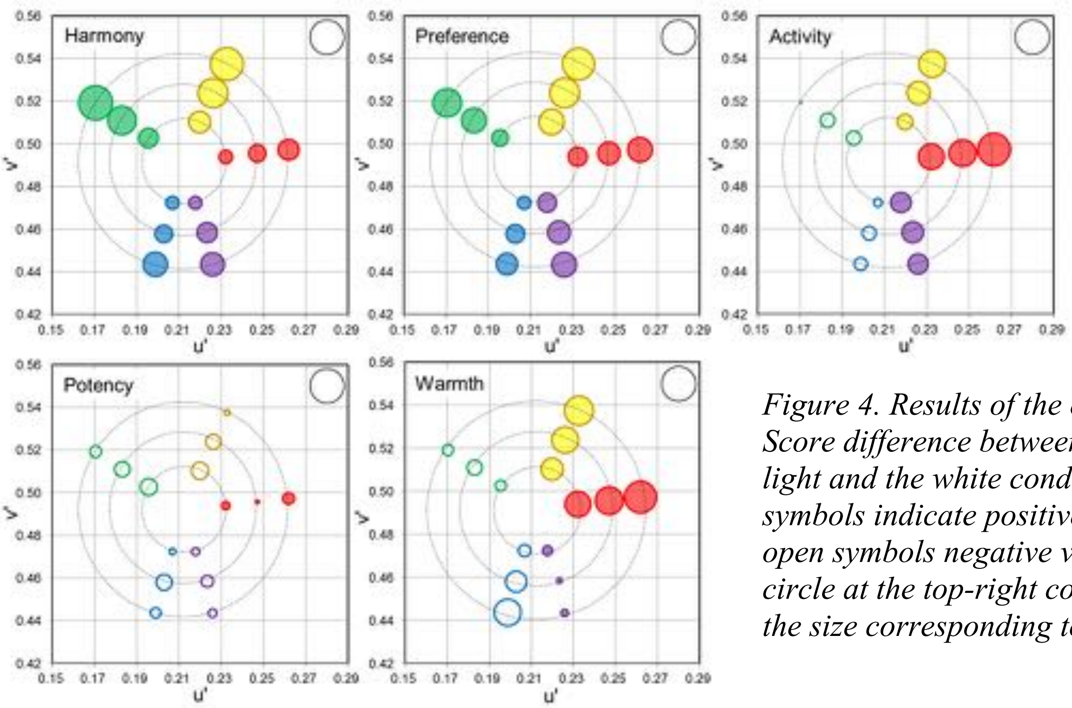

Figure 4. Results of the experiment 1. Score difference between the colored light and the white conditions. Filled symbols indicate positive values and open symbols negative values. A circle at the top-right corner denotes the size corresponding to 6.

3. Experiment 2: visual impression of an interior space arranged by the characterized color group

3.1 Experiment 2: methods and results

In the experiment 2, we tested if the visual impressions obtained for the color arrangements could be reproduced when we applied those colors to actual scenes. A computer graphics[1] of a single room was created and colors chosen from the color groups characterized by the colored lights were applied to several items in the room as shown in Figure 5. We prepared 110 room images; 5 sets of color chips, 11 characterizing colored lights and two interior types. Thirteen subjects from the department of architecture participated in the experiment 2.

[1] POV-Ray 3.6

Figure 6 shows the results of the experiment 2; the difference between scores for the characterized colors and the white conditions. The characterized colors gave similar effects as in the experiment 1 to warmth and activity for the room images. However, the senses of harmony, preference and potency differed somewhat when the colors were applied to the room images. The results suggested that some interactions between colors and actual images existed. The applicability of the characterized color group to color designing will be discussed.

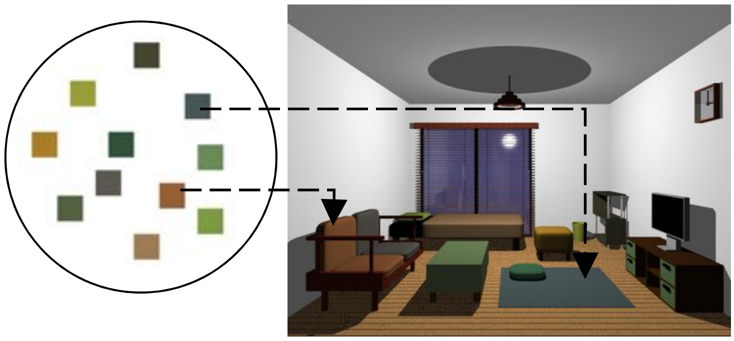

Figure 5. Experiment 2: Applying colors selected from the characterized color group to several items in the room produced by the computer graphics.

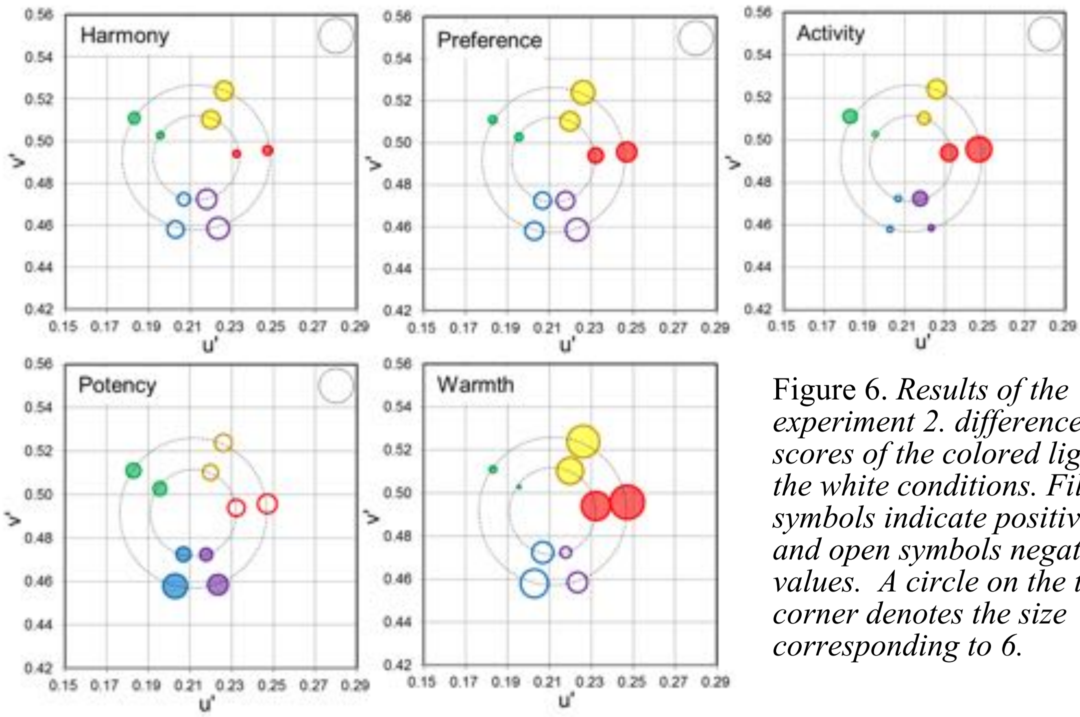

Figure 6. *Results of the experiment 2. difference between scores of the colored light and the white conditions. Filled symbols indicate positive values and open symbols negative values. A circle on the top-right corner denotes the size corresponding to 6.*

REFERENCES

Arnkil, H. (2008). What is colour harmony? Proceedings of Interim Meeting of the International Colour Association, paper No.97.

Ishida, T. and B. Mori (2011). "Harmonious color group characterized by a colored light source." Proceedings of the Midterm Meeting of the International Colour Association: 213-216.

Judd, D. E. (1955). "Classic lows of color harmony expressed in terms of color solid." Inter-Society Color Council news letter 119: 13.

Moon, P. and D. E. Spencer (1944). "Geometric formulation of classical color harmony." Journal of the Optical Society of America 34(1): 46-59.

O'Connor, Z. (2010). "Colour Harmony Revisited." Color Research and Application 35(4): 267-273.

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oral paper

Spectral-based Optimal Daltonization Model for Dichromatic Color Vision

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ABSTRACT

This paper proposes a spectral-based image daltonization model for dichromats getting the best visibility against their color deficiencies. The proposed model extracts the visible and invisible spectra based on Matrix-***R*** theory. First, the fundamental spectra $\boldsymbol{C}^*_{LMS}$ visible to normals are captured from the conventional *sRGB* images by a pseudo-inverse projection. Second, the fundamental spectra $\boldsymbol{C}^*_{DIC}$ visible to dichromats are obtained by operating the matrix-$\boldsymbol{R}_{DIC}$ extended to 2-D version. Thirdly, the lost spectra $\square\boldsymbol{C}_{DIC}$ are calculated as the difference between $\boldsymbol{C}^*_{LMS}$ and $\boldsymbol{C}^*_{DIC}$. The key point is to make use of the lost spectra for image daltonization revived again. Though the lost spectra $\square\boldsymbol{C}_{DIC}$ are invisible to dichromats if left alone, they are shifted to the visible region and added to the fundamental $\boldsymbol{C}^*_{LMS}$ of source image. The optimal spectral shift is determined to maximizing the spectral visibility for the dichromats and minimizing the visual gap from the normals. The proposed algorithm is designed to solve this contradictory demand to cope with both dichromats and normals.

1. INTRODUCTION

Most of the color blindness simulators have followed the Brettel-Vienot-Mollon's (1997) model but take a troublesome procedure to find the corresponding color pairs between the normals and the dichromats. Capilla (2004), simplified this procedure with a systematic model. Recently, Pardo and Sharma (2011) further proposed an advanced 2-step model. These popular simulators are widely accepted, but any of them didn't deal with the spectral analysis.

In the previous paper, Kotera (2011) proposed a spectral-based dichromatic model based on the extended Matrix-***R*** theory. The model clarified what parts in the spectra are visible to the dichromats and extracted the lost spectra as a spectral difference from the normals. The lost spectra interpreted the spectral background behind the blindness and proved useful for the image daltonization. However, the previous model needed an expensive spectral image input.

The improved model makes use of conventional sRGB image instead of spectral image and proposes an optimal daltonization algorithm to cope with both dichromats and normals.

2. ADVANCED SPECTRAL-BASED DICHROMATIC MODEL

Figure 1 overviews the core procedures in the proposed spectral-based simulation model.

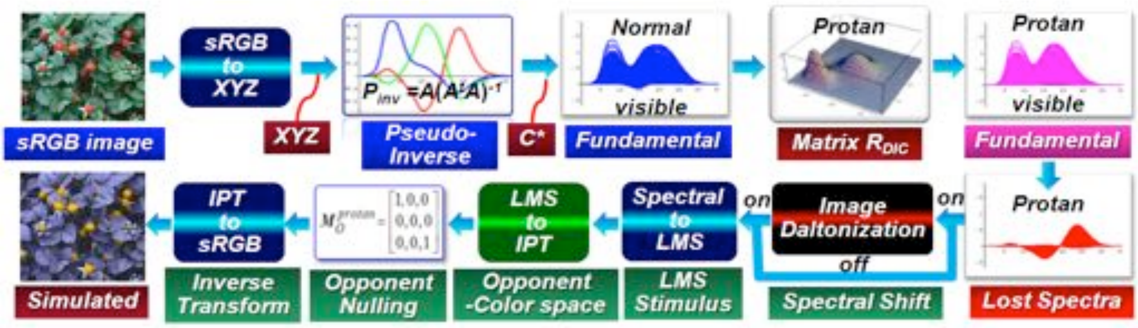

Figure 1. Overview of proposed model (in case of dichromatic vision for protanopes)

2.1 Getting Fundamentals from sRGB Camera Image

Based on matrix-$\boldsymbol{R}$ (Cohen 2001), the projector $\boldsymbol{R}_{LMS}$ from spectral to *LMS* space is given by

$$\boldsymbol{R}_{LMS} = \boldsymbol{A}_{LMS}(\boldsymbol{A}_{LMS}{}^{t}\boldsymbol{A}_{LMS})^{-1}\boldsymbol{A}_{LMS}{}^{t} \quad for\ \boldsymbol{A}_{LMS} = [\boldsymbol{l}(\lambda)\boldsymbol{m}(\lambda)\boldsymbol{s}(\lambda)]: LMS\ cone\ sensitivity. \tag{1}$$

In the *HVSS* (*Human Visual Sub-Space*), *n*-dimensional spectral input $\boldsymbol{C}$ is decomposed into

$$\boldsymbol{C} = \boldsymbol{C}^{*}_{LMS} + \boldsymbol{B},\ \boldsymbol{C}^{*}_{LMS} = \boldsymbol{R}_{LMS}\boldsymbol{C},\ \boldsymbol{B} = (\boldsymbol{I} - \boldsymbol{R}_{LMS})\boldsymbol{C}. \tag{2}$$

The *fundamental* $\boldsymbol{C}^{*}_{LMS}$ is visible but the *metameric black* $\boldsymbol{B}$ is by-passed as invisible spectra. Since the *fundamental* $\boldsymbol{C}^{*}_{LMS}$ carries the tristimulus value $\boldsymbol{LMS}$ as same as the input spectra $\boldsymbol{C}$, it's exactly recovered from $\boldsymbol{LMS}$ by the pseudo-inverse transform (Kotera 1996) as follows.

$$\boldsymbol{LMS} = \boldsymbol{A}^{t}_{LMS}\boldsymbol{C} = \boldsymbol{A}^{t}_{LMS}\boldsymbol{C}^{*}_{LMS},\ then\ \boldsymbol{C}^{*}_{LMS} = \boldsymbol{P}^{inv}_{LMS}\boldsymbol{LMS},\ where,\ \boldsymbol{P}^{inv}_{LMS} = \boldsymbol{A}_{LMS}(\boldsymbol{A}_{LMS}{}^{t}\boldsymbol{A}_{LMS})^{-1}, \tag{3}$$

Letting a calibrated *sRGB* image be $\boldsymbol{sRGB}$, the *LMS* fundamental spectral image is given by

$$\boldsymbol{C}^{*}_{LMS} = \boldsymbol{P}^{inv}_{LMS}\boldsymbol{LMS} = \boldsymbol{P}^{inv}_{LMS}(\boldsymbol{M}_{XYZ->LMS})(\boldsymbol{M}_{sRGB->XYZ})\boldsymbol{sRGB};\ \boldsymbol{M}_{A->B} = linear\ matrix. \tag{4}$$

Thus we can get the fundamental spectral image $\boldsymbol{C}^{*}_{LMS}$ for normals from *sRGB* camera images.

2.2 Extraction of Visible Spectra and Lost Spectra for Dichromats

Reducing the dimension of $\boldsymbol{R}_{LMS}$ to 2-D, it's extended to the dichromatic matrix $\boldsymbol{R}_{DIC}$ as

$$\begin{aligned}&\boldsymbol{R}_{DIC} = \boldsymbol{A}_{DIC}(\boldsymbol{A}_{DIC}{}^{t}\boldsymbol{A}_{DIC})^{-1}\boldsymbol{A}_{DIC}{}^{t}\\ &where,\ \boldsymbol{A}_{DIC} = [\boldsymbol{m}(\lambda),\boldsymbol{s}(\lambda)]: protan,\ = [\boldsymbol{l}(\lambda),\boldsymbol{s}(\lambda)]: deutan,\ = [\boldsymbol{l}(\lambda),\boldsymbol{m}(\lambda)]: tritan\end{aligned} \tag{5}$$

Figure 2 illustrates the matrix $\boldsymbol{R}_{DIC}$ extended to the dichromats from the $\boldsymbol{R}_{LMS}$ of normals. The dichromatic fundamental $\boldsymbol{C}^{*}_{DIC}$ is obtained by operating the projector $\boldsymbol{R}_{DIC}$ on $\boldsymbol{C}^{*}_{LMS}$ as

$$\boldsymbol{C}^{*}_{DIC} = \boldsymbol{R}_{DIC}\boldsymbol{C} = \boldsymbol{A}_{DIC}(\boldsymbol{A}_{DIC}{}^{t}\boldsymbol{A}_{DIC})^{-1}\boldsymbol{A}_{DIC}{}^{t}\boldsymbol{C}^{*}_{LMS}. \tag{6}$$

Since the fundamental $\boldsymbol{C}^{*}_{DIC}$ denotes the spectra visible to dichromats, the difference in the fundamentals between normals and dichromats gives the lost spectra for dichromats as

$$\Delta\boldsymbol{C}_{DIC} = \boldsymbol{C}^{*}_{LMS} - \boldsymbol{C}^{*}_{DIC} = (\boldsymbol{R}_{LMS} - \boldsymbol{R}_{DIC})\boldsymbol{C}^{*}_{LMS}. \tag{7}$$

Figure 3 shows the visible spectra and invisible lost spectra to protan for Macbeth color checkers in comparison with normal vision. It is notable that the lost spectra include the negative responses just corresponding to the opponent-color components of *Red-Green*.

Now, substituting the *LMS* fundamental image $\boldsymbol{C}^{*}_{LMS}$ in Eq.(4) for that in Eq. (6), the fundamental spectral image $\boldsymbol{C}^{*}_{DIC}$ for dichromats is calculated from *sRGB* image as

$$\boldsymbol{C}^{*}_{DIC} = \boldsymbol{R}_{DIC}\boldsymbol{C}^{*}_{LMS} = \left[\boldsymbol{A}_{DIC}(\boldsymbol{A}_{DIC}{}^{t}\boldsymbol{A}_{DIC})^{-1}\boldsymbol{A}_{DIC}{}^{t}\right]\left[\boldsymbol{A}_{LMS}(\boldsymbol{A}_{LMS}{}^{t}\boldsymbol{A}_{LMS})\right]\cdot(\boldsymbol{M}_{XYZ->LMS})(\boldsymbol{M}_{sRGB->XYZ})\boldsymbol{sRGB} \tag{8}$$

As a result by Eq. (8), the dichromatic spectral image is captured from outside scenes using a *sRGB* camera not spectral camera, and applied to simulate the colors on *sRGB* display.

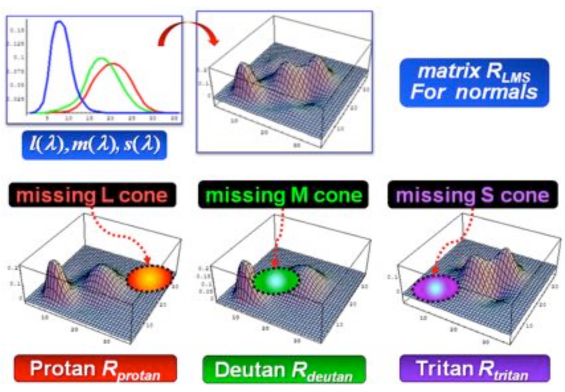

Figure 2. Extended matrix $\boldsymbol{R}_{DIC}$ for dichromats

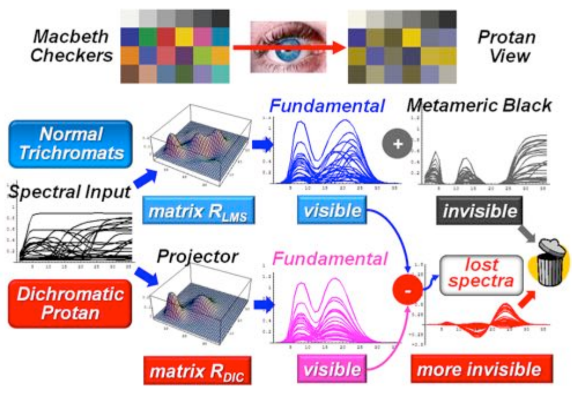

Figure 3. Visible and invisible spectra

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2.3 Simulation on Dichromatic Color Vision

According to Figure 1, the simulation follows Capilla (2004) with opponent-color process as
[Step1] **Getting** ΔC_{DIC} **by Eq.(9)** and [Step2] **Getting** C^{*}_{DIC} **by Eq.(10)**

[Step3] **Opponent-Color Nulling Process in *IPT* Opponent-Color Space**

IPT space (Ebner&Fairchild 1998) is used for its excellent color-opponency. C^{*}_{DIC} to IPT_{DIC} is

$$IPT_{DIC} = M_O(M_{LMS\to IPT})S_{IPT}\cdot LMS_{DIC} \ \ for\ LMS_{DIC} = A^{t}_{LMS}C^{*}_{DIC}. \tag{9}$$

S_{IPT} denotes the *IPT* nonlinear scaling with power of 0.43 for each entry of LMS_{DIC}.

M_O works to nullify one of the opponent mechanisms either (*Red–Green*) or (*Blue–Yellow*).

[Step4] **Inverse Transform to sRGB Display**

Finally, the simulated colors are displayed on *sRGB* monitor by the inverse transforms as

$$D_{sRGB} = (M_{sRGB\to XYZ})^{-1}(M_{XYZ\to LMS})^{-1}\cdot(M_{LMS\to IPT})^{-1}IPT_{DIC}. \tag{10}$$

3. OPTIMAL DALTONIZATION USING LOST SPECTRA

The lost spectra ΔC_{DIC} are invisible if left alone but revived for the image daltonization by shifting into the visual range. The optimal spectral shift algorithm follows [Step5] to [Step9].

[Step5] **Shift-Rotate-Left Algorithm:** ΔC_{DIC} is converted to ΔC_{SHT} after shifting by λ_{SHT} as

$$\begin{aligned} &if\ \lambda_{max} \geq \lambda \geq \lambda_{SHT} + \lambda_{min},\ \Delta C_{SHT}(\lambda - \lambda_{SHT}) = \Delta C_{DIC}(\lambda) \\ &else\,if\ \lambda_{SHT} + \lambda_{min} > \lambda \geq \lambda_{min},\ \Delta C_{SHT}(\lambda_{max} + \lambda_{min} + \lambda - \lambda_{SHT}) = \Delta C_{DIC}(\lambda). \end{aligned} \tag{11}$$

[Step6] **Daltonize:** Daltonized image is cretated by adding the shifted lost spectra ΔC_{SHT} as

$$_{DAL}C_{LMS}(\lambda) = C^{*}_{LMS}(\lambda) + \Delta C_{SHT}(\lambda). \tag{12}$$

[Step7] **Evaluation Function** Ψ_{FIT} **: Measure for Maximizing Dichromatic Visibility**

The fundamental for each pixel g_j of the shifted ΔC_{SHT} gives its visible component as

$$\Delta C^{*}_{SHT}(\lambda, g_j) = R_{DIC}\Delta C_{SHT}(\lambda, g_j) : \textit{note super subscript}^{*}\textit{denotes fundamental}. \tag{13}$$

Since the power spectra is meaningfull, taking the norm of ΔC_{SHT} and its sum, we get

$$\Psi_{FIT}(\lambda_{SHT}) = \sum_{j=1}^{J}\left\|\Delta C^{*}_{SHTimg}(\lambda, g_j)\right\|^2 \left\|\Delta C^{*}_{SHTimg}\right\|^2 = \left\langle \Delta C^{*}_{SHTimg}(\lambda, g_j)\bullet \Delta C^{*}_{SHTimg}(\lambda, g_j)\right\rangle. \tag{14}$$

The best fit shift wavelength $\lambda_{SHT} = \lambda_{FIT}$ is determind to maximize the function Ψ_{FIT}.

[Step8] **Evaluation Function** Ψ_{DIF} **: Measure for Minimizing Visual Gap from Normals**

Another demand arises for minimizing the visual gap from normals. The second measure is defined to evaluate the spectral difference between the normals and dichromats.

The second evaluation function $\Psi_{DIF}(\lambda_{SHT})$ is defined by the sum of spectral difference as

$$\Psi_{DIF}(\lambda_{SHT}) = \sum_{j=1}^{J}\left\|\Delta C_{DIF}(\lambda, g_j)\right\|^2 \ for\ \Delta C_{DIF}(\lambda) = \Delta C_{DIC}(\lambda) + (R_{LMS} - R_{DIC})\Delta C_{SHT}(\lambda). \tag{15}$$

As the value of $\Psi_{DIF}(\lambda_{SHT})$ goes down, the visual gap is decreased into spectral matching.

[Step9] **Evaluation Function** Ψ_{OPT} **: Total Measure for Optimal Daltonization**

The total evaluation function $\Psi_{OPT}(\lambda_{SHT})$ is defined by combining both functions as

$$\Psi_{OPT}(\lambda_{SHT}) = w\Psi_{FIT}(\lambda_{SHT}) + (1-w)(1-\Psi_{DIF}(\lambda_{SHT}))\ for\ 0 \leq \Psi_{FIT}(\lambda_{SHT}) \leq 1, 0 \leq \Psi_{DIF}(\lambda_{SHT}) \leq 1, \tag{16}$$

where, $\Psi_{DIF}(\lambda_{SHT})$ is reversed to take the maximum value at the minimum difference point.

The best shift wavelength λ_{OPT} is determined to maximize the function $\Psi_{OPT}(\lambda_{SHT})$ as

$$\lambda_{SHT} = \lambda_{OPT} \ \ for\ \Psi_{OPT}(\lambda_{OPT}) = \max_{\lambda_{SHT}=0}^{\lambda_{BAND}}\{\Psi_{OPT}(\lambda_{SHT})\}. \tag{17}$$

EXPERIMENTAL RESULTS

The effects in daltonization are compared with the popular blindness simulator Vischeck. Figure 4 **(a)** ~ **(c)** show the results for "*wild strawberry*". **(a)** illustrates how the proposed ***spectral shift algorithm*** moves the lost spectra by $\lambda_{SHT} \approx \lambda_{OPT}$=80nm into the visible range. The shifted spectra automatically match with the overall dichromatic spectral sensitivity ***r*** (λ). Though Vischeck in **(b)** improved the ***red*** fruits viewed as ***mazenta*** for normals and ***cyan*** for deutans, but still confused with leaves. While the proposed model in **(c)** daltonized the ***red*** fruits viewed as ***orange*** both for normals and deutans clearly distinguished from the leaves. **(d)-(e)** and **(f)-(g)** are the results for "*Ishihara chart*" and "*Subway map*" better than Vischeck.

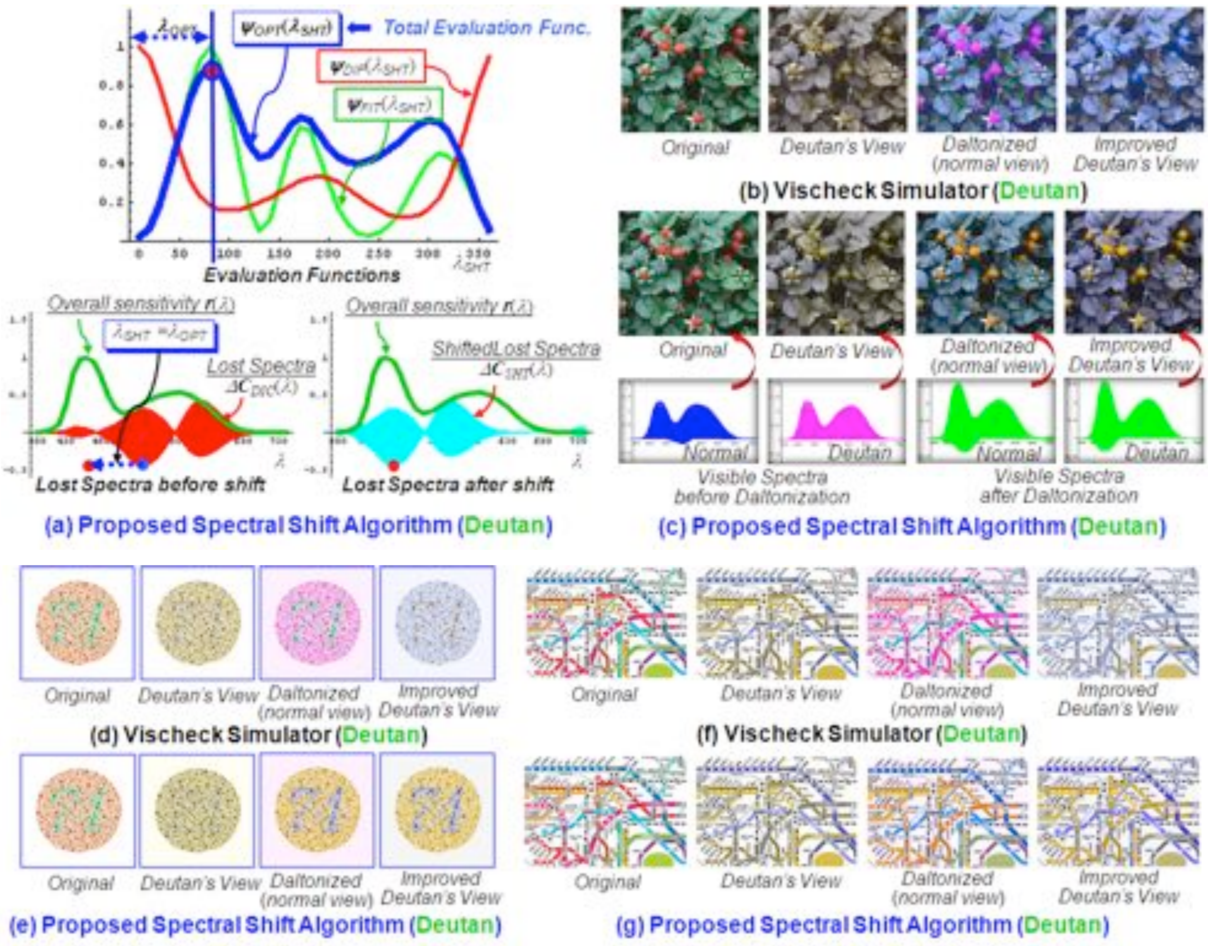

Figure 4. Daltonization results for deutan in comparisons with Vischeck simulator

CONCLUSIONS

The proposed model with different concept from Brettel's advanced its performances on

[1] Capturing the fundamental spectra from sRGB images without spectral camera.
[2] Image daltonization by spectral shift using the lost spectra revived again.
[3] Optimal spectral shift algorithm to cope with both dichromats and normals.

REFERENCES

H. Brettel et al. 1997. Computerized simulation …. for dichromats, *JOSA*, 14, 10: 2641-265
P. Capilla et al. 2004. Corresponding-pair procedure ..…, *JOSA*. A, 21,2: 176-186
C. E. R. Pardo and G. Sharma. 2011. Dichromatic color percept….*Proc. IEEE IVMSP*, 12-17
H. Kotera. 2011. A Study on Spectral Response for Dichromatic Vision, *Proc.CIC19*: 8-13
J. B. Cohen. 2001. *Visual Color and Color Mixture*. Illinois Press
H. Kotera et al. 1996. Recovery of Fundamental Spectrum from Color... *Proc. CIC4*: 141-144
F. Ebner and M. D. Fairchild. 1998. Development …a Color Space (IPT).... *Proc. CIC6*: 8-13

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Early fungus infection detection in lemon fruits by means of spectral and colour analysis.

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ABSTRACT

Citrus are one of the major plants cultivated in the world. Current commercial systems classify the fruit based on quality parameters. Fungi of the genera Penicillium are responsible for substantial losses in citrus fruit during post harvest processes. It is imperative to detect the problem as early as possible, before it becomes visible, to allow the producer to take the corrective actions. Measurements of spectral reflectance and colour characteristics of healthy and inoculated lemons were taken with a PR715 Photo Research spectroradiometer in four experiments with controlled conditions. From the results, a wavelength (676 nm), and particularly its temporal variation were identified as carriers of useful information about the infection process. The increased gradient of the spectral reflectance value at 676 nm compared with the gradient corresponding to the healthy portion of the fruit could be an indicator of the presence of the infection. Other analyses were done taking into account the colour measurements. Results obtained suggest that consideration and analysis of "colour-change speed" (i.e. the colour displacement within a suitable colour space divided by the time it takes), seems to be a very efficient tool to diagnose the infection before it becomes visible.

1.- INTRODUCTION

Citrus are one of the major plants cultivated in the world. They are grown in more than 100 countries including the main producers such as China, Brazil, the USA, Spain, Mexico, Italy and Argentina. With respect to lemon, Argentina is the first producer (approx. 1.4 Mt). This number shows the economic importance of this activity (Sighicelli et al. 2003). Current commercial systems classify the fruit based on quality parameters. The main characteristic to attribute the quality of fresh fruits is the appearance, characterized by combination of size, shape, colour and absence of defects. The defects could be caused by biological, physiological or environmental factors in addition to mechanical damage. These defects could be originated in the cultivar or in the post harvest management. Among the later, fungi of the genera Penicillium are responsible for substantial losses in citrus fruit during post harvest processes. Due to citrus fruit infected with that fungus are not marketable, it is imperative to detect the problem as early as possible, before it becomes visible, to allow the producer to take the corrective actions. As was stated by Merzlyak et al. (1999) plant tissues undergo sometimes remarkable changes in spectral reflectance and colour as well, as a result of changes in the content and proportion of individual pigments. This fact makes reflectance spectroscopy a suitable technique for the assessment and monitoring of the physiological state of plants. Merzlyak examined changes in reflectance of plants related to mechanisms responsible for the senescence of their tissues, identifying some specially significant bands and wavelengths, like 500 nm and 670-680 nm and their relationships with respect to senescence and ripening. This suggests to carefully examining the spectral response of the fruit searching for clues that indicate the presence of fungus infection. (Merzlyak et al. 1999, Sandoval et al. 2010)

2.- OBJECTIVES

The importance of spectroscopy in plant and post harvest monitoring becomes evident from the recent increase in research projects and publications dealing with the identification and measure of various quality attributes of fruit and vegetables (Nicolaï et al. 2007, Liew et al. 2008). In that context, the objectives of this research were (1) to acquire spectral reflectance of fungus attacked citrus peel conditions, (2) to identify the significant wavelengths that have the maximum discriminatory capability, and (3) to derive a methodology using these wavelengths that could allow the early detection of the infection. Besides, an approach based on colour description as an early detection methodology was tested.

3.- MATERIALS AND METHODS

In order to reach those objectives we analyse the process by means of spectral reflectance techniques, to detect the infection between 24 and 48 hours after the inoculation (Blasco et al. 2009). For this purpose, four sets of 10 lemons each, without visible skin defects were collected at random from a packing line. Five of them act as a control (healthy) group and the rest was inoculated with (*Penicillium digitatum*) by means of a standardized procedure. Figure 1 shows details of the situation.

Figure 1: left) healthy lemon sample; middle) infected sample after 72 hours from inoculation when rottenness is already clearly visible; right) zone of measurement.

Measurements of spectral reflectance and colour characteristics of healthy and inoculated lemons were taken with a PR715 Photo Research spectroradiometer, in the range of 380-1050 nm under diffuse lighting conditions, in four experiments with controlled conditions. In all the four series measurements were taken periodically on the inoculation point and on the opposite side of the fruit with intervals of 12 hours, over samples with different size and ripening.

4.- RESULTS

Figure 1 shows an example of the results obtained for the spectral reflectance of a measuring spot (1 cm diameter around the inoculation point). From the results, a wavelength (676 nm) was identified as a carrier of useful information about the infection process, particularly the temporal variation of the spectral reflectance at 676 nm. Values of reflectance at 676 nm from averaged curves corresponding to all inoculated samples (upper curve) and to healthy (control) samples plus healthy side of the inoculated samples are plotted in Figure 3.

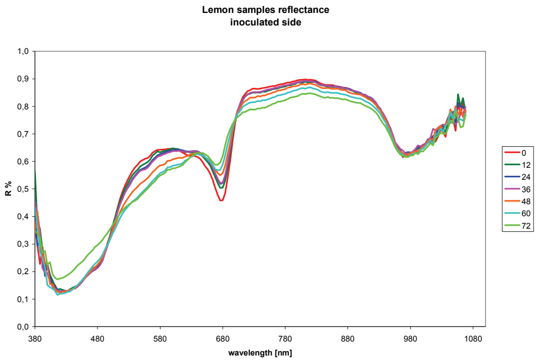

Figure 2: Temporary evolution of the spectral reflectance of the zone of measurement around the inoculation point.

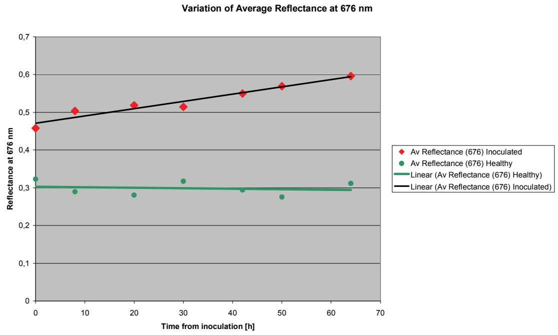

Figure 3: Values of reflectance at 676 nm for inoculated samples (upper curve) and healthy samples (lower curve) as function of time from inoculation

The increased gradient of the spectral reflectance value at 676 nm compared with the gradient corresponding to the healthy portion of the fruit seems to be an indicator of the presence of the infection. Measuring the spectral reflectance of samples at regular time intervals, extracting from them the reflectance value at 676 nm and calculating the gradient for reflectance change arise as a useful tool for early detection of infection by *Penicillium digitatum* in a packing line or storage stage of the fruit process.

Table 1: Colour points (u', v') for Sample set 3, measurements of inoculated and healthy side at different times.

S3-inoc.	u'	v'	S3-healthy	u'	v'
0	0,2699	0,5511	**0**	0,2855	0,5469
12	0,2702	0,5510	**12**	0,2911	0,5459
24	0,2721	0,5507	**24**	0,2950	0,5454
36	0,2708	0,5509	**36**	0,2930	0,5457
48	0,2728	0,5506	**48**	0,2983	0,5442
60	0,2718	0,5510	**60**	0,2990	0,5436
72	0,2759	0,5503	**72**	0,2933	0,5403

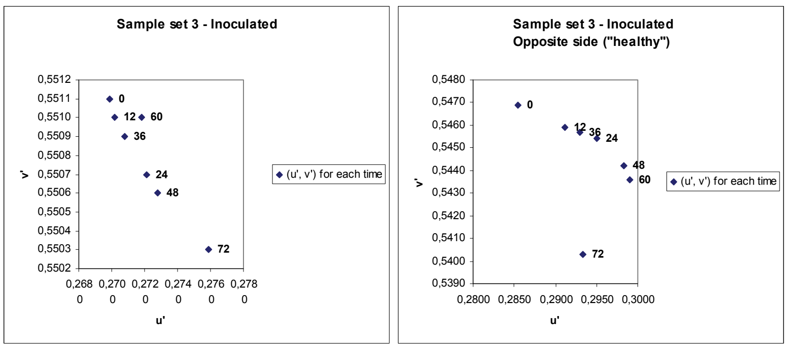

Figure 4: Points (u', v') averaged over sample set 3 as function of time from inoculation.

A different approach in analyzing reflectance characteristics employs a colour description system that models colour perception over the visible range. Since many plant stress factors impact on leaf biochemistry and morphology and consequently on reflectance spectral characteristics in the visible range, it follows that these changes can be related to leaf/fruit colour (Liew et al. 2008). Similar analyses were then done, taking into account the colour measurements. Results obtained suggest that consideration and analysis of "colour-change speed" (i.e. the colour displacement within a suitable colour space divided by the time it takes) seems to be a very efficient tool to diagnose the infection before it becomes visible. From the measurements, the colour points (u', v') corresponding to inoculated and healthy samples were determined and plotted in a u', v' space, as shows Figure 4. As an example, we calculate the distance between points corresponding to 0 hours (inoculation time) and 36 hours after, for "inoculated" and "healthy" side of the samples by: $\mathbf{D_{36} = \sqrt{(u'_0 - u'_{36})^2 + (v'_0 - v'_{36})^2}}$, resulting $D_{36\text{-healthy}} \cong 0.0076$ and $D_{36\text{-inoculated}} \cong 0.0009$. Then, we define a Colour Speed value (distance the colour point (u', v') shifts from 0 to 36 hours divided by 36 hours) as: $\mathbf{CS_{36} = D_{36} / 36}$ (or 24, 48 or the time interval more suitable for the situation we deal with). In our case, we choose 36 hours because this time interval appears to be enough to take preventive and corrective actions before the infection becomes visible, avoiding major damage. Calculating CS_{36} we obtain 0.000210 unit/h for healthy and 0.000025 unit/h for inoculated case. These results suggest that the presence of fungus infection slows down the colour speed of the lemon with respect to natural ripening process.

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5.- CONCLUSIONS

The determination at regular time intervals of reflectance values at 676 nm and calculus of the gradient for reflectance change compared with the gradient corresponding to natural ripening process arise as a very useful tool for early detection of infection by *Penicillium digitatum* in a packing line or storage stage of the fruit process. Besides, taking into account the colour measurements and applying a very simple analysis of what we name "colour-change speed" (i.e. the colour displacement within a suitable colour space divided by the time it takes), seems to be also a very efficient tool to diagnose the infection before it becomes visible. Although much work has to be put on it and refinement has to be done, this approach appears as a very promising way, which allows producers to take preventive and corrective actions in the lemon process, before the infection becomes visible, avoiding major damage over the whole lemon production.

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REFERENCES

Blasco J., N. Aleixos, J. Gómez-Sanchís and E. Molto, "Recognition and classification of external skin damage in citrus fruits using multispectral data and morphological features", Biosystems Engineering 103, 2009.

Liew O.W, P. C. J. Chong, B. Li and A. K. Asundi, "Signature Optical Cues: Emerging Technologies for Monitoring Plant Health", Sensors 8, 2008.

Merzlyak M. N., A. A. Gitelson, O. B. Chivkunova and V. Y. Rakitin, "Non-destructive optical detection of pigment changes during leaf senescence and fruit ripening", Physiologia Plantarum 106: 135-141, 1999.

Nicolaï B. M., K. Beullens, E. Bobelyn, A. Peirs, W. Saeys, K. I. Theron and J. Lammertyn, "Nondestructive measurement of fruit and vegetable quality by means of NIR spectroscopy: A review", Postharvest Biology and Technology 46, 2007.

Sandoval J. D., S. R. Gor, J. Ramallo, A. Sfer, E. Colombo, M. Vilaseca, and J. Pujol, "Spectral signatures: A way to identify species and conditions of vegetables", In Proceedings AIC 2010 "Color and Food", J. L. Caivano and M. A. López Edts., Mar del Plata, 2010.

Sighicelli M., S. Patsayeva and A. Lai, "Characterization of citrus fruit quality using reflectance spectroscopy", 2003.

Intelligent spectral design for 3G and 4G light sources

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ABSTRACT

We optimize mixtures of narrow spectral bands to produce prospective white-light spectra having optimal combinations of high radiant luminous efficacy and high colour rendering performance. The narrow spectral bands are obtained from two sources: either published spectra for commercially-available LEDs, or mathematically synthesised spectra of similar bandwidths to current LEDs. The optimization process employs a type of genetic algorithm known as differential evolution, which aims to maximise the value of a fitness function. We implemented two forms of fitness function: one based on the CIE colour rendering index, and the second on the NIST colour quality scale. Our results are intended to assist light-source manufacturers in the design of high-performance lighting. These developments are likely to have an impact in illumination engineering generally, but specifically in areas requiring highly efficient lighting with minimal associated radiant energy, such as the lighting of artworks for conservation.

1. INTRODUCTION

The energy-saving light sources of the first two decades of the 21st century (CFLs, LEDs, *etc.*) may be thought of as 3G light sources, while 4G light sources are those that are still beyond our current technological horizon, with spectra represented here by mathematical functions.

While energy saving is an important property of all such light sources, there are also instances when superior colour rendering performance is a prime requirement (*e.g.* lighting for merchandising, lighting of artworks, lighting for colour processes, *etc.*). The aim of our work has been the creation of computational tools for the optimum design of the spectrum for such a light source, to achieve an effective combination of both colour rendering and energy efficiency.

Our approach excludes the physical processes that are needed for the conversion of input energy (most often electrical) into radiant energy. Our focus is rather on the distribution of energy within the radiant spectrum since this determines both the luminous efficacy of the radiation and its colour rendering properties.

The optimization tool is an implementation of the population-based differential evolution (DE) algorithm where a population of possible solutions is evaluated using a fitness function, and only those solutions having better scores are further optimised and others are discarded from the optimization. The optimum solution is determined after having performed G generations (or, cycles) of the evaluations and optimizations.

2. COLOUR RENDERING INDEX

Colour rendering is the characteristic of light sources that describes the effect of a light source on the colour appearance of an object. The CIE[1] colour rendering index (CRI) is a single number based on the calculation of the average colour shift in a specified set of test colours as recommended in CIE (1995).

[1] Commission Internationale de l'Eclairage

This method utilizes eight standard test colour samples of moderate chroma and medium lightness, and calculates their colour change under the test source as compared with their colours under a reference spectrum of the same correlated colour temperature (CCT). These eight colour shifts are used in the calculation of the 'special' (individual) colour rendering indices, R_i, for each sample plus the general colour rendering index, R_a , obtained from an average of the eight R_i values.

The descriptive power of the CRI system was improved by including six new samples representing saturated red, yellow, green and blue, plus light human complexion and leaf green. We developed an additional index, termed R_b, based on the R_i values for the additional six colour samples; and a further index, R_c, using the R_i terms for all fourteen samples. Finally, we chose also to quote R_{min}, the R_i index of the test colour yielding the worst colour-rendering performance. Quantities R_a, R_b, R_c and R_{min} are used as elements in our first fitness function used for the grading of candidate solutions in our search algorithm (Section 5).

3. COLOUR QUALITY SCALE (CQS)

An alternative to the CIE system has been developed and published by Davis and Ohno (2010) of NIST[2]. Their method also derives a single-number index based on the colour shift method, and compares fifteen *saturated* test colour samples when illuminated with the test source and its matching reference illuminant. The individual colour differences for the samples are combined using a root mean square calculation. A correlated colour temperature factor is included in the calculation to reduce the value of the index for test light sources having CCT < 3200K. The final result is termed the general CQS (symbol: Q_a).

The special CQS (Q_i) for each colour test sample may be calculated for a more thorough colour-rendering investigation of a test source. We use the minimum value of Q_i (designated Q_{min}) from the set of fifteen Q_i values, as an optimization parameter. Quantities Q_a and Q_{min} are used as elements in the fitness function for the second of our search algorithms (Section 5).

4. RADIANT LUMINOUS EFFICACY

We rate the performance of the test sources in terms of radiant luminous efficacy[3], η_{rad} (lm/W), which compares the source's emitted luminous flux and radiant flux, evaluated in accordance with current definitions:

$$\eta_{rad} = \frac{683\int_\lambda V(\lambda)S(\lambda)d\lambda}{\int_\lambda S(\lambda)d\lambda}, \qquad (1)$$

where $S(\lambda)$ is the spectral radiant flux of the light source and $V(\lambda)$ is the CIE spectral sensitivity function for photopic vision. The radiant luminous efficacy of the light sources is an important feature and we use η_{rad} as a term in the fitness functions in both our search algorithms.

A high value of η_{rad} is particularly important in terms of energy conservation, and is especially important in specific applications (*e.g.* lighting for conservation in museums and art galleries) where it ensures the lowest possible radiation exposure for a given light level. We believe that our optimization technique assists in achieving these objectives.

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[2] National Institute of Standards and Technology (USA)

[3] Also known as Luminous Efficacy of Radiation, or LER

5. DIFFERENTIAL EVOLUTION (DE)

Mixtures of multiple narrow spectral bands were optimized using a differential evolution (DE) algorithm (Storn and Price 1997). Differential evolution is a population-based evolutionary algorithm where a population of possible solutions is evaluated using a fitness function, and only those solutions having better scores are further optimised and others are discarded from the optimization. Our two alternative fitness functions are given in equations (2) and (3):

$$f_{fit(CRI)} = aR_a + bR_b + cR_c + d\eta_{rad} + eR_{min} \tag{2}$$

$$f_{fit(CQS)} = aQ_a + b\eta_{rad} + cQ_{min} \tag{3}$$

where *a, b, c, d, e* are user-selected weighting factors. After G cycles of evaluations and optimizations have been performed, the optimum solution is determined. A solution is the spectrum of the light produced by a mixture of narrow bands, and only those spectra having better colour-rendering characteristics and higher radiant luminous efficacy are kept for further optimization. The best solution in cycle G is accepted as the best white-light spectrum. The details of this process are explained elsewhere (Soltic and Chalmers 2012).

6. EXAMPLES OF RESULTS

We have used these methods to produce optimized spectra for LED mixtures (3^{rd} generation sources) and mixtures of mathematically-created spectra as examples of possible future (4^{th} generation) white light sources. Figures 1–4 show the spectra achieved, together with data on their colour rendering and luminous efficacy properties.

Our LED optimizations were based on the published spectra for a family of commercially available coloured LEDs. Their colour names (and peak wavelengths) were: Royal-blue (450 nm), Blue (460 nm), Cyan (505 nm), Green (525 nm), Amber (590 nm), Red-orange (630 nm), and Red (640 nm).

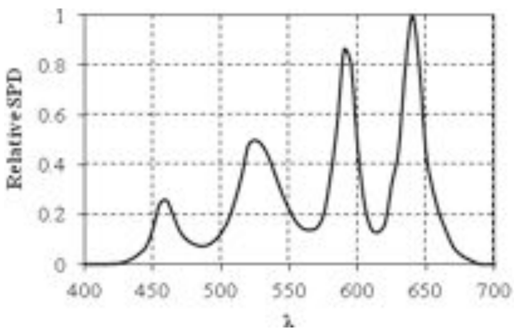

Figure 1: Relative SPD of the 4-band LED mixture (blue-green-amber-red mixture).
CCT = 3268K, η_{rad} = 339 lm/W.
R_a = 95, R_b = 86, R_{min} = 76.

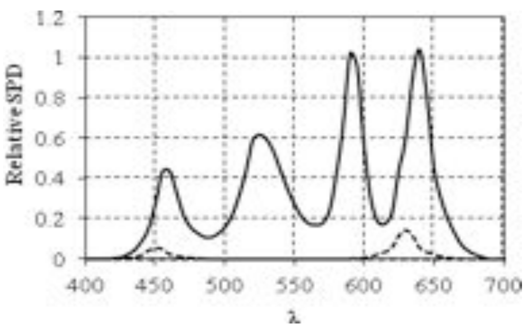

Figure 2: 4-band source (as in Figure 1) with the addition of royal-blue and red-orange (contributions shown with dashed lines).
CCT = 3356K, η_{rad} = 338 lm/W.
R_a = 96, R_b = 86, R_{min} = 75

Figures 1 and 2 illustrate an investigation of the perceived benefits of increasing the numbers of LEDs in the mixture. A comparison of the results shows that, in this instance at least, there was a small change in CCT but no improvement in performance.

Figure 3 (Soltic and Chalmers 2012) shows two LED optimizations with effectively the same colour appearance ($CCT \approx$ 5050K) – one based on CRI optimization, and the second on CQS. In this case, the CRI optimization led to higher colour rendering performance in both domains, whereas the CQS optimization yielded the higher η_{rad} value. It should be noted that these findings were specific to this pair of experiments, and cannot be generalized.

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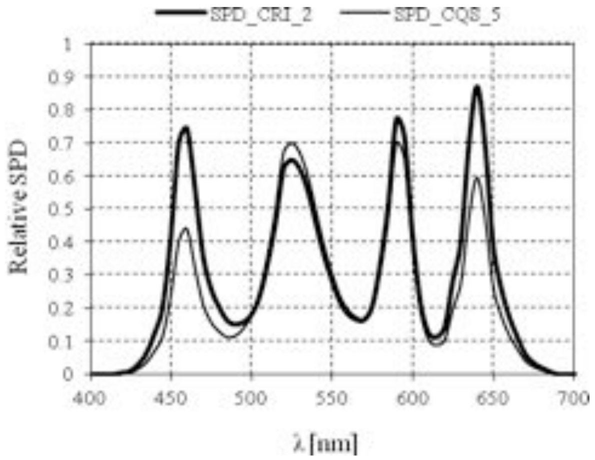

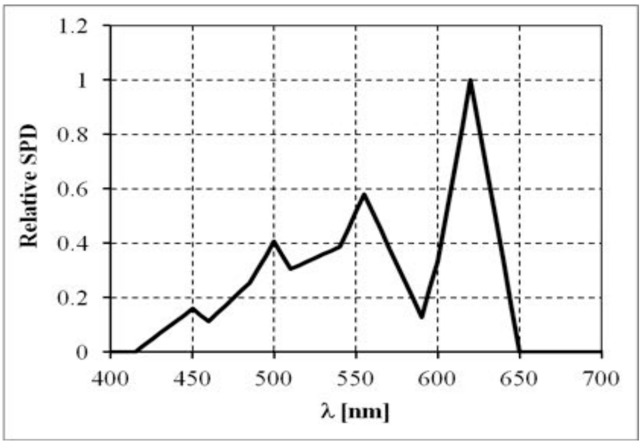

Figure 3: Comparison of two optimizations for equal colour temperature.
Heavy line: CRI optimization:
CCT = 5063K, η_{rad} = 315 lm/W.
R_a = 96, R_b = 88, R_{min} = 67, Q_a = 94, Q_{min} = 89
Thin line: CQS optimization:
CCT = 5041K, η_{rad} = 367 lm/W.
R_a = 83, R_b = 63, R_{min} = 8, Q_a = 84, Q_{min} = 75

Figure 4: Optimum SPD using 4-band synthesised triangular components (CRI optimization).
CCT = 3619K, η_{rad} = 371 lm/W.
$\boldsymbol{R_a}$ = 93, $\boldsymbol{R_b}$ = 90, $\boldsymbol{R_{min}}$ = 86, $\boldsymbol{Q_a}$ = 83, $\boldsymbol{Q_{min}}$ = 71

Figure 4 is an example of a set of CRI-based optimizations (Chalmers and Soltic 2012) using mathematically-generated functions to represent possible future (4G) light-source spectra. This instance provided both high $\square_{rad}$ and good colour rendering in both CRI and CQS domains.

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REFERENCES

CIE (Commission Internationale de l'Eclairage). 1995. Method of measuring and specifying colour rendering properties of light sources, CIE Publication 13.3, CIE, Vienna.

Davis, W. and Y. Ohno. 2010. Color quality scale, *Optical Engineering*, 49 (3), 033602.

Storn, R. and K. Price. 1997. Differential evolution – a simple and efficient heuristic for global optimization over continuous space, *Journal of Global Optimization*, 11, 341–359.

Soltic, S. and A.N. Chalmers. 2012. Differential evolution for the optimisation of multi-band white LED light sources, *Lighting Research & Technology*, 44 (2), 224–237.

Chalmers, A.N. and S. Soltic. 2012. Light source optimization, *Optical Engineering*, 51 (4), 044003.

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The Modified Uniform Oil Colour Scale (MUOCS)

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ABSTRACT

The Modified Uniform Oil Colour Scale (MUOCS) is a simplified method for colour specification of virgin olive oils based on a set of 60 points (MUOCS standards) sampling the colour gamut provided by 1700 virgin-olive-oil samples produced in Spain. The MUOCS assumes virgin-olive-oil samples measured by transmittance in 5-mm pathlength cells, D65 illuminant, and CIE 1964 standard colorimetric observer. Final MUOCS specification is a 3-numbers (Lightness-Green-Yellow) code computed from the lowest DIN99d colour-difference between the oil sample and each one of the 60 MUOCS standards. The MUOCS strongly improves the Bromthymol Blue (BTB) method currently recommended for colour specification of virgin olive oils. Specifically, for the 1700 virgin-olive-oil samples the average colour differences to the closest MUOCS and BTB standards were 2.86 and 8.17 CIELAB units, respectively. We have designed a low-cost (<60 Euros) portable electronic device providing colour specifications of a virgin-olive-oil sample in the MUOCS and BTB scales, with acceptable accuracy, avoiding the use of expensive colorimetric instrumentation. We have developed linear regression models approaching each one of the 3-numbers code in MUOCS specification from the CIELAB colour coordinates of the virgin-olive-oil sample, trying to avoid the use of the advanced DIN99d colour-difference formula.

1. INTRODUCTION

Virgin olive oils from Spain are generally recognized as very high quality foods with interesting beneficial health properties. Spain is the world's leading producer of virgin olive oils with a total production of 39.3% in the period 2005-2010 (International Olive Council, 2011). Production of best virgin olive oils is important for Spanish economy, and requires improved quality control. Appropriate virgin-olive-oil colour specification methods are part of this quality control. This paper reports on some recent advances in colour specification of virgin olive oils (Gómez-Robledo, 2011; Salmerón et al., 2012).

Colour specification of virgin olive oils using a specific colour scale was first proposed in 1986 (Gutiérrez and Gutiérrez, 1986) and latter standardized in 1997 (AENOR, 1997). This method is called Bromthymol Blue (BTB), and proposes a visual comparison between the colour of a virgin-olive-oil sample and a set of 60 fixed colours (BTB standards) placed in a two-dimensional scale, looking for the standard with the closest colour to the sample. The BTB scale has been connected with the internationally-recommended colour specification in CIELAB space (Moyano et al., 1999). Different flaws of the BTB method have been reported (Melgosa et al., 2000; Melgosa et al., 2001), in addition to the undesirable subjectivity inherent to any visual colour-matching method, which led to the proposal of the Uniform Oil Colour Scale (UOCS) (Melgosa et al., 2004). The UOCS is a set of 60 theoretical standard colours (the same number of standards than in the BTB scale) placed on a rhombohedral lattice like the one employed by the Uniform Colour Scales of the Optical Society of America (MacAdam, 1974) in the DIN99d (Cui et al., 2002) approximately uniform colour space.

This paper proposes the Modified Uniform Oil Colour Scale (MUOCS), a new set of 60 standard colours providing relevant improvements with respect to BTB and UOCS standards. In connection with the practical use of the MUOCS, we also propose: 1) A low-cost portable electronic device providing the MUOCS and BTB codes of a virgin-olive-oil sample; 2) Linear regression models providing a transformation from CIELAB coordinates to MUOCS code.

2. RESULTS

2.1 Development of the Modified Uniform Oil Colour Scale (MUOCS)

Like the UOCS (Melgosa et al., 2004), the MUOCS is an objective (non-visual) method for colour specification of virgin olive oils, which is based on a set of 60 standard colours obtained from a wide dataset of 1700 colours from virgin-olive-oil samples produced in Spain (Moyano, 2002), using a rhombohedral geometry (MacAdam, 1974) in the DIN99d (Cui et al, 2002) colour space. The proposal of MUCOS is based on two flaws detected at the development of UOCS: 1) Direct experimental measurements at 5-mm pathlength were converted to 10-mm pathlength assuming the Bouguer-Lambert-Beer law, which is not accurate in this particular case (Gómez-Robledo et al., 2008); 2) The UOCS lattice was developed by layers and subsequent removal of marginal samples by inspection, which introduced some undesirable discontinuities in the final lattice (Salmerón et al., 2012). From transmittance experimental measurements at 5-mm pathlength of 1700 virgin-olive-oil samples (assuming D65 illuminant and CIE 1964 standard colorimetric observer), using a new three dimensional algorithm for the “grow” of the lattice, the 60 MUOCS standards were obtained. Table 1 shows improvements achieved by the MUOCS. Specifically, comparing UOCS and MUOCS we can note that the average CIELAB colour differences and standard deviations are reduced about 25% and 50%, respectively.

2.2 Low-cost electronic device for the MUOCS and BTB colour specification

We designed (Carvajal et al., 2011) a low-cost (<60 Euros) electronic device (Figure 1) allowing fast (<0.25 s) BTB and MUOCS measurements of virgin olive oils by non-technician users. This device operates with USB connection to a computer or AAA batteries, performing transmittance measurements of a sample placed in a 5-mm pathlength quartz cell. The device has a NSPW300

Table 1. Average CIELAB colour difference ΔE^*_{ab} and standard deviations between 1700 virgin-olive-oil samples and the nearest standard colours proposed by BTB, UOCS, and MUOCS.

	ΔE^*_{ab}	**Standard Deviation**
BTB	8.17	6.64
UOCS	3.99	3.05
MUOCS	2.86	1.43

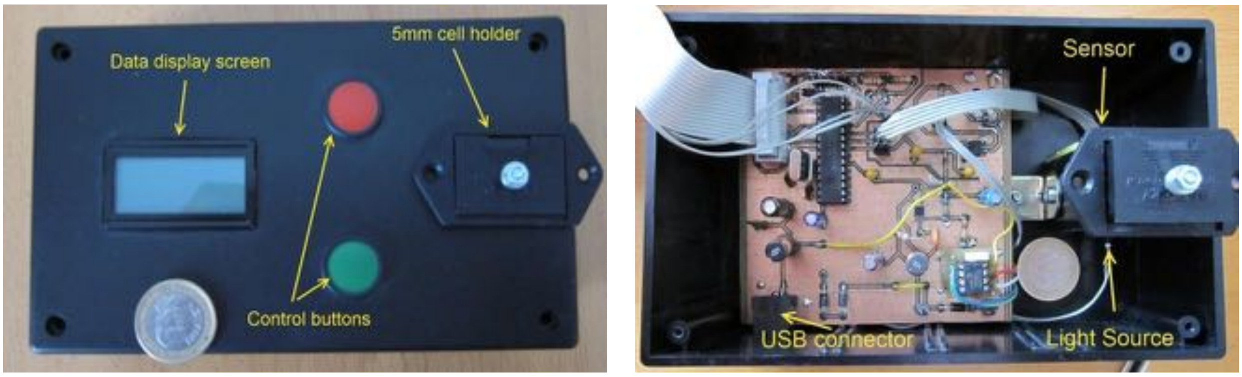

Figure 1. External (left) and internal (right) views of our electronic device allowing BTB and MUOCS measurements of virgin-olive-oil samples. The 1 Euro coins indicate real sizes.

white LED source (Nichia, Japan), an S9704 colour sensor (Hamamatsu, Japan), a PIC18F2550 microcontroller (Microsoft, USA), and a supplementary 25LC1024 EEPROM memory (Micorsoft, USA). A software application in Visual Basic 2008 developed by us takes the whole control of the device. Calibrations of the device were based on experimental measurements of the 60 BTB standard colours, using a JASCO-V650 spectrophotometer as reference instrument. The pseudo-inverse method (Moore, 1920; Penrose, 1955) was used to formulate transformation equations from RGB to XYZ. For a reduced set of 37 commercial virgin-olive-oil samples the MUOCS code provided by this inexpensive device was correct in 92% of the cases. Obviously this device is not a colorimeter; it just provides accurate colour classifications of virgin-olive-oil samples according to the BTB and MUOCS standards.

2.3 Linear models for transformations from CIELAB to MUOCS

The 60 MUOCS standards have specific colour coordinates in the DIN99d colour space (which can be transformed to CIELAB), as well as 3-numbers codes related to their colour attributes of lightness, green and yellow, respectively (Salmerón et al., 2012). Both MUOCS lightness and yellow are always integer numbers in the range 1-14, while MUOCS green is an even integer in the range 2-16. In order to avoid the use of the DIN99d colour space (Cui et al., 2002), we developed three linear regression models based on the 60 MUOCS standards, looking for direct transformation from CIELAB coordinates to the MUOCS 3-numbers code. These models were found statistically significant ($p<0.01$) and are summarized by the next equations:

$$Lightness_{MUOCS} = Round\left(-50.071 + 0.736L^* - 0.001L^{*2}\right)$$

$$Green_{MUOCS} = Round\left(11.570 - 0.131b^* + 0.002b^{*2} - 0.020L^*a^* - 0.002L^*b^* - 6.22\ 10^{-5}L^*a^*b^*\right)$$

$$Yellow_{MUOCS} = Round\left(-1.926 - 0.425a^* + 0.237b^* - 0.001b^{*2} + 0.003L^*a^* + 2.48\ 10^{-5}L^*a^*b^*\right)$$

For a random set of 10000 theoretical samples in the colour gamut of the 1700 virgin-olive-oil samples, assuming a tolerance of ±1 step in each one of the components, these models correctly classified MUOCS Lightness, Green, and Yellow codes in 98.6%, 88.3% and 100% of the cases, respectively. However, although this result may be considered satisfactory, only 72.8% of these 10000 samples have a completely correct 3-numbers MUOCS code, with a tolerance of ±1 step in one of the 3 numbers, which claim for future research to improve current models.

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REFERENCES

AENOR (Asociación Española de Normalización y Certificación). 1997. Índice de Color A.B.T., Norma UNE 55021. Madrid (Spain).

Carvajal, M. A., Huertas, R., Melgosa, M., Palma, A. J., Fernández Salmerón, J., Gómez Robledo, L. 2011. Método y dispositivo para caracterizar y clasificar el color de aceites de oliva. Patent Number 201191400000480 (under evaluation). University of Granada, Spain, March 21 (2011).

Cui, G., Luo, M.R., Rigg, B., Roesler, G., & Witt, K. 2002. Uniform colour spaces based on the DIN99 colour-difference formula. *Color Research and Application* 27: 282-290.

Gómez-Robledo, L., Melgosa, M., Huertas, R., Roa, R., Moyano, M. J., Heredia, F. J. 2008. Virgin-olive-oil color in relation to sample thickness and the measurement method. *Journal of the American Oil Chemists Society* 85: 1063-1071.

Gómez-Robledo, L. 2011. Aportaciones colorimétricas a la caracterización y mejora de aceites de oliva virgen. Ph.D. Dissertation, including a 100 pages extended summary in English language. University of Granada, Spain.

Gutiérrez, R., & Gutiérrez, F. 1986. Método rápido para definir y clasificar el color de los aceites de oliva vírgenes, *Grasas Aceites* 37: 282-284.

International Olive Council. 2011. http://www.internationaloliveoil.org/estaticos/view/131-world-olive-oil-figures?lang=en_US. Accessed: June 27, 2012.

MacAdam, D.L. 1974. Uniform color scales. *Journal of the Optical Society of America* 64: 1691-1702.

Melgosa, M., Pérez, M. M., Hita, E., Moyano, M. J., Alba, J., Heredia, F. J. 2000. Precision and accuracy in the color specification of virgin olive oils from the bromthymol blue method. *Journal of the American Oil Chemists Society* 77: 1093-1099.

Melgosa, M., Pérez, M. M., Hita, E., Heredia, F.J., Alba, J., Moyano, M. J. 2001. Reproducibility of the bromthymol blue standards used for color specification of virgin olive oil. *Journal of the American Oil Chemists Society* 78: 265-270.

Melgosa, M., Huertas, R., Hita, E., Roa, J. M., Heredia, F.J., Alba, J. Moyano M. J. (2004). Proposal of a uniform color scale for virgin olive oils. *Journal of the American Oil Chemists Society* 81: 323-329.

Moore E. H. 1920. On the reciprocal of the general algebraic matrix. *Bulletin of the American Mathematical Society* 26: 394-395.

Moyano, M. J., Melgosa, M., Alba, J., Hita, E., Heredia, F. J. 1999. Reliability of the bromthymol blue method for color in virgin olive oils. *Journal of the American Oil Chemists Society* 76: 687-692.

Moyano, M. J. 2002. Estudio del color de aceites de oliva vírgenes de Andalucía. Ph.D. Dissertation (in Spanish language). Facultad de Farmacia (Universidad de Sevilla), Instituto de la Grasa (Consejo Superior de Investigaciones Científicas), Spain.

Penrose, R. 1955. A generalized inverse for matrices. *Mathematical Proceedings of the Cambridge Philosophical Society* 51.

Salmerón, J. F., Gómez-Robledo, L., Carvajal, M. A., Huertas, R., Moyano, M. J., Gordillo, B., Palma, A. J., Heredia, F. J., Melgosa, M. 2012. Measuring the colour of virgin olive oils in a new colour scale using a low-cost portable electronic device. *Journal of Food Engineering* 111: 247-254.

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Legibility Study of the Layouts and Color Combinations of e-Book Titles

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ABSTRACT

The worldwide fast growing digital industries and networks demand a remarkable increase in the use of digital communication. Preferred choices of digital content and its layout inevitably become the focus of interest of research and industries. In order to find out the impacts of layout formats and color combinations on the legibility of e-book titles, this study investigated arrangements of horizontal and vertical text orientation, fonts, and various color styles of e-book titles and their backgrounds by eye-tracking method. It was explored whether layout formats and color styles of e-book titles have an effect on the physical activities of the eyes: on reading time, fixation duration, saccadic amplitude, and blink frequency. First, a pilot study was conducted to determine the procedure and the stimuli to be employed in the formal experiment. Here it was found that horizontal or vertical directions of the text have no significant effect on text legibility. The final design of the study included (a) the presentation of the title in two types of fonts and (b) thirty sets of color combinations. The experiment was conducted in a controlled laboratory setting: an eye tracker precisely recorded eye fixation and fixation duration. 30 virtual articles with various character-background color combinations chosen from four basic colors (red, blue, green, and yellow) based on the NCS system, and three neutral ones (black, grey, and white).were displayed to the subjects in a randomly determined order. The study involved a five-point Likert Scale survey presenting twenty-four types of layout to 16 art editors and text editing experts to find out two most frequently used layout types. Results showed that color combinations of words and their backgrounds have significant effects on text legibility while font types and text directions have not. More legible color combinations are white text on black background, white on blue, red on grey and green text on white background. Less legible combinations are green text on grey background, grey text on green, blue text on grey and yellow text on white background.

1. INTRODUCTION

People get knowledge by reading, which is a complex mind process involving physical and mental activities. Different types of reading patterns have been documented to explain reading behaviors. The layout, for example, has been found to have an influence on how a text is received and comprehended. The present study investigates the legibility of various layout arrangements of e-book titles: whether they can cause different reading speed, and whether they have an effect on physical activities of the eyes, such as fixation duration, saccadic amplitude, and the number of blinks.

2. METHOD

2.1. Experimental Setup

Reading experiments were conducted in the Center for Color Culture and Informatics, Chinese Culture University, Taipei.

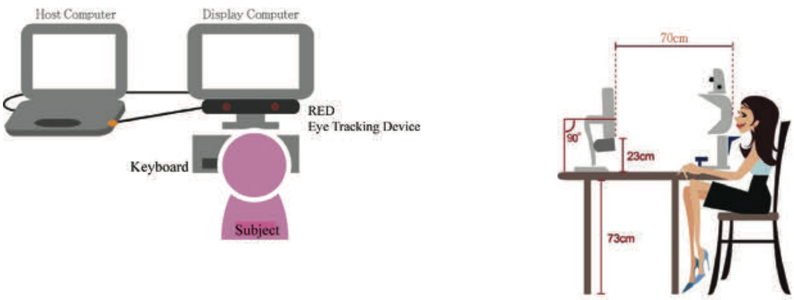

Figure 1. Experimental setup

A video eye tracker (SMI RED) was used to record eye movements during e-book title reading, and the data were converted to scan paths of reading, with information for fixations and saccades. The legibility was defined by the average time measured for reading the title text, eye fixation duration, saccadic amplitude, and the number of blinks recorded by the SMI RED eye tracker. Those recorded data were then used as indexes to evaluate text legibility of e-books.

2.2. Subjects

Forty-nine subjects (23 male and 26 female) participated in the experiments. Each of them was screened for normal color vision with an Ishihara color vision test. In each experimental session, the procedures were first explained to the subject, then the eye tracker calibration was run 30 virtual articles composed of different character-background color combinations were displayed in a randomly determined order. The subject was instructed to "read the title fluently" for each randomly displayed virtual article.

2.3. Stimulus

The reading materials were "virtual articles. Each was composed of a twelve-character title and blurred content texts, arranged to look like an article displayed in an e-book screen. However, the title was meaningless and only a combination of randomly-chosen Chinese characters, and the blurred texts were in fact unreadable. The colors used to present the title characters and background were seven colors selected from the NCS system, including six elementary colors plus grey. In total, 30 character/background color combinations were used in the present study, consisting of 24 chromatic and 6 achromatic combinations. Based on previous pilot studies, sets of clear and bold types of fonts were selected to present the virtual titles in horizontal format. The visual angle of each character was 1.5 degree of arc in a viewing distance of 0.7 M.

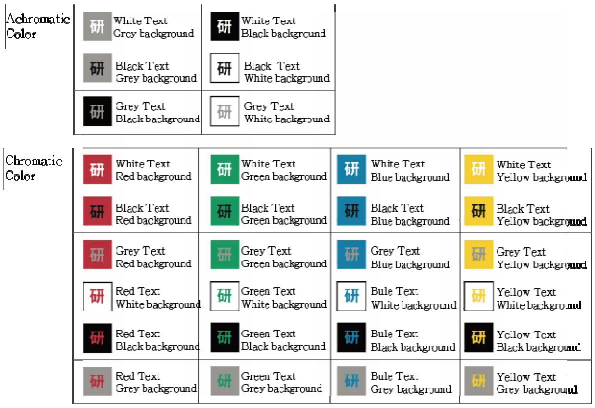

Figure 2: Color combinations used in the present study

Figure 3: Example of the text article

3. RESULTS AND DISCUSSION

Are there certain kinds of text/background color combinations that have significantly higher legibility than others? Generally speaking, we did not find a clear answer in the present study. Important findings revealed by analyzing the experiment data are listed below:

1. Reading time:
   Texts of better legibility should have shorter average reading time. The measured average reading time does not show statistically significant differences among the text/background color combinations tested in the present study. The only significant reading time difference found is the bold vs. clear type characters with white text/black background. (Figures 4 ~6)
2. Fixation duration:
   Texts with shorter averaged fixation duration are assumed to have better legibility. Generally, there are no statistically significant differences found among the text/background color combinations tested in the present study. The only significant fixation duration effect is found among achromatic texts/blue background combinations. White text/blue background titles show better legibility than grey and black texts on blue background.
3. Saccadic amplitude:
   Texts of better legibility are assumed to have larger saccadic amplitude recorded during reading. Generally, there are no statistically significant differences in saccadic amplitude found among the tested samples. The only significant difference is found for achromatic texts on yellow background, where grey texts on yellow combination shows smaller saccadic amplitude, thus less legibility.
4. The number of blinks:
   The number of blinks recorded during reading texts is considered as another legibility index. Better legibility relates to fewer blink numbers. The present study found certain statistically significant results among title text/background combinations. A general tendency is that the text/background color combinations with higher luminous contrast have better legibility suggested by the recorded number of blinks.

The experimental data of the present study cannot suggest a clear profile about what kinds of title text/background color combinations have better legibility than others. A linear regression analysis of the luminous contrast vs. all above indexes shows none or very weak correlations. A possible reason for this might be due to the instruction we used in the experiment. The subjects were asked to read the virtual title “fluently,” which might lead them to read all titles in an approximate speed. If the subjects were instructed to read the title “as fast as possible,” a significant effect of title text/background color combinations may have been observed.

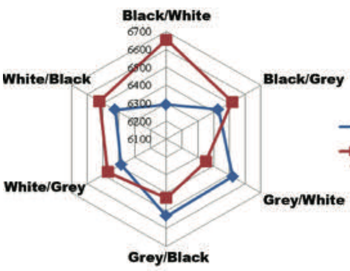

Figure 4

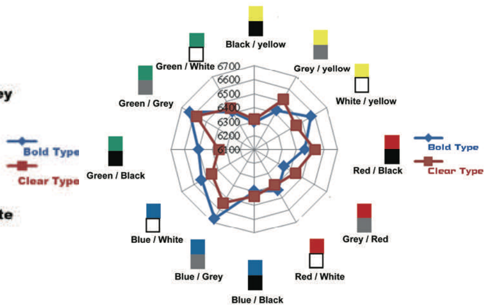

Figure 5

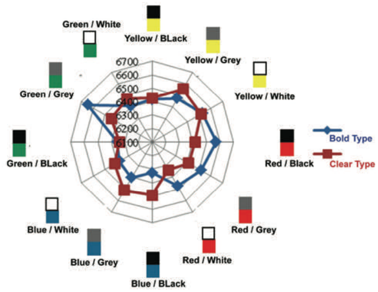

Figure 6

Figure 4. Distribution profile of reading time for achromatic texts on achromatic backgrounds.

Figure 5. Chromatic texts on achromatic backgrounds. Figure 6. Achromatic texts on chromatic backgrounds.

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REFERENCES

Connolly, G. K. (1998). *Legibility and readability of small print: Effects of font, observer age and spatial vision*: University of Calgary.

Henderson, J. M., & Hollingworth, A. (2003). Eye movements and visual memory: Detecting changes to saccade targets in scenes. *Perception & Psychophysics, 65*(1), 58-71.

Pearson, R., & Schaik, P. v. (2003). The effect of spatial layout of and link colour in web pages on performance in a visual search task and an interactive search tas. *International Journal of Human-Computer Studies, 59*(3), 327-353.

Rayner, K., Warren, T., Juhasz, B. J., & Liversedge, S. P. (2004). The Effect of Plausibility on Eye Movements in Reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*(6), 1290-1301.

Shieh, K.-K., Chen, M.-T., & Chuang, J.-H. (1997). Effects of Color Combination and Typography on Identification of Characters Briefly Presented on VDTs. *INTERNATIONALJOURNALOF HUMAN-COMPUTER INTERACTION, 9*(2), 169-181.

Effects of colour and chromatic light on depth perception

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ABSTRACT

The main purpose of this study is to understand the effect of chromaticity combinations on depth perception. A forced choice paired comparison test was used to evaluate distance differences between colour combinations created by chromatic light in the background and coloured objects in front. The experiments indicated perceptual variations in depth assessments between different participants, which needed to be taken into consideration. The findings suggest a significant effect of some colour combinations on depth perception.

1. INTRODUCTION

Understanding the interaction between surface colours and illumination chromaticity enables effective use of space in interior architecture, lighting and stage design. Space perception is the ability to estimate the three-dimensional layout of our environment from arrangement of individual objects, their location and size. In that context, many studies focus on the perception of distance as the central problem of space perception. In this distance estimation, the human visual system uses a number of physical attributes, or cues, from the environment (Sekuler and Blake, 1994, Michel, 1996).

Among the monocular cues, colour is one of the most debated. Starting with the study of Luckiesh (1918) done with an apparatus of red and blue letters that can be moved back and forth, colour has long been studied as an influencing factor for judgment of distance. The effect of brightness and saturation on depth perception, both absolute and with relation to the background has been studied extensively. According to the studies, the objects or the images with higher brightness and/or saturation were perceived closer to the participants (Mount et. al., 1956, Bailey et. al., 2006). Other than that, effect of brightness contrast on judgment of distance was also studied (Ichihara, Kitagawa and Akutsu, 2007, Dresp and Guibal, 2004). These studies include a distance comparison of coloured objects when they were presented in front of coloured backgrounds. In these studies, the coloured patch which resembled the background the most was perceived more distant then the other coloured patches. All the above studies were done with coloured objects or patches under achromatic light. There are only a few studies which explore the chromatic light effect on depth perception. In one of the earlier studies, an experiment was designed with red neon or blue neon and argon lights (Pillsbury and Schaefer, 1937). The results showed blue light was perceived nearer even when it was at a larger distance than red light. However, this study does not give details to understand which attribute of the light or colour affected the perception. Similarly, in a more recent study which used chromatic light and coloured surfaces, the cause of the effect is unclear due to different intensities and different hues used in the experiment (Huang, 2009). The study presented in this paper attempts to bridge this gap by studying the effect of chromatic light and chromaticity combinations on depth perception.

2. THE EXPERIMENT

Twenty one students aged between 22 and 29 years participated in the experiment taking place in a 1/1 interior space. The stimuli consisted of a two part background which was lit with separately controllable wall washers and two objects in front. Six different colours were used for the background: orange, blue, red, green, warm white (3000K) and cool white (6500K). The objects were 45cm x 45cm squares painted in one of the colours orange, blue and gray. The objects were lit with halogen spots (3000K) from the top. The brightness and saturation of the lights and objects were matched with each other as much as possible in order investigate out the hue effect on depth perception.

Each experiment included two sets of colour combinations in which the colour of the objects was equal but the background colours were different. In one of the sets, the background colour was always fixed to cool white light for both sides as a neutral background chromaticity and in the second set a background with two different colours adjacent to each other was presented (Figure 1).

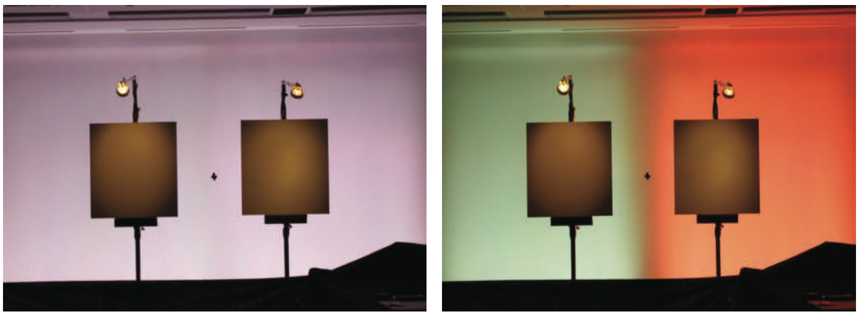

Figure 1. Example stimuli demonstrating background chromaticity variations. Left: baseline stimulus, right: colour combination stimulus.

Five of the background colours were paired with cool white light for the second set of combination in each session. Additional to this five colour pairs, the pairs of red-green background and orange-blue background were also presented as they had been found useful on exploring the chromaticity effect on depth perception in the pilot study. For the blue and orange objects, the identical background colour was not displayed. There were 17 object and background colour combinations in total. The right object of the apparatus was fixed and the left one was moved to seven positions determined previously. These seven points were 10cm, 20cm and 30cm in the front and back of the right object and both objects being in the same distance. Each point was presented 10 times randomly during the experiment, resulting with 70 points for each background. To minimize measurement error, a forced choice paired comparison was used. The participants were asked which one of the objects appeared closer to them, left or right one. They judged the stimuli using monocular viewing at a distance of 10 meters using their dominant eye.

3. RESULTS AND DISCUSSION

The responses of the repeated measurements were aggregated per participant to compute an estimate of the probability of an object being observed in front of another object, given their colour, the background colours and the relative distance between the objects. Based on the computed probabilities, a psychometric curve was fitted. To compute the distance at which the objects were perceived equidistant the 50% points on the psychometric curves were used. The standard error of the result was estimated using a parametric bootstrap procedure.

Results showed a surprising, but consistent inter-observer variance in depth perception in the right and left visual field. A repeatable, participant dependent offset of up to 25cm for two neutral chromaticity objects on a neutral background was demonstrated. For some observers, the object in the right visual field appeared closer, and for some in the left. To correct for this effect, the baseline difference was subtracted from all the colour combination results. After correcting for the baseline differences, the corrected distance was used as a dependent variable in an ANOVA procedure. The background colours and the colour of the objects were used as independent variables. A significant effect of both colour and colour combination on depth perception was found, $F(2,34) = 13.83$, $p < 0.001$. Hochberg's GT2 test revealed that there were different depth perceptions occurring between orange and the other two object colours (blue and gray). Cooler objects were generally found to be perceived as further away than warmer ones, as were the achromatic objects.

When the colour combinations were analysed the effect was mostly increased by increasing the chromaticity difference with the background. As expected there were no significant effects of colour temperature when warm white and cool white background pair was displayed with gray objects. The orange object had a tendency to be perceived nearer in front of cool white background and the blue object had a tendency to be perceived nearer in front of warm white background (Figure 2). The horizontal axis in the figure represents the displacement of the left object. A negative value denotes a situation where the left object is closer to the observer.

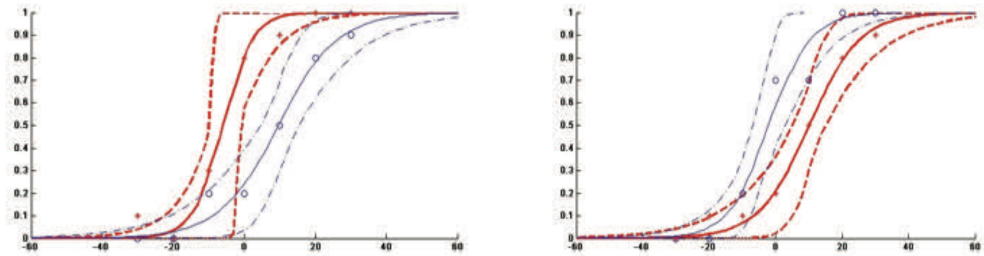

Figure 2. Example psychometric curves for a warm white-cool white background pair. The blue line represents the baseline results. Left: orange objects, -15 cm, right: blue object, 12cm

The largest distance difference was obtained with a blue object and cool white-red background combination and similarly, with an orange object and cool white-blue background combination. Additionally, opponent colours showed similar results. Cool white-red and cool white-green background pairs showed similar amount of difference in the same direction when displayed with gray objects. The same holds for the cool white-orange and cool white-blue background pairs. No difference was perceived with red-green background pair (see Table 1).

Table 1. Summary of the results. The side on which the object appears nearer is given. Pairs that were not measured are denoted by N/A

Background Pair	Orange Object	Blue Object	Gray Object
Cool white-blue	Cool white	N/A	Blue
Cool white-green	no sig. difference	no sig. difference	Green
Cool white-red	Red	Red	Red
Cool white-orange	N/A	no sig. difference	Orange
Warm white-cool white	Warm white	Cool white	no sig. difference
Red-green	Red	Green	Green
Orange-blue	N/A	N/A	Blue

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The effect of the hue on perception of depth was smaller than the inter-observer variance in the baseline, which shows a limited utility for chromaticity as a tool for depth perception manipulation. However, given the effect of chromaticity on atmosphere perception in a space, the results also show that using the lighting chromaticity, the atmosphere in an environment can be manipulated without strongly influencing space perception. Even more, the methodology developed can be used in future psychophysical studies that expect a large baseline variation between observers.

REFERENCES

Bailey, R., Grimm, C. & Davoli, C. (2006). The real effect of warm-cool colors. *International Conference on Computer Graphics and Interactive Techniques*. Boston: Massachusetts.

Dresp, B. & Guibal, C. R. (2004). Interaction of color and geometric cues in depth perception: When does "red" mean "near"? *Psychological Research, 69*, 30-40.

Huang, K. C. (2009). Effects of colored lights, spacing between stimuli, and viewing distance on error in a depth- matching task. *Perceptual and Motor Skills, 108*, 636-642.

Ichihara, S., Kitagawa, N. & Akutsu, H. (2007). Contrast and depth perception: Effects of texture contrast and area contrast. *Perception, 36*, 686-695.

Luckiesh, M. (1918). On "retiring" and "advancing" colors. *American Journal of Psychology,29*.

Michel, L. (1996). *Light: The Shape of Space- Designing with Space and Light*. New York: Van Nostrand Reinhold.

Mount, G. E., Case, H. W., Sanderson, J. W. & Brenner, R. (1956). Distance judgment of colored objects. *The Journal of General Psychology, 55*, 207-214.

Pillsbury, W. B. & Schaefer, B.R. (1937). A note on advancing-retreating colors. *American Journal of Psychology, 49*, 126-130.

Sekuler, R. & Blake, R. (1994). *Perception* (3rd edition). New York: Mc Graw- Hill.

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oral paper

Color matching for color constancy and inconstancy in the transition between foveal vision and extra-macular vision

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ABSTRACT

Color constancy holds true in the passage from foveal to extra macular vision for a very large set of lights. The violation of such a color constancy phenomenon depends on the light spectra and has been shown by color-matching measurements. The minimal bandwidth of the spectral lights entering the mixture satisfying the color constancy has been defined empirically. Color constancy holds true for narrow bandwidths, below 15nm, only for wavelengths longer than 520 nm and around 475 nm. The choice of the considered wide band primary lights in color matching has little influence on color constancy.

1. INTRODUCTION

The daily experience of color vision leads us to ignore the filtering due to the macula lutea and to consider the foveal and the extra-macular visions as equal. Only rarely are the colors in foveal vision different from those seen in extra-macular vision and this happens in the presence of narrow-band spectral lights. This phenomenon is possible in color matching with a 2 degree bipartite field, where, after obtaining a match for foveal vision, the observer moves the attention point and the bipartite field is seen by the extra-macular retina.
Since the main difference between the two kinds of vision is produced by the filtering of the macula lutea, the equality of the colors perceived in these two visual situations is considered as a color-constancy phenomenon and the difference in the perceived colors as a color-inconstancy phenomenon.
This work proceeds in two steps:

1) Checking the existence of color matching made by wide band lights true for foveal and extra macular vision and for different individual observers;
2) Empirical estimation of the minimum band-width of spectral lights required to have color matching for foveal and extra macular vision and for different individual observers.

2. COLOR-MATCHING WITH WIDE BAND LIGHTS

The observers involved in this experiment are three, with normal trichromatic vision, but different sex, age (CO male 67 years, MP female 37, NF male 37) and color-matching functions (CMF). A population of three individuals has no statistical significance, but it is important to note that three such different observers are in agreement on the considered color matching.
Cross-media color matching made by a mixture of wide band lights has shown that equal color matching holds true for all these observers in foveal vision and extra-macular vision.

The lights of the bipartite field are produced by a CRT monitor on one side (Figure 1 left), and by the Philips LED lamp “Living colors” illuminating a white paper (Figure 1 right). The lights are measured by a Hamamatsu PM11 spectroradiometer. This phenomenon shows color constancy between the two kinds of vision present in human vision. The chromaticities of the lights in the two parts of the bipartite field computed for the CIE standard observers are different and show regularity on the chromaticity diagrams (Figure 2). This difference in color specification could suggest improving the CMFs of both observers, CIE 1931 and CIE 1964, and also supposing that equal CMFs are possible for the two observers. However, this second hypothesis is unsuccessful, because the CMFs are functions of the wavelength and color constancy in fovea and in extra-macula regions depends on the light spectra.

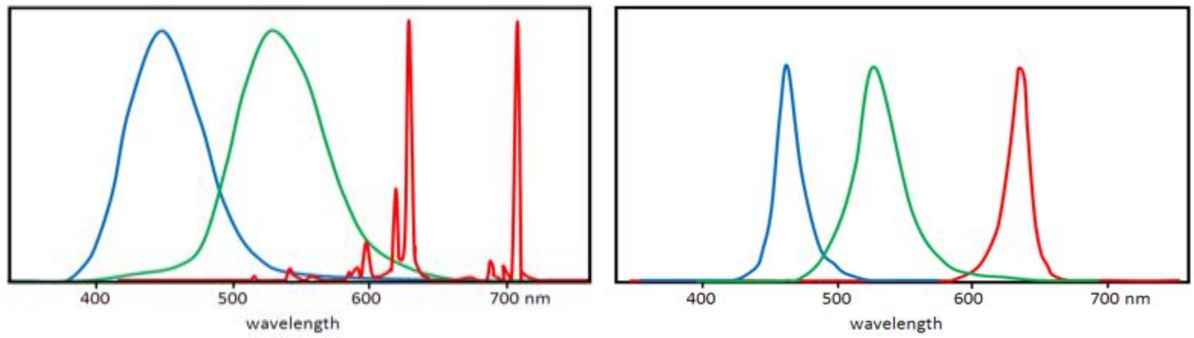

Figure 1. Relative spectral power distributions of the Cathodic Ray Tube primary lights (left) and of the lights emitted by the Philips LED lamp “Living colors” (right)

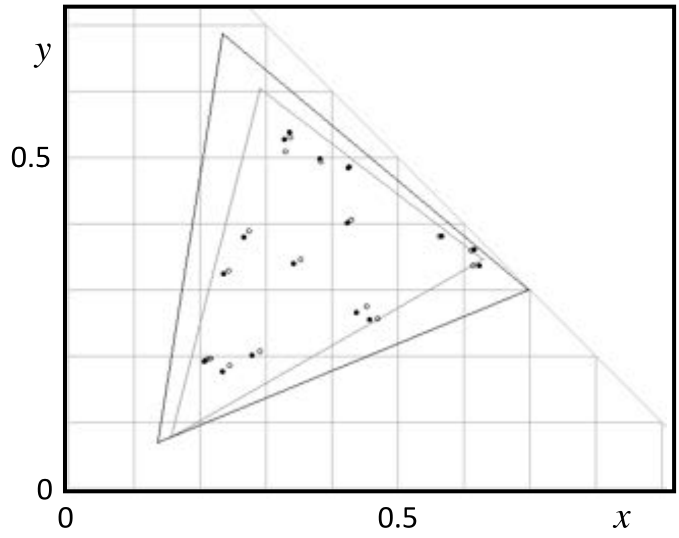

Figure 2. CIE 1931 chromaticities of the color gamut of the PHILIPS LEDs lamp (black triangle) and of the CRT monitor (grey triangle) and of 16 color pairs matching in foveal and extra macular vision, obtained from an average of 10 color matches in Cross-media color matching (solid circles for PHILIPS LEDs lamp and empty circles for CRT monitor)

3. MAXIMUM SATURATION MATCHING WITH A NARROW BAND LIGHT

The apparatus for color matching in a 2 deg bipartite field uses two sets of three wide band primary lights obtained with three halogen lamps combined with two sets of three interference filters and a spectral light obtained by a xenon lamp with a monochromator Jobin-Yvon H10-VIS. The bandwidth of the spectral light is selectable with a set of different exit slits (0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 6, 8, 10, 12, 14 mm). Any further increment on the slit width has no significant effect on the bandwidth. The Full Width at Half Max (FWHM) bandwidth corresponding to the 14mm slit is in the order of 48.5nm and for the 0.5mm slit of 15nm throughout the wavelength range considered. The two sets of primary lights, called RGB and CMY respectively, have relative spectral power distributions shown in Figure 3 and chromaticities in Figure 4). The light exiting the two parts of the bipartite field is lambertian because it is diffused by two integration spheres. This color-matching apparatus is the same one used in a published experiment (Oleari and Pavesi, 2008).

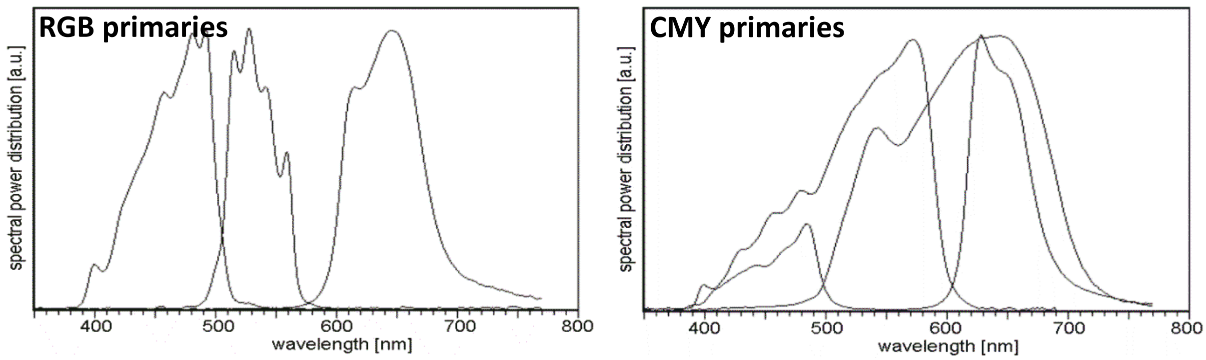

Figure 3. RGB (left) and CMY(right) wide band primary lights used in color matching.

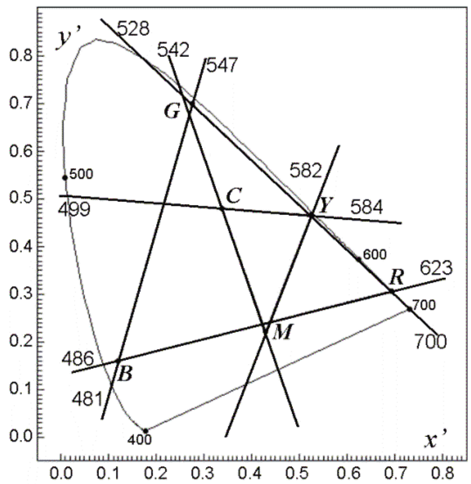

Figure 4. Chromaticities of the RGB and CMY wide band primary lights.

Maximum saturation color matching is possible by mixing a spectral light with variable bandwidth with the RGB or CMY primaries. In this way it is possible, for any wavelength, to select the narrowest slit with color constancy (black bars in Figure 5) and the largest slit with color inconstancy (red bars in Figure 5), i.e. a range of bandwidths containing the threshold value between color constancy and color inconstancy is evaluated.

The results for the two sets of primaries are equal and are summarized in Figures 5(a) and 5(b). The color matching proved to be true for foveal and extra macular vision and for three different individual observers, i.e. the three individual observers were in complete agreement and no average among the observers has been made.

This investigation on the bandwidth shows that the color matching, obtained with a slit of 0.5 mm (bandwidth FWHM ~ 15 nm) for wavelengths $\lambda > \sim 520$ nm and for λ around 475 nm, is true for foveal and extra macular vision and for different observers. The bandwidth necessary for color constancy grows rapidly out of these regions.

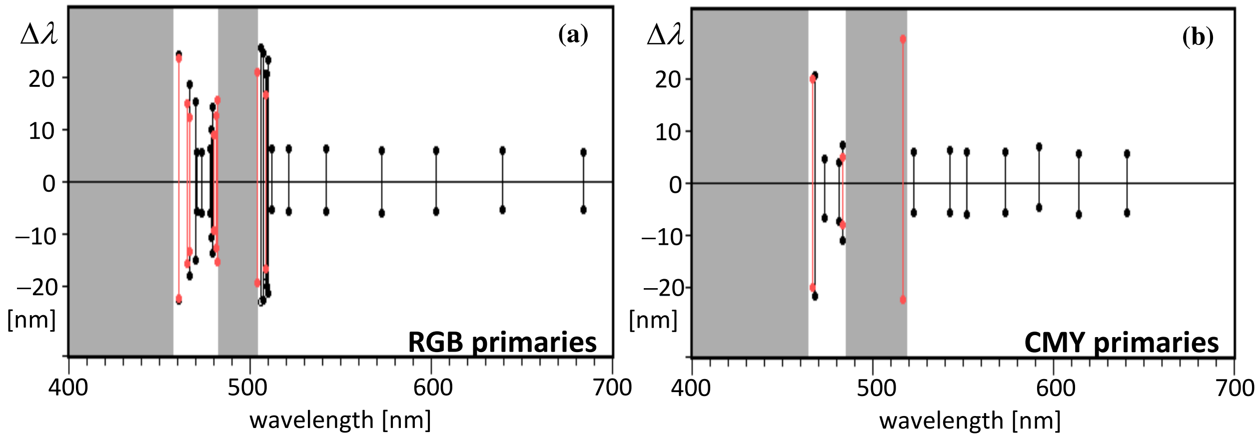

Figure 5. Bandwidth bars corresponding to good color matching (color constancy) in foveal and extra macular vision and different individual observers (black bars) and to bad color-matching (color inconstancy) (red bars) for RGB primaries (a) and for CMY primaries (b), respectively. The bandwidth threshold is in the region between the red and black bars. No color matching in foveal and extra macular vision and different individual observers is possible with a 14mm slit in the monochromator (FWHM~48.5nm) in the grey region without black bars.

4. CONCLUSION

Empirically it is shown that color-matching made by mixing wide band lights holds true for foveal and extra-macular vision and for different individual observers. This color-constancy phenomenon fails when narrow band spectral lights with wavelength below ~465 nm and between ~485÷~515nm enter the mixture.

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REFERENCES

Oleari, C., Pavesi, M. 2008. Grassmann's laws and individual color-matching functions for non-spectral primaries evaluated by maximum saturation technique in foveal vision, *Color Research and Application* 33: 271- 281.

Vienót, F. 1980. Relation between inter- and intra-individual variability of color-matching functions. Experimental results. *Journal of the Optical Society of America* 70: 1476-1483.

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Demonstration of the Color Constancy in Picture

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ABSTRACT

The paper focuses on demonstrating the color constancy in a picture using a stereoscope technique to turn two-dimensional (2D) perception of picture into three-dimensional perception (3D). We illuminated a room with 22 conditions of orange, blue and white lights. We took 2 pictures to produce a stereoscopic picture pair for individual condition. Observers looked in the room, illuminated by one condition, and subsequently the stereoscopic picture pairs. They judged if the pairs had the same color impression as they saw in the room. The stereoscopic picture pair gave a three-dimensional viewing. The observers did the same observations and judgments but the normal pictures were shown in order to give two-dimensional viewing. We found that observers could perceive the same color appearance of the room as of the image with stereoscopic pair, giving three-dimensional impression, but this did not happen when they looked at the normal pictures giving two-dimensional perception.

1. INTRODUCTION

Color constancy is a property of an object giving the same color appearance under different illuminations. A white paper taken under an incandescent lamp appears very reddish in a picture when we look at the picture under white illumination. The concept of Recognized Visual Space of illumination (RVSI), introduced by Ikeda (2004), explains why the color constancy does not hold for a picture. The RVSI concept emphasizes that the 3D perception for a space is the necessary condition for the color constancy. When we enter a room illuminated by red light, firstly we recognize the space and understand the illumination in the space and we adapt to red illumination. We perceive a white object in the room as white in spite of the red illumination. Poungsuwan (Phuangsuwan) et al. (2010) showed that the color constancy took place in a photograph if we can perceive a 3D space in the photograph by a technique called D-up viewer, observed the photograph with one eye. In this paper we employed a stereoscope to obtain a 3D space perception, observed the photograph with two eyes, and to show the color constancy in the photograph. In our life we always use two eyes to see the real world. This technique gives us the familiar 3D space perception when we observe the picture so that the color constancy should hold in the picture.

2. EXPERIMENT

Apparatus

A stereoscope apparatus was constructed with two mirrors (ML and MR) arranged in left-right symmetry as shown in figure 1. To perceive a 3D space in a picture, we presented two pictures (P_L and P_R) through two mirrors. When an observer looks at the mirrors, two pictures will be merged into a single picture (FP).

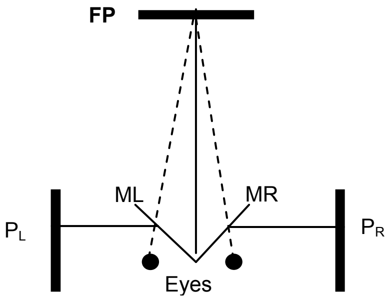
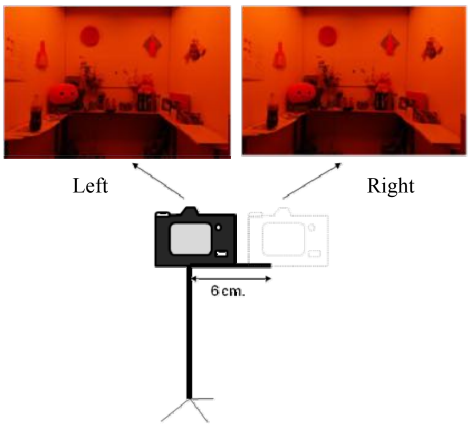


Figure 1 illustration of stereoscope viewer and experimental room.

We built the experimental room with the size of 130 cm x 200 cm x 200 cm (W x L x H). We decorated the room with a clock, a mask, books, artificial flowers, dolls and others. The room was illuminated by 3 fluorescent lamps: 1of white light (Lw) and 2 of colored lights (Lc). Lw was a daylight illumination and Lc was daylight illumination covered with orange filter in one experiment and with blue filter in another experiment. We could separately adjust the intensities of Lw and Lc. The room illumination was kept constant at 80 lux. Eleven intensity levels for blue and for orange illuminations were used in total of twenty-two levels of illuminations. For individual level of illumination we took two photographs of the room, the second one was 6 cm. laterally shifted from the first one in order to simulate binocular disparity as shown in figure 2 (a). We controlled the color reproduction of the photographs by matching the color of the white wall in the room to the color of the white wall in the picture as shown in the xy chromaticity diagram (figure 2 (b)).

(a)



(b)

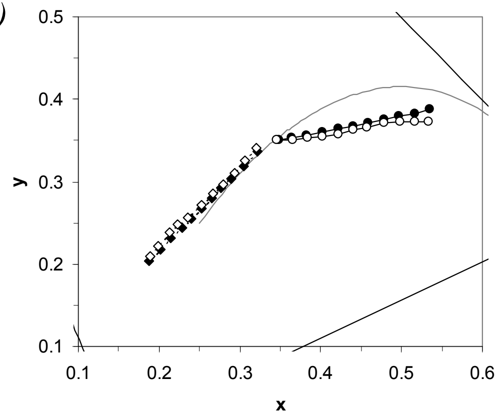


Figure 2 (a) photographs simulated binocular disparity. (b) xy chromaticity coordinates of the white wall in the room (Blue; ■, Orange; ●) and the white wall in the picture (□, ○).

Procedure

We conducted 3 different viewing sessions, 3D viewing, 2D normal viewing and 2D mirror viewing. In 3D viewing session, the experimenter adjusted the room illumination condition and told the observer to sit down on a chair facing the main wall and looked around in the experimental room as shown in figure 1 (right). The observer had to remember the color of the room, came out to see the stereoscopic picture pair (figure 3, left), pair by pair, under daylight illumination, and responded "redder" or "whiter" compared to the color appearance of the room. Then the experimenter randomly presented all pictures to the observers. They could re-look into the experimental room anytime if they wanted.

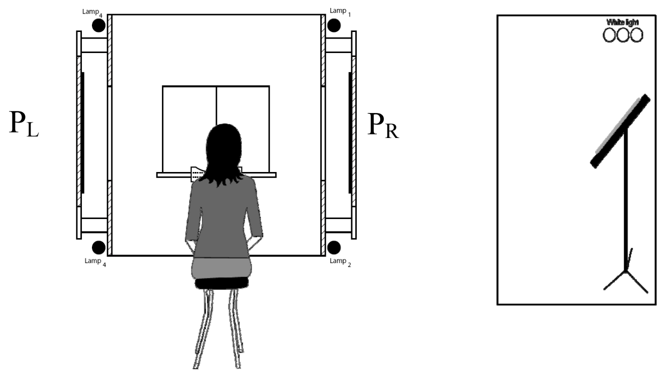


Figure 3 schemes of the stereoscope viewing and normal viewing.

In 2D normal viewing session, after remembering the color of the room, they came out to the next room to see the picture, one by one on the holding stand (figure 3, right), under daylight illumination, and responded “redder” or “whiter” compared to the color appearance of the experimental room.

To see the influence of stereoscope technique we avoided the stereo images by employing the same picture at P1 and P2. This experiment procedure was the same as in the first session. If we could perceive a 3D space in a picture by only the influence of stereoscope the responding of the observers should shift toward white when they looked at the picture pair that were taken with the same as illumination condition in the room. This experiment is called “2D mirror viewing”.

3. RESULT AND DISCUSSION

We obtained the results from five observers for all illumination conditions as shown in figure 4 (a). The abscissa represents the picture color (u’) of the wall area. The ordinate shows bluer or redder percentages of chosen picture obtained from observer. When the observer judged the picture color at stereoscope viewer with the room color, the chosen picture was almost the same as the room color for both blue and orange illuminations. However, in the blue illumination, the result was closer to white than in the orange illumination. The variation among the observers was larger in 2D normal viewing condition than other viewing conditions. Figure 4 (b) shows the average probability-of-bluer or –redder curves from five observers in three illumination conditions (IL3, IL6 and IL9). The top, middle and bottom figures are the average data from 3D, 2D normal and 2D mirror viewing respectively. The abscissa shows the distance between u’v’ coordinates of the white wall on the photograph taken under white illumination to the white walls on other photographs as shown in figure 2b. The positive side of abscissa represents the distance of orange photographs and the negative side represents the distance of blue photographs. Short bars indicate the color of the room under three illuminations investigated. The ordinate shows the percentage of responding “redder” or “bluer”. The result from stereoscope viewing implies that the observers perceive the same color appearance between the picture and the room. However, the result from 2D normal viewing can confirm that the color constancy does not take place for the picture when the observers in the normal viewing condition, the white object in the picture is not the same as in the room. The color impression in the room is rather white to the observer. This implies that the color constancy takes place in the room but it does not take place in the picture. The 2D mirror viewing gives a similar result to the normal 2D normal viewing. However, the responded curves are slightly scattered from the white illumination. This situation may be resulted from the effect of the masking technique that we limited only the picture area that was shown to the observers.

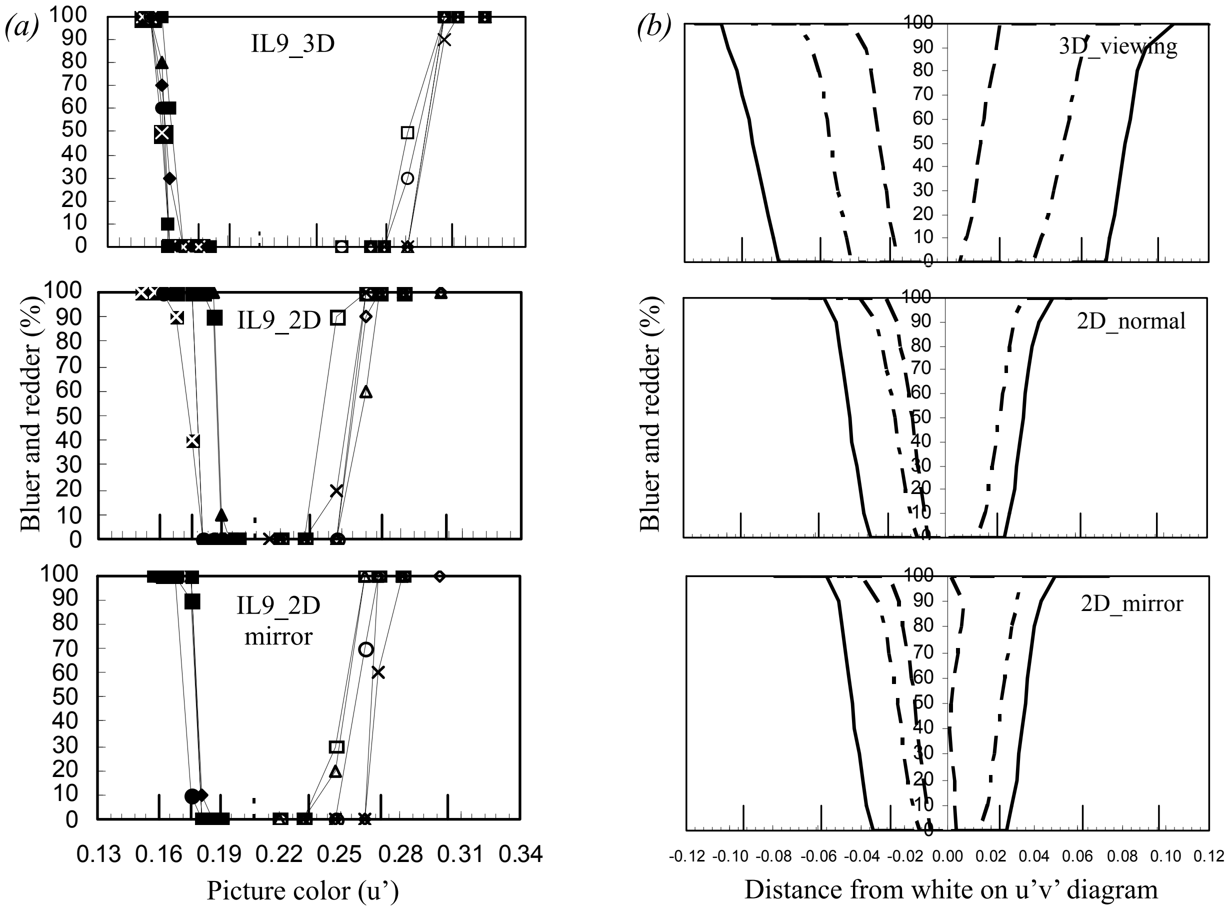


Figure 4 (a) Frequency of bluer and redder response curves from 5 observers in 22 illuminations. (b) Averaged probability-of-bluer or –redder curves from 5 observers. The solid bars represent the illumination color investigated. Dashed curves, IL3; one dotted one dashed curves, IL6; solid curves, IL9.

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REFERENCES

Ikeda, M. 2004. Color appearance explained, predicted and confirmed by concept of recognized visual space of illumination. *Optical review* 11: 217-225.

Puangsuwan, J., M. Ikeda, P. Katemake and T.Obama. 2010. Color constancy observable in a picture. *In CSAJ 2010, Proceedings*. 36-37.

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Investigation of the Color Appearance of Color Chips under Bi-Combinations of Various Light Sources Commonly Used in Indoor Environments

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ABSTRACT

Light sources substantially affect the color appearance of objects. Color rendering evaluates how a color appears to an observer when it is illuminated by a particular light source. A color rendering index (CRI) is used to quantify color rendering of one light source. However, it is common to apply a combination of light sources in modern indoor environments. The purpose of the present work is to determine the correlation between the spectral power distributions (SPD) of components in the combination of various light sources. In this way, the effect of light combinations on color appearance of objects could possibly be estimated. Experiments were conducted according to a standard color order system. A set of common light sources were selected to act as single sources and in bi-combinations to assess the color appearance of a series of reference color chips. The spectral power distribution of the applied light sources was measured by a CS-2000 spectroradiometer from Konica-Minolta. The results show that the color appearance of the color chips is non-linearly related to the spectral power distribution of the combined light sources. Additionally, the color appearance of a bi-combined light source would very much depend on the similarity or dissimilarities of the spectral power distribution of the two utilized original single light sources.

1. INTRODUCTION

In modern indoor environments aesthetics and energy-saving problems are two topics of great interest for investigation. It is common to apply a combination of light sources to artificial copy variations of illumination in natural environments: Embrechts (1999). Light sources substantially affect the color appearance of objects: Ohta et al (2005). Color rendering evaluates how a color appears to an observer when it is illuminated by a particular light source. According to the CIE definition, color rendering is the effect of an illuminant on the color appearance of objects by conscious or subconscious comparison with their color appearance under a reference illuminant: CIE (1987). From an interior design point of view, it is valuable to be able to predict the color rendering properties of combined light source.

In the present work, the CIE color rendering index (CRI) as well as the fundamental color stimulus (FCS) of Cohen and Kappauf: Cohen (1982) were determined spectral power distribution (SPD) of the various light sources as well as their Planckian radiator equivalents for single and bi-combination light sources. Percent coverage of superimposed FCS of single and bi-combined with that of the FCS of the Planckian radiator was evaluated. This percent coverage was used to predict the color rendition of single and bi-combination of light sources.

2. EXPERIMENTAL

Four warm and cool fluorescent light sources (FL) (see table 1) supplied by domestic producers was were selected. The SPD of these light sources were measured by a CS-2000 spectroradiometer from Konica-Minolta. Figure 1 shows the spectral power distribution (SPD) of each selected light source. Correlated Color Temperature (CCT) CIE color rendering index (R_a) and percent coverage of FCS of the corresponding Planckian radiator by each light source is illustrated in table 1.

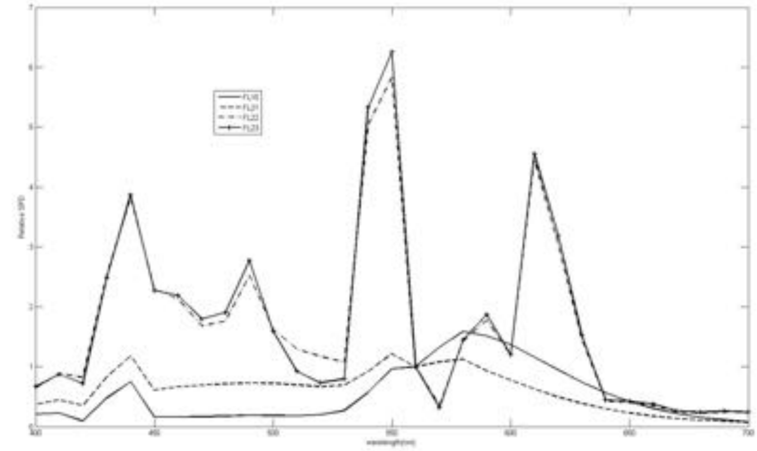

Figure 1. Spectral power distribution of selected light sources.

Table 1. Colorimetric properties of selected light sources.

Light Source	Correlated Color Temperature (CCT)	Color Rendering Index (Ra)	Color Coordinates		Percent Coverage of FCS of the respective Planckian radiator %
			x	y	
FL15	2762	50.9	0.45	0.40	66.7
FL21	5946	67.5	0.32	0.36	82.4
FL23	6269	89.5	0.32	0.34	95.2
FL25	6088	91.2	0.32	0.33	92.9

The correlated color temperature (CCT) was estimated by using the McCamy's approximation algorithm (Eq. 1 and 2): Ohta (2005).

$$CCT(x, y) = -437n^3 + 3601n^2 – 6861n + 5524.31 \quad (1)$$

$$n = (x-0.3320)/(y-0.1858) \quad (2)$$

where x and y are the chromaticity coordinates in CIEXYZ color space. The CIE $L^*U^*V^*$ color coordinates were calculated using Eq. 3 and 4: MINOLTA(2000).

$$L^* = 116 (Y/ Y0)^{1/3} -16 \quad \text{when } Y/ Y0 > 0.008856 \quad (3)$$

$$u^*=13L^*(u'-u'_0),\ v^*=13L^*(v'-v'_0),\ u'= 4X/(X+15Y+3Z),\ v'= 9Y/(X+15Y+3Z) \quad (4)$$

where, Y shows tristimulus value Y. u' and v' are chromaticity coordinates in the CIE 1976 UCS space. Y_0, u'_0 and v'_0 are color parameters Y and chromaticity coordinates u', v' of the perfect diffuser. The CIE test procedure for calculating the CRI was as follows:

- Determination of the correlated color temperature (CCT) of each test light source.
- Selection of an equivalent Planck-radiator having the same CCT as each test light source in order to avoid chromatic adaption transformations.
- Determination of the CIE 1964 $L^*u^*v^*$ color coordinates of the 8 recommended Munsell chips irradiated by the reference and test illuminants.
- Determination of color differences (ΔE_i) for each of the 8 chips under the two illuminants.
- Conversion of these color differences to indices of color rendering for each sample as follows:

$$R_i=100-4.6\Delta E_i$$

$$R_a = \frac{1}{8}\sum_{i=1}^{8} R_i$$

- Determination of the general color rendering indexby averaging.

A R_a = 100 represents zero color difference for all eight chips under the test and reference illuminants. According to the Cohen and Kappauf`s spectral decomposition procedure, a spectral reflectance (N) could be divided to its fundamental color stimulus (FCS) and its black metamer(FMB). FCS is determined from matrix R (Eq. 5 and 6): Cohen et al (1982).

$$FCS = R\times N \tag{5}$$

$$R = A \times (A\times A')^{-1}\times A' \tag{6}$$

where A is a 31 by 3 matrix representing the color matching functions of 1931 standard observer multiplied by the SPD of a selected illuminant.

3. RESULTS AND DISCUSSION

In the present work, three bi-combination of the selected light sources were used as shown in table 2.

Table 2. Colorimetric properties of the selected bi-combined light sources.

Light Sources Mix	Correlated Color Temperature (CCT) K°	Color Rendering Index (Ra)	Color Coordinates		Percent Coverage of FCS of the respective Planckian radiator %
			x	y	
FL15-FL21	3960	64.9	0.38	0.38	77.6
FL15-FL23	4834	83.8	0.35	0.35	93.0
FL15-FL25	4735	81.6	0.35	0.35	90.8

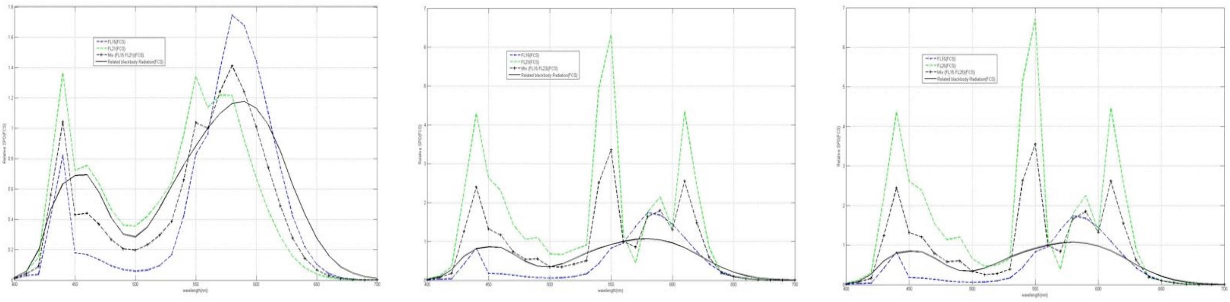

Figure2. The FCS of the SPD of single and three bi-combined illuminants together with the FCS of the corresponding Planckian radiator having the same CCT.

In general terms, CRI is a measure of a light source's ability to show the “true color” of object colors compared to a standard reference source, say a Planckian radiator having the same CCT. The FCS of bi-combined light sources and the FCS of the corresponding Planckian radiator are depicted in figure 2. It is clear that the color portion of SPD is derived from the FCS. In other words, the percent coverage of FSCs of the Planckian radiator by a test light source determines who the color rendering approaches one of the light sources. For a combination of two light sources with different CRI, the light source with the higher CRI shows more percent coverage of the FCS of the Planckian radiator.

Therefore, the present study illustrates a novel procedure for predicting how the value of color rendering of bi-combined (or even multi-combined) light sources approaches the CRI of the light source which has maximum coverage of the superimposed FCS of the corresponding Planckian radiator having the same CCT.

REFERENCES

Embrechts, J. J. 1988. The combination of illuminants and its effects on colour rendering, *Lighting Research and Technology*, 20: 1-10.

Lin,k.c.2010.Approach for optimization of the color rendering index of light mixtures, *J Opt Soc Am A Opt Image Sci Vis.* 1;27(7):1510-20.

Ohta, N., Robertson, A.R., 2005.*Colorimetry: fundamentals and applications.* England:John Wiley & Sons.

*Publication CIE 17.4.*1987. Commission Internationale de l’Eclairage: International lighting vocabulary.

Precise color communication, color control from perception to instrumentation. 1998. KONICA MINOLTA SENSING

Cohen, J. B. and Kappauf , W.E. 1982. Metameric Color Stimuli ,Fundamental Metamers and Wyszecki's Metameric blacks, *Am J Psychol*,95,pp537-564.

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Evaluating Color Appearance and Visual Comfort of a Living Environment Using a Panoramic Camera

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ABSTRACT

The study present an imaging system to capture HDR panoramic image for various applications including absolute XYZ measurement for diagnosing visual discomfort of a scene and color appearance estimation of it using iCAM06 for interior design. Two psycho-visual experiments were conducted to further determine visual discomfort thresholds of a circular white patch against a black background in dark surround. The results agree CIE UGR metric partly.

1. INTRODUCTION

To improve visual comfort of our living environment, a colorimetric imaging device is designed to capture scene luminance and chromaticity for evaluating visual responses to the scene. To capture the scene over large fields of view, there are two main classes of techniques: image stitching (mosaicing) (Aggarwal and Ahuja 2011) or using omni-directional cameras. The former can achieve higher resolution but it takes longer time to complete the measures. The latter can use fish-eye lens (Xiong and Turkowski 1997) to cover a field of view up to 360x360 or use parabolic mirrors (Chahl and Srinivasan 2000) to image a large field of view onto a single sensor. We choose the parabolic-mirror approach as it is the most efficient way to capture a 360 scene. However, the scene includes light sources and shadows normally. To measure the light distribution without signal clipping, panoramic images generated under multiple exposure settings can be fused together to obtain a high dynamic range panoramic image. It needs a characterization model to obtain accurate XYZ image (Martínez-Verdú, Pujol and Capilla 2003).

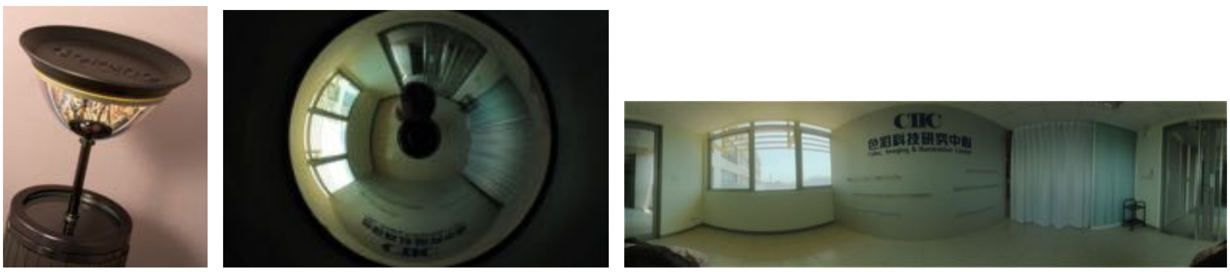

Figure 1. Left: a parabolic-mirror. Middle: the donut-like image. Right: HDR panoramic image.

2. CHARACTERIZATION MODEL

A Canon EOS 60D DLSR with GoPano™ parabolic-mirror (Figure 1-left) is used to capture raw image files in CS2 format. To widen its depth of field, a Sigma's 50mm micro lens and a 50mm tube were installed between the camera and the 360° parabolic-mirror. The raw images are converted to 16-bit tiff format in linear (gamma = 1) Adobe RGB space to minimize the impact of tone enhancement while ensuring wide color gamut. The tiff images are donut-like (Figure 1-middle). They all unwrap to panoramic images (Figure 1-right) using PhotoWarp 2.5.8 based on spherical projection (Rondinelli et al. 2006). To characterize the panoramic camera as an image colorimeter, we put Kodak Q-13 grayscale and X-rite's ColorChecker Mini under a dimmable viewing booth (Just Normlicht Color Communicator 2). The camera took a series of shot towards the booth with different Exposure Values (EVs) under ISO 100. On the other hand, the XYZ tristimuli of the color patches were measured by a Topcon SR-UL1 spectroradiometer. A 3rd-order polynomial regression model was used to correlate the linear RGB value to its EV weighted XYZ value. The conversion matrix M_{3x14} was determined by un-saturated RGB values and their corresponding XYZ values. Note "un-saturated" means that only the samples (color patches in the panoramic images) whose normalized RGB values are within 0.03 to 0.85 were used in the optimization. Equation 1 shows the functions where RGB are linear image signal range from 0 to 1. To fuse a high-dynamic-range (HDR) XYZ image from multipe exposure images, a weighting function is used to degrade the XYZ prediction of saturate RGB values.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = 2^{EV} M_{3\times14} \begin{bmatrix} R^3 & G^3 & B^3 & R^2 & G^2 & B^2 & R & G & B & RG & GB & RB & RGB & 1 \end{bmatrix}^T \quad (1)$$

8 EV levels (from EV5 to EV12) were tested. The mean and maximum errors for 20 grayscales in the Q13 target were 1.08 and 3.28 ΔE_{00} respectively. In terms of ColorChecker Mini, the mean and maximum errors were 3.66 and 12.17. The mean XYZ errors were 3.05%.

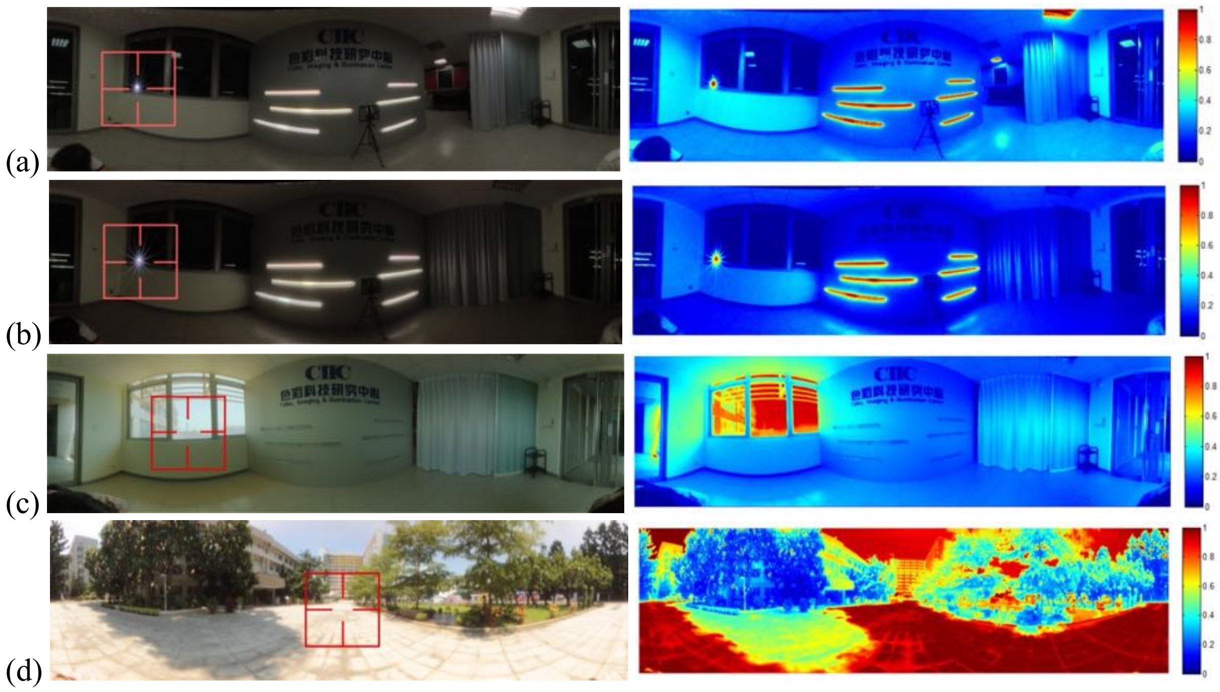

Figure 2. (a) ceiling light on; (b) ceiling light off; (c) daytime; (d) outdoor scene.

3. EVALUATE UGR

CIE Unified Glare Ratio (UGR) is a well-known metric for estimating visual discomfort of interior lighting (CIE 1995). Luminance level, solid angle and relative position of each light source are required in the calculation. They all can be estimated roughly from an HDR panoramic XYZ image. Figure 2-left show a series of panoramic images taken by the proposed imaging system with their relative luminance on the right side. If an observer gazes at the red cross, the UGR values are 19, 23, 13 and 21 for Figure 2(a) to (d) respectively. The values proportion to visual discomfort to some extend where huge luminance contrast between the background and light sources results in high UGR value. We developed a software to detect visual discomfort regions (high UGR areas) for warning. Note that the UGR was derived for estimating visual glare of interior lighting. However, it seems the model can be extended to measure visual discomfort of an outdoor environment (Figure 2(d)).

4. VISUAL DISCOMFORT THRESHOLDS

Two psycho-visual experiments were conducted to further determine visual discomfort thresholds of a circular white patch against a black background in dark surround. Visual angle and relative position are two independent variables in the two experiments. A high-power DLP projector was used to display the patch from 0.38 to 870 cd/m^2 with 6,420K correlated color temperature. 15 color normal observers did the experiment. The projector was located at 1.33m away from a white screen and the observer viewed the patch in 75cm distance to the screen. The observer was asked to adjust a small slider bar on the GUI written by Matlab for increasing the luminance of the white patch from black to his visual discomfort threshold. Experiment 1 varied the size of the circle from 10^o to 71^o visual angle. The mean visual discomfort thresholds are shown in Figure 3-left. A clear V-shape curve can be observed in the figure where the valley is located at 40 degrees. It does not follow the characteristic of UGR ccompletely. Experiment 2 tested a white circle with 16.5^o visual angle in 9 different positions. The observer was asked to gaze at a marker on the screen and then scale the visual discomfort threshold of the circle outside his/her viewing axis. R, T and H represent viewing distance, off-axis distance in horizontal direction and off-axis distance in vertical direction respectively. The mean thresholds for the 9 positions are shown in Figure 3-right in a relative manner. It has very high correlation (r = 0.95) to the Guth Position Index using in the CIE UGR (1995). Our results confirm the usability of the Index and it can be used to evaluate visual discomfort of a living environment in night time. More applications based on the panoramic XYZ image will be studied next.

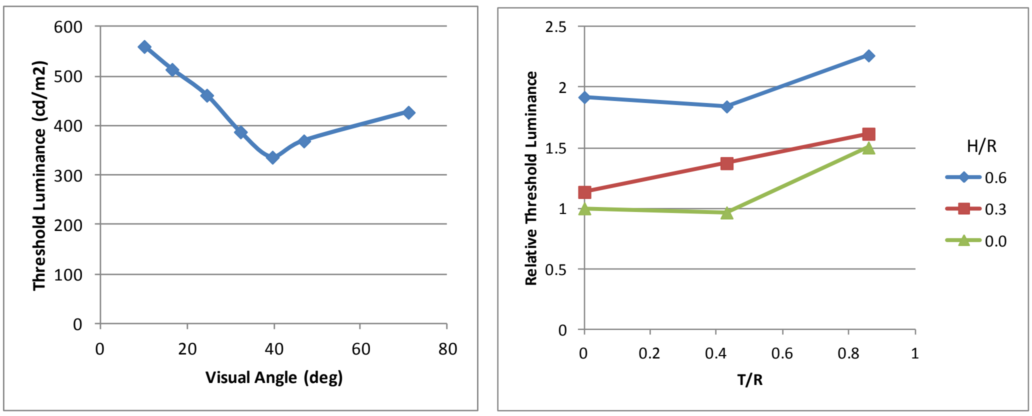

Figure 3. Left: Visual discomfort threshold as a function of patch size. Right: Relative visual discomfort threshold a function of viewing position (relating to the viewing axis).

5. COLOR APPEARANCE OF A LIVING ENVIRONMENT

Color appearance of a large scene depends on not only reference white, but also local luminance. iCAM-based color appearance model (Kuang, Johnson and Fairchild 2007) therefore can be used to convert the absolute XYZ image into color appearance space (Figure 4). Perceptual edges can be estimated in the space using Sobel filter. The clarity of the edges is important to symbol design. Color emotion models (Ou et al. 2004) can be applied in this space to estimate whether the color design of the living environment is suitable.

Figure 4. Left: HDR panoramic image. Middle: Image color appearance calculated by iCAM06. Right: Perceptual edges in the appearance space.

6. CONCLUSIONS

An imaging system to capture HDR panoramic image for various applications including absolute XYZ measurement for diagnosing visual discomfort of a scene and color appearance estimation of it using iCAM06 for interior design is proposed. Two psycho-visual experiments were conducted to further determine visual discomfort thresholds of a circular white patch against a black background in dark surround. The result shows the mimimum lumiance threshold is 336 cd/m^2 and the size of the pathc is around 40^{o} visual angle. It partly agrees the CIE UGR metric. In terms of relative position, our results correlate to Guth Position Index very well (r = 0.95). More applications based on the panoramic XYZ image will be studied next.

REFERENCES

Aggarwal, M. and N. Ahuja. 2011. High dynamic range panoramic imaging, *Int'l Conf. on Computer Vision*, 1:2-9.

Chahl, J. S. and M. V. Srinivasan. 2000. A complete panoramic vision system, incorporating imaging, ranging, and three dimensional navigation. In Workshop on Omnidirectional Vision, 104-111.

International Commission on Illumination (CIE). 1995. *Discomfort Glare in Interior Lighting*. CIE 117-1995, CIE Central Bureau, Vienna.

Kuang, J., G. M. Johnson and M. D. Fairchild. 2007. iCAM06: A refined image appearance model for HDR image rendering, *Journal of Visual Communication and Image Representation*, 18: 106-414.

Martínez-Verdú, F., J. Pujol and P. Capilla. 2003. Characterization of a digital camera as an absolute tristimulus, colorimeter, *J. Imaging Sci. & Tech.*, 47:279-295.

Ou, L. C., M. R. Luo, A. Woodcock and A. Wright. 2004. A study of colour emotion and colour preference. Part I: Colour emotions for single colours, *Color Research & Application*, 29(3), 232-240.

Rondinelli et al. 2006. *System and method for panoramic imaging*, US Patent No. 7,123,777 B2.

Xiong, Y. and K. Turkowski. 1997. Creating image-based VR using a self-calibrating fisheye lens. *Int’l Conf. on Computer Vision and Pattern Recognition*, 237-243.

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A Study of Color Image in the Urban Waterfront Space

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ABSTRACT

The research of environmental color was first proposed in 1960. Urbanized modern artificial environment has turned the concentration into overall study of the whole environment up to now. In the urban waterfront, Bridges, which represent an image of city entrance, plays an important roles on a city. The city could be infused new energy and fun, if we try to spray some color over it.

The disorder is mainly presented in the urban and rural of Taiwan because the environmental color is rarely discussed and estimated in a scientific way. For this reason, we use the method of surveying environmental color pronouced by French scholar Jean Philippe Lcnclos, and the method of estimating urban image presented by Kevin Lynch as the basis of our theory. Moreover, we set the waterfront in Tamsui river watershed area in Taipei as our research regime to contrast the NCS of time line and space line with a roaming way over the river and field study method to collect the color image of the bridge over Tamsui River. At the same time we establish the environment main key color spectrum by the color territory discussion to present the correlation between city waterfront and color images. This environmental color analysis system can control the color images of the city's landscape effectively; furthermore, it can be referenced as the substance of urban design.

1. INTRODUCTION

Looking around the world-renowned cities, beautiful rivers are in endless winding of which, such as London's River Thames, the Seine in Paris, Niu Yueha Hudson River, etc. These rivers obtained world reputation because they all have flow lifeblood. Taipei City, the capital city of Taiwan, North and South-East of which are the mountainous; West of which is Tamsui River and Hsintien River; Keelung River passes through the city. In addition, river is the artery of human life. The development of the urban civilization is as a result of it. Bridges link the traffic between both sides which connect the life of riverside's residents. There are some cities and counties of Taipei City and New Taipei City across Tamsui River, the relation between riverside residents' life and urban waterfront development is inseparable. After changing times, the urban waterfront space not only plays the role of flood control buffer green belt; more importantly, it provides an amiable water leisure environment to a high-density city.

In view of Taipei has a rich natural and human resources, the mountain ranges and river systems surround of which makes Taipei has more potential of sight-seeing. In recent years, the public and private sectors' efforts make the remediation of Tamsui River quite effectively. Sailing Blue Highway, establishing bicycle system and developing and planning costal recreation attractions connect integration to create Taipei sight-seeing features. If apply colors are provided with the functions of regulating urban landscape which could not only strengthen the local culture of self-evidence and create a unique urban style, but also be use as an urban marketing strategy to enhance the city image and show the charm of the city.

2. RESEARCH METHODS

In this study, according to the spatial structure is divided into point, line and surface environment, then according to Kevin Lynch on the classification of the urban image elements is divided into five important types by substance type: Path, Edge, District, Node and Landmark. Contracting colors items accomplish environmental colors analysis. According to time and weather are divided into sunny, cloud with rain, sunset and night light, and then apply natural color system of color analysis chart (color circle and color triangle) and Shigenobu Kobayashi Color Image Scale to arrange urban waterfront space Timeline chromatography and the space axis chromatography to incorporate the color and tone of the overall environment, and to explore the relationship between urban color image of the distribution in this study.

NCS application methods: applying Color Circle and Color Triangle to summarize and analysis environmental colors of urban waterfront. Corresponding the color data to the relative position of NCS color space to compare the relationship between the color and image of urban landscape, and analyze the difference between colors. Applying NCS system to describe Hue, Value and Chroma, the method of the basic attributes, and then analyze the relationship between the definition of the color in the color data of a single object.

3. RESEARCH RESULTS

Light, sunshine and climat make hue, brightness and saturation of environment color to present the different color distribution; therefore, investigation time and conditions affect environmental color analysis and survey results.

The investigation of integrated environmental color and color image analysis (Figure 1), Environmental tone color chromatography (Table 1) and investigation of the color gamut (Table 2) sum up the results of the following:

- Due to do the swatch comparison, takes Taipei Tamsui River Blue Highway as the universality of color selection to identify rich color diversity of urban waterfront space. As a result, the distribution of hue presents diversity tones and the saturation distributes evenly.
- The brightness distributes evenly during the sunny days; the brightness distributes middle and low brightness during the overcast days with rain, which informs that the climatic factors affect the color greatly.
- The colors of sunset change extremely diversely. If add the impact factors, light, sunshine and climate, which to make the color of sunset changes more diversely. Because of lighting projects on water of night landscape that makes reflection color more diversely. The sunset and the night lights present high saturation in the color maps as a result.
- In urban image, urban waterfront present the gray tone. On account of affects of time, climate, etc., it presents the range of the light gray tone to the muddy tone (moderation tone) during sunny days; it presents the gray tone during the overcast days with rain; it presents the light and the dark tones during the sunset; it presents the dark tone duing the night light.

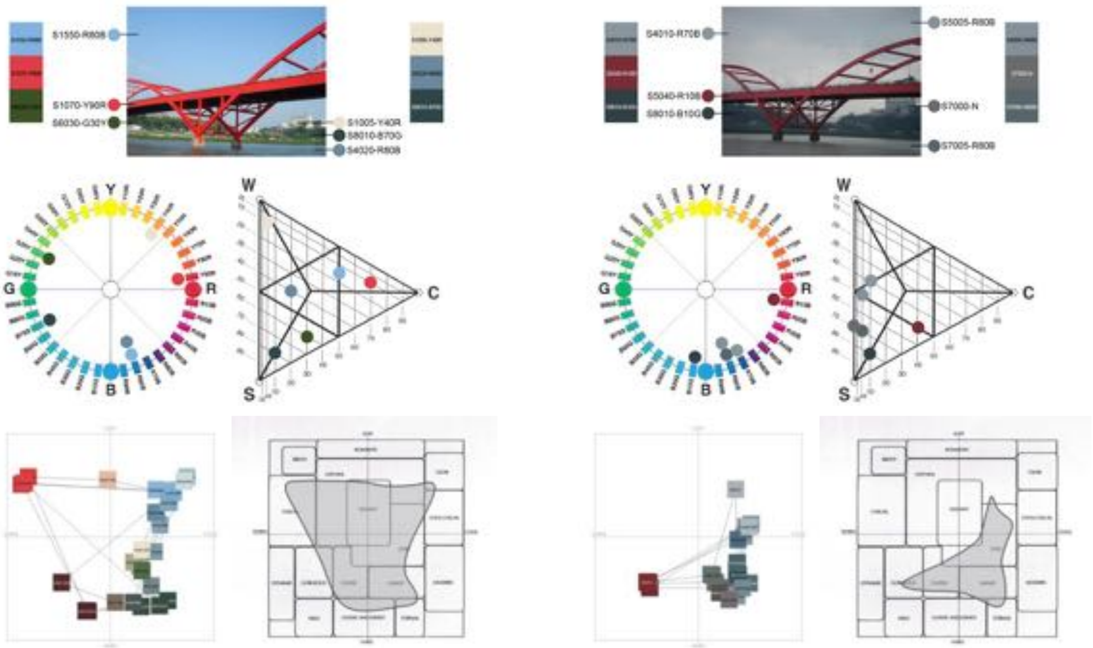
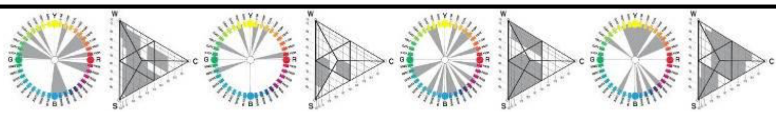


Figure 1. environmental color and color image analysis（Landmark - QuanDu Bridge）

Table 1. environment main key color spectrum.

Yellow	Y	Y10R	Y20R	Y30R	Y40R	Y50R	Y60R	Y70R	Y80R	Y90R
Red	R	R10B	R20B	R30B	R40B	R50B	R60B	R70B	R80B	R90B
Blue	B	B10G	B20G	B30G	B50G	B70G	B80G	B90G		
Green	G	G10Y	G20Y	G30Y	G40Y	G50Y	G70Y	G80Y	G90Y	
N	N									

Table 2. color territory discussion.

Urban Image Elements		**Color Distribution**
Node	Dadaocheng Wharf	 Daytime Sunny / Daytime Overcast with Rain / Evening Sunset / Night Lights

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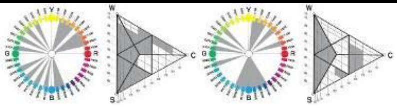
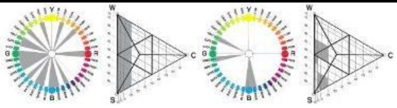
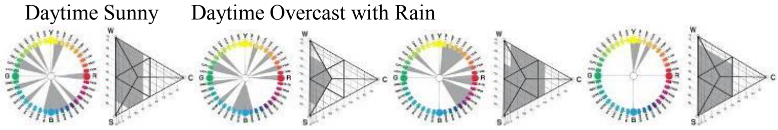
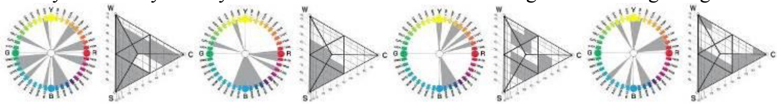
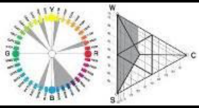
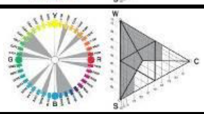
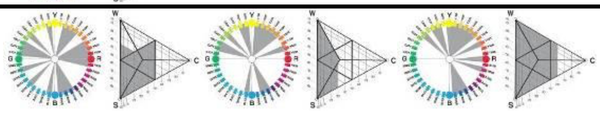
Urban Image Elements		Color Distribution
Node	Guandu Wharf	 Daytime Sunny; Daytime Overcast with Rain
Landmark	Taipei Bridge	 Daytime Sunny; Daytime Overcast with Rain
	Chung Young Bridge	 Daytime Sunny; Daytime Overcast with Rain; Evening Sunset; Night Lights
	QuanDu Bridge	 Daytime Sunny; Daytime Overcast with Rain; Evening Sunset; Night Lights
Path	River Space	
Edge	Waterfront Landscape	
District	Urban Landscape	 Close-View; Middle-View; Far-View

4. DISCUSSIONS AND RECOMMENDATIONS

In this study, it took 69 photos at Tamsui River randomly to establish 302 kinds of swatches of color database. Countering statutory policy, government implementation, environmental planning, design and construction, management and maintenance, color education dimensions provide substance recommendations to urban design. It will be able to be classified sampling of scale and distance in the future, in order to obtain more diversity colors change of urban waterfront. Updating the dynamic information regularly and implementing color management system facilitate the application of environmental color plan.

REFERENCES

J. Lenclos, 2004. *Colors of the World: The Geography of Color*, W W Norton & Co Inc, USA.

K. Lynch, 1960. *THE IMAGE OF THE CITY*, MIT Press,USA.

S.Kobayashi.1990. *COLOR IMAGE SCALE*. Kodansha international.

S.Kobayashi.1998. *COLORIST—A Practical Handbook for Personal and Professional Use*. Kodansha international .

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Colors in preschools, between theory and praxis

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ABSTRACT

Preschools are special spaces for children personality development. The pupils, aged from 3 to 6 years, change rapidly, everyday. The intensity of change varies from subject to subject and the stimuli received are responsible for much of their development. The educators are familiar with the behaviors that children exhibit in this particular period of their life, especially because their communication is particularly evident. In terms of color, this amplification produces a consequential adult behavior providing colorful spaces for children and for pupil objects (toys, clothing, household goods, furniture, etc.). The preschools fully reflect this logic. We apply many different wall colors, sometimes using colorfulness, chroma and saturation often irritating.

The Municipality of Verona and the University Iuav, Colour&Light in Architecture research unit, signed an agreement to study the impact of the color choice in schools, from preschool to high school. The first exercise was, occurred as a result of the need for expansion and requalification of a small preschool, to try an approach using some wall colors for both internal and external spaces. The study case will be monitored over time. The paper will report this experience of changing all the previous colors and the limits that such operation entails.

1. COLOR PERCEPTION IN OUR TIMES

Preschools are built environments having particular importance in the child's personality development. These places are attended by preschool children of age between 3 and 6 years. In this life period the children change rapidly. The mutations are detectable day by day and relate the character, the behavior, adaptation to the environment, the knowledge and skills, both intellectual and practical, and many other aspects that set up a very complex perceptive and behavioral situation. The change seems to be due both of biological hereditary factors and of environmental ones. Both these factors are responsible for the psychological development of individuals. If in the nature the biological factors are responsible for the greatest change as result of inheritance, the environmental factors contribute to the very founding of the future adult behavior. The intensity of change, in terms of speed and sharpness of the inner and outer manifestations, varies from subject to subject and the stimuli received are responsible for much of their mental development and future behavior (Barrett 2010). Educators are familiar with the children behavior exhibited at this particular time of their lives, mainly because their external manifestations are particularly evident, extroverted. This successful combination facilitates the researchers dealing with child behavior, because the data retrieval is easier and then usually every inquiry isn't particularly difficult. The children ingenuousness, coupled with their frankness in responses, results in a good aid when the administration of tests is required and the feed-back results evident.

In terms of color, the amplification of signals and appreciation or dislike expressions is extremely useful for designers dealing with the spaces and artifacts for children project. In turn, the interpretation that the consumerist society has towards children choices is another data necessary to understand the chromatic childhood world. We also must take into consideration the fact that most of the furnishings or a toy for children appears to be considerably colored, presenting tones and saturations very accentuated. Where the market offers this hyper colored landscape no child can expect that parents make different choices (Gasparini 2007). In a certain sense they are forced to buy and adapt themselves to the products offered for sale, where there are little alternatives. The context that the market suggests for children remains a sort of fairy tale world where the eyes are no longer able to grasp the reality if not violently highlighted.

The parents' lack of knowledge about the effects that color has on their children is an aspect that is rarely taken into account. Being read as an incontrovertible fact, they give their children an artificial landscape served by the producers: from objects to furniture, from clothing to television broadcasts, using strong colors to objects, furniture and spaces. Inexorably adults tend to give to their children space and objects very far from those suggested by the nature.

The colors adopted in our society are a sort of conviction weapon for marketing purposes, offering more colorful, bright and saturated tones solutions. To attract the buyers attention the exception is shown, very far from the banal everyday situations, giving dreamlike landscapes, imaginary places, where reason must be put aside in favor of unconscious impulse. In this dreamy world the use of color is strategic. Thus we can see that colors affect a lot of people, unaware of being unconscious instrument used exclusively for commercial purposes. For example, in neuromarketing studies the neuroscience discoveries are applied to marketing (Gasparini 2011). All these aspects and the use of electronic devices in everyday life, the augmented reality, the video screens, the TV sets, the web and a variety of media and mass entertainment have impact in education. The new electronic landscape is indeed forcing educators to update their theories and teaching approaches in any grade school to fit the new world. This new contemporary environment has very destabilizing effects because new strategies are not yet developed. To adapt to new conditions the educators haven't yet experimented new approaches, testing the not well defined boundaries. Preschools tend to fully reflect this logic, which in turn comes up against regulatory, economic and everyday limitations. Usually, in preschools different colors on the walls are applied, sometimes using colors, tones and saturations often irritating or even depressing, almost always inadequate.

Sensitized to this, as researchers, teachers and architects, we started a research for a new approach to color in schools.

2. COLOR FOR PRESCHOOLS

The Verona Municipality and the Research Unit "Colour and Light in Architecture" of the University Iuav of Venice, in the year 2010 signed an agreement "for the development of research and experimental design activities for school buildings, particularly in relation to aspects of adaptation to the educational needs by making use of aspects of color spaces in use, resulting in better learning and increasing student achievement" from preschools to middle school and junior high school. The first research project and subsequent experimental exercise occurred because of the need for expansion and redevelopment of a small preschool. We attempted a new approach to the choice of wall colors, both interior and exterior spaces. This preschool, located in a neighborhood of Verona called Bassona, was originally designed large enough for only three classrooms, one for each age group (3-4years, 4-5 years, 5-6 years). The current expansion, designed by the municipal office, consists in the addition of a new classroom.

This preschool is one of the few schools in Verona where the children are still separated by age. Most of other preschools in Verona mix children putting together the three different age groups in the same classroom, with dramatic effects for the development of children. In the same class some learning activities are sometimes common for all age groups and sometimes separate, according to the learning set program. For example, children older should start to read and write and they cannot do this work together with those who need to before understand the body care and control their sphincters. Moreover, the massive presence of immigrant children, recent immigrants which is typical north-Italian phenomenon, unable to speak the new language because the family still speaks the language of origin, make impossible to teachers the management of education at normal levels. The behavior and especially the foreign language inexorably depresses the learning conditions of the natives, who on one hand, are facilitated in the aspects of racial integration, but on the other hand the learning delay will be not easily recoverable on the future, because every age has its own specific connotations. Teachers are forced to isolate the native since the time required for integration of children coming from outside is subtracted from the normal curriculum. This situation inexorably affects the early grade levels, lowering the level of growth that would occur in a no emergency situation.

In the early stages of color project, therefore, we had to take account of this aspect. The color choices are based on some perception and fruition considerations (Niero, Premier: 2010). In example, the school is open for use from late September through early June, so the seasons involved are primarily those that go around the winter: autumn and spring. In summer the school is normally closed. This means that the lighting conditions vary from low to medium intensity. In this period many of the educational activities will be carried on indoors. The daily opening is from 8-9 in the morning until about 16. So the useful part of the day is the naturally lighted.

In view of all these assumptions, it was thought to subdivide the space, in terms of color, according to the space functions. Therefore, in all common areas we have opted to apply complementary colors (orange for the entrance and the hall, green spaces dedicated to offices and service to teachers, more private). Each classroom is equipped with a primary color selected by age: yellow for the smaller, red for medium and blue for the older children. The yellow, slightly warmed, plays as activator of psychomotor activity, facilitator for the spaces and objects reading. The deep red was used to paint the walls of the classroom used by children of median age. Being halfway between the acquisition of rules and the beginning of the world knowledge with more attention, are stimulated by color but also controlled and intrigued by the activities and training courses. The blue, which was applied to the third classroom, acts as a calming children hyperactivity and in the meantime directed them to pay more attention to intellectual activities. In this period of their life they begin to know how to read and write, so it's better that they are not distracted by the environment and more focused on learning. The fourth class was colored with a blue-green, a sort of turquoise. This color was chosen to dedicate space for various activities, or mixing of different age groups. Neither heat nor cold this space can serve as a rotation classroom. Two areas have been specially drawn inside of the hall, paved with grass green in shock absorption material. In the main hall, divisible into two parts by a movable wall of mobile modules of various colors, you enter thru the main entrance. To the hall the doors of every classroom are overlooking, the same color of the classroom. This solution enables small pupils immediately identify their classroom: yellow, red, blue and turquoise. The orange color of the salon is a socializing solution and also being the less bright because of the limited openings to the outside, oriented to the north, takes a less dramatic than the place. All bathrooms are accessible from within each class, treated in the same way: gray vinyl flooring with micro intrusion orange and gray, wall tiles coated with plugs geometrically designed in orange color.

All interior floors were made of resilient shock absorbing material. The walls were painted up to 1.50 meters from the ground to match the floor, which, being obtained with two-color design, has provided the base color for the walls. Up to 30 cm from the ground has used the darker color and the rest with a lighter tone. For a local hygiene law on spaces intended for public use it's required that the walls are 1.50 meters washable. This usually generates a wall subdivision claustrophobic effect on space users. It was therefore decided to make this less dramatic effect, creating a rise that may constitute a kind of horizon line to climb over by small pupils.

Any other parts of wall and ceilings, made of material with a high sound absorption, have been painted white in color, so the floor, reflecting, produces a lighter shade of the floor and the lower part of the wall. Finally, all other finishes have been chosen in gray color. The exterior of the school before the renovation was white, turned gray by smog and tear of time. Because the school is a one level, nestled in a small green park, it seemed like a house of many of those homes that are built around the 70s of last century. Nobody would have thought that this was a public school, and even less dedicated to children. Taking the opportunity of work on thermal insulation we decided to give new color outside of school.

The building plant was designed to aggregate volumes, thus generating an articulated facade design as well as the slope of the roofs. This sort of confusion has been reported to rule painting diagonally the smaller walls and the others of a single color, thus following a sort of red and yellow wave that extends over the whole development of the school elevation. We have also keep the opportunity of an old volume over the roof which contained the chimneys where put a kind of metal pyramid topped by a weathervane shaped like a yellow flag. The new expression gives to the school building a sense. Throughout the City of Verona the outside of schools doesn't indicate the function being held inside. So this is the first test of renovation that will affect the welfare of schoolchildren.

This case study will be monitored over time, meaning they are under investigation on the behavior of users: students, teachers, parents and residents in the district. Any color changes are possible over time. As a result of this research is also the indication of some guidelines for choosing the color of the school buildings in the town of Verona aimed at facilitating the technicians in the future choice of color in schools.

REFERENCES

Barrett, P. 2010. Creating Sensory-Sensitive Creative Spaes. In *Colour&Light in Architecture*, ed. by P. Zennaro. Verona: Knemesi, 187-192.

Gasparini, K. 2007. Superfici in mutazione. In *Il colore nella produzione di architettura*, ed. by P. Zennaro. Verona: Iperedizioni, 71-80.

Gasparini, K. 2011. Visioni superficiali. In *in Superficie*, ed. by A.Premier. Verona: Knemesi, 43-61.

Niero, D.; A. Premier. 2010. Colour in the Schools. In *Colour&Light in Architecture*, ed. By P. Zennaro. Verona: Knemesi, 475-481.

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Colour & smart technology for cultural heritage requalification and valorization

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ABSTRACT

The European 7th research program planning 2007-2013 identifies as priorities for the development the enhancement of infrastructures, the mobility of people and goods, the improvement of European town systems. The purpose of this attitude is the social, economic, environmental and management growth of local communities. Participation, identity and sustainability are the main conditions for a lasting development which consider life and environmental quality, information and culture as principles of a sustainable and culturally founded local development. This study deals with the proposal of planning guidelines for valorizing the disused Venetian military heritage using color and light. The abandoned military heritage, present in the Veneto Region, is a system of great historical, cultural and environmental importance, quantitatively significant, which requires a specific approach with regard to recovery, valorization and management. In the case of fortified systems, these buildings cannot be read as isolated objects, but fall within organic defensive systems spread over the territory in the evolving history. We are studying a system of interventions involving the conversion of historical artifact in active, environmental responsive context in which the building is inserted. One of the targets is to improve the energy building performance through the application of embedded systems, integrating smart technologies in the building structure and in its envelope. The use of latest technologies (nanotech and smart) with low environmental and economic impact allows designing and visually enhancing a type of building usually camouflaged in nature and the environment. This makes possible to directly relate the shape and building visibility with environmental stimuli.

This research is coming from the Media Architecture Subunit, part of the Research Unit "Colour and Light in Architecture" of the University Iuav of Venice.

1. INTRODUCTION

The abandoned military heritage of the Veneto Region (Italy) is quantitatively significant and constitutes a system of such historical, cultural and environmental importance that needs a specific approach with regard to its requalification, valorization and management. So it's necessary to make some strategic choices useful to resources preservations and try an approach site respective. Because the artifacts were placed in strategic defense sites, they had a very high impact on neighboring land transformation along all historical periods. The fortified systems cannot be read as isolated objects, regardless of their size, but as part of a wider organic defense system, spread on the territory, conditioning the historical site evolution. Therefore, their location, shape, size, visibility or camouflage, including construction techniques, materials or colors was chosen to make them hidden or evident (P. Zennaro: 2010). They are part of a thought, caused by the lack of their use, running to oblivion much faster than other kind of artifacts do. The case of the fortified system of Cavallino-Treporti, unique in Italy for the amount and type of defensive buildings, can become a case-history of how we can develop, in peace time, those structures that were built and designed for functions now perfectly useless, giving new functions and visibility.

2. Si.S.Sy PROJECT

The Si.S.Sy project (Site Specific System) is the enhancement of the relationship between the *site* (the decommissioned military artifact and its surroundings) and the *project*. The project is made by an organic intervention system designed for converting an historical artifact in an active and reactive structure immersed into an environmental context. The "reactive architectures" measure the environmental conditions through a sensor (embedded) system designed to enable buildings to adapt their shape, color or light in response to an input coming from inside or outside the building. The optical and acoustic stimulation (images, sounds, symbols, signals) will generate the changing scenes, projected on the military buildings walls and in the surrounding landscape.

Another goal of the Si.S.Sy project at the Cavallino-Treporti fortified system consists also on the improving of the building *energy efficiency* through the application of smart technologies in cooperation with embedded systems, integrating smart materials and technologies into the building and its envelope. The smart materials are also environmental input reactive (light, moisture, sound, etc..), acting as reversible and zero energy. In this way it's possible to relate the building shape and visibility with the environmental input. The use of low environmental impact smart/nanotech technology can valorize this type of construction, usually camouflaged into the nature, from a visual, design and economic point of view. The environmental project impact will aim to valorize the application of smart technologies with results zero energy or energy plus oriented. The application of smart digital technologies ensures energy self-sufficient systems for use in ordinary and extraordinary management and maintenance conditions within 24 hours.

The project consists of three closely interrelated areas:

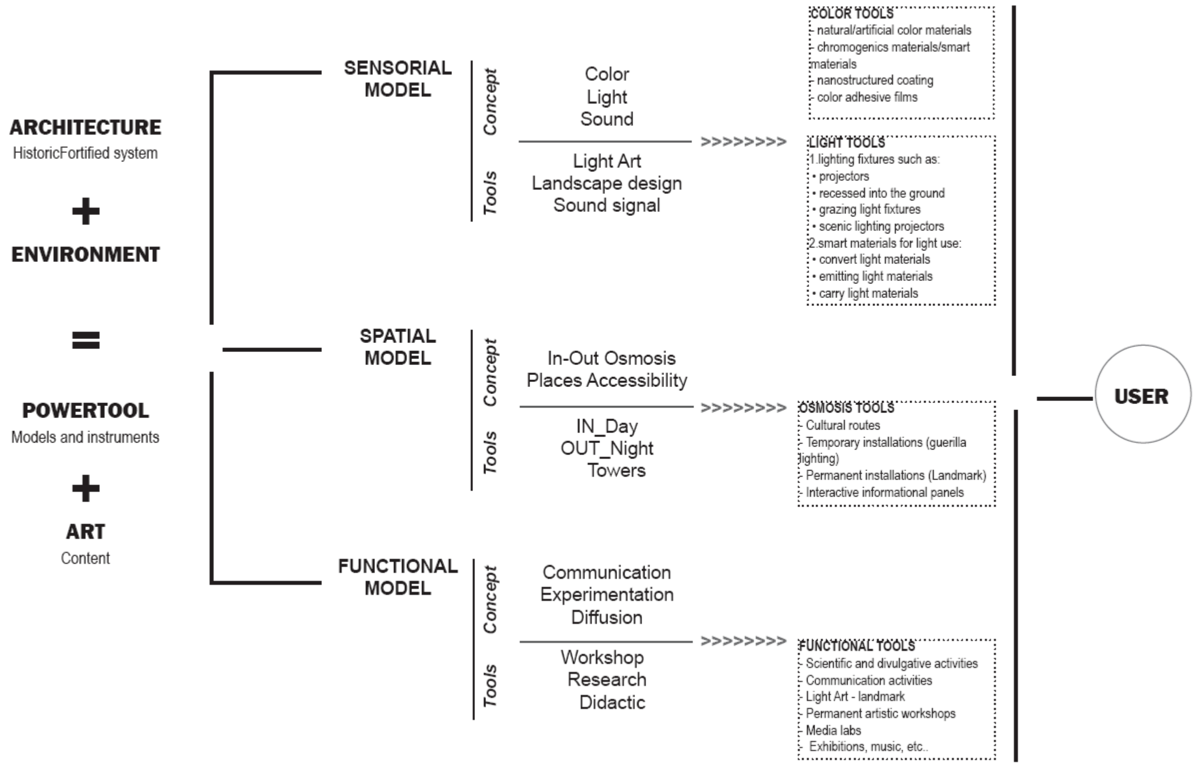
- Project management and identity of places
- Recovery, Requalification and Environmental Valorization
- Model Experimental Verification.

3. RECOVERING, REQUALIFICATION AND ENVIRONMENTAL VALORIZATION

The paper focuses on the more important part of the research, concerning the requalification and environmental valorization instruments. Environmental requalification in the Cavallino-Treporti case history requires a diversified approach, depending on many parameters: the fortification and the defense typology, their location, their conservation status, the potential use of the areas, the usability of outdoor spaces, the network of connections, the security level and other unique aspects that may emerge in the individual analysis cases. This is possible only planning project actions having the aim of integrate the building with the design of electronic and digital technologies (A. Premier: 2011), giving a new interactive Landmark role for the control towers. It's also possible to use light sources for light art installations, or color technologies able to create landscape design object, or sound installations. These projects can be designed and made on site through thematic workshops or research creations.

The possible action with a Si.S.Sy. is designed by the distribution of some technical equipment (like as: projectors, light systems, light sources, etc..) located near the monument or building. In this way, the control towers and fortifications could be like a movie set where movies, images, graphics and other communications elements are projected. The *site-specific* may consist in *works of art* created and placed in a specific site to be viewed comfortably during daylight hours, or in colored nighttime lighted installations able to extend their useful life during the night (light art). The project consists of *three models*, each identified by a specific concept, created with different tools. The models (see fig.1) designed in this study are: 1. sensorial model; 2. spatial model; 3. functional model.

Figure 1. Diagram of model simulation



3.1 Sensorial model

The concept of this model is developed by synesthesia topics, in places where an audition, olfaction, tactility or visual stimulation, is perceived as a distinct sensorial event but living together. In the specific Cavallino_Treporti case history the principal subject are based on assumptions of: color - light - sound and their meanings in context. This is a model that connects the cultural and scientific part of project with the most constructive part, so by semantics to technology.

The tools used in these cases are derived prevalently from the *lighting area*, but interact with the *color and formal perception* of objects, marking their shape and architecture user interactive. From this point of view, we can consider two main categories of the bright components and materials:

1. lighting fixtures such as:
    - projectors
    - recessed into the ground
    - grazing light fixtures
    - scenic lighting projectors
2. smart materials for light use:

• converting light materials (photovoltaic)
• emitting light materials (electroluminescent, phosphorescent, laser, OLED, etc.)
• carry light materials (fiber optics, light pipes)

3.2 Spatial model

The spatial model pays attention to the flows and the site *accessibility* concept. The assumption of this model consists in the realization of a two-way communication between the architecture (forts, towers, etc.) and the context; in fact: between architecture, the context and the user. The model aim is the realization of an osmotic flow between these three "elements" within 24 hours in a material, cultural and perceptual sense. In this way the spatial model is physically and logically connected to the sensory model.

In this phase the tool is explicit on three levels:

- IN_ diurnal osmosis
- OUT_ nighttime osmosis
- architecture.

The buildings valorization and their visual interaction with the landscape are part of this model. The routes (at different levels) and the areas of landscaping are related to the sensory model. From this point of view, the applicable systems can be summarized as follows:

- Cultural routes
- Temporary installations (like as "guerilla lighting")
- Permanent installations (Landmarks)
- Interactive informational panels

3.3 Functional Model

The functional model integrates the previous ones and concretizes their results through research activities of planning and management, or art/architectural workshops, or educational activities organized within the area and spread in a capillary system in the territory. The concept underlying the model can be synthesized in three points: Experimentation; Communication; Dissemination.

In this case, the artifacts and the pertinence areas can be transformed into experimental laboratories making the Lido of Cavallino-Treporti in a "diffused laboratory". This is a real expression in the concept of "Social Art," which in modern times goes into contact with the people who lives the environment and relates with the urban and sociological topics. The environment becomes a *work of art*, running on the possible meanings and exchanges with the community.

REFERENCES

Premier, A. 2011. Il futuro in superficie. In *in Superficie*, ed. by A.Premier. Verona: Knemesi, 165-177.

Zennaro, P. 2010. Towards an Architecture of Chromatic Immateriality. In *Colour&Light in Architecture*, ed. by P. Zennaro. Verona: Knemesi, 444-449.

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Color Structure Analysis according to the Type of Media Façade as the Construction Materials

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ABSTRACT

This study is to ascertain whether the color structure of media façade with the function of construction materials is different from that of the general media façade for advertisements and if such difference can be analyzed. The methods adopted for the study are as follows: First, the case study was made with the media façades installed in Manhattan, New York, because the media façade was originated in New York and the current trends of media façade are led by them. After having surveyed the media facades in Manhattan, New York through the literatures, cases proper to this study were selected. Second, the selected cases were classified into four different types. Third, each case was measured by the naked eye using a digital camera and the color brightness photometer. The colors of each case were analyzed based on the CIE color coordinates for the color difference and chromaticity. As a result of this study, the method to measure the quantitative color distribution using the brightness photometer and CIE chromaticity coordinate diagram was drawn and the resulting values by the chromaticity area distribution and the distance value through the color analysis process could be acquired.

1. INTRODUCTION

Due to the advancement of light emitting diode (LED) lighting industry along with media technology, media-façade is able to display various forms and colors. This cultural trend could be perceived as sentimental interaction in which people and buildings are interconnected. Moreover, thinking from the aspect of environment color design, the night landscape reflecting urban cultural trend constitutes crucial part in color design of urban landscape. Installation of media-façade is widely applied from the interior design to the exterior of high-rise buildings and conveys rapidly changing contents according to people's needs including delivery of information. In order for conventional commercial information contents to be considered as new architectural materials of advanced level, proposals and methods of color composition for media-façade contents are essential. However, quantitative analysis on colors has been insufficiently performed. Therefore, color conditioning and harmony of media-façade have to be approached from the aspect of landscape color design. Furthermore, concrete color composition methods have to be proposed. This study investigated on buildings and sculptures in New York City leading media-façade cultural trend. Moreover, characteristics of each case were analyzed by assessing colors according to transformation of media-façade. The classification was categorized based on each case's characteristics. By comparing color distribution based on categorization, color composition of media-façade was examined whether it could be used as architectural materials.

2. PURPOSE AND METHODS OF THE STUDY

This study is focusing on the media facades constructed in Manhattan, New York which the media façade was originated from and is leading the current trends of media façade. The media facades located in Manhattan, New York were investigated and selected as the cases through the documentary survey. After classifying the selected cases into types, each case was photographed using the digital cameras with the naked eye and measured by the color brightness photometer CS-100s device. Consecutive measurements were made 200 times for each case in the interval of 1 second according to the changes of the media facades to determine the color difference, chromaticity and brightness. The colors of each case were analyzed by CIE chromaticity coordinates to see the color difference and the chromaticity. The study aims to make a comparison by analyzing media-façade that could perform function of architectural materials and how color composition of media-façade differs from that of general advertising façade.

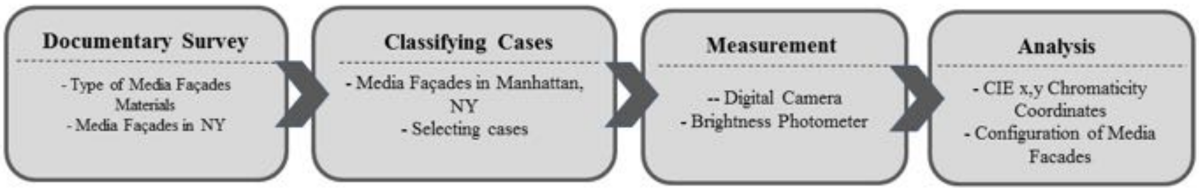

Figure 1. Research Process and Scope

3. INTEGRATION OF MEDIA-FAÇADE AND ARCHITECTURE

Media technology is accepted as one of the factors in architecture rather than an independent subject from buildings, in other words, it is regarded as an integrated factor. The media technology is now considered as new architectural aesthetics by means of a media complex unlike before when it was regarded as a deteriorating factor of architectural aesthetics. There are some cases, unlike being confined to commercial advertisement, where architecture and media technology are integrated. In 2004, UN studio designed façade of Galleria department store, located in business district of Apgujeong-dong in Seoul, and presented façade as architectural materials with high sensibility. The building envelope was decorated with 4330 pieces of glass disk with diameter of 83cm attached to holograms, and LED lighting programmed with every single RGB color codes applied at the backside of each glass disk. The building itself became the city landmark promoting fashion images by creating diverse dynamic images. (Fig. 2) The solar-powered GreenPix Media Wall in Beijing enhanced energy efficiency and showed artistic aspect by introducing digital media art. Media-façade in buildings was merely finishing materials relying on physical properties of the material itself. However, it is emerged as an independent apparatus. (Fig. 3) By looking at the two cases accomplished by architects, efforts to search for new colorful spaces for media-façade by experimenting various sensibility of materials are revealed. Realization of various colors is achievable depending on architectural materials. Creation of new color palette is expected through this progress. The study aims to advance methods for color extraction data through architectural materials based on color testing prototypes of architecturally-integrated façade. Even though color variations are expressed, the colors obtained from architectural materials are forecasted to be within the common range of colors available or have certain patterns.

Figure 2. Façade Galleria Department Store(Seoul, South Korea) and Study model

Figure 3. Lighting test using the prototype and façade GreenPix(Beijing, China)

4. CATEGORIZATION OF CASE STUDIES AND COLOR ANALYSIS

Media-façade is predicted to be originated from "zipper" displaying daily importance messages briefly in Time Square in New York City in 1928. Based on the "zipper", the first signboard was put up in building elevation. Since then, the development of LED screen technology led to the appearance of super-sized billboards. Nowadays, LED technology is applied to architectural surfaces and media-façade has genuinely emerged. The study categorized the characteristics of case studies examined by visiting New York City's Time Square, the origin of media-façade.The types of media façades can be divided as follows: The first type is the billboard that plays the role of large outdoor signboard. The second type is the one displaying the contents in consideration of the building shape. The main purpose of these two types is commercial advertising. The third type is the media façades with abstract and artistic expression, not intended for commercial use. In case of this type, they are composed of LED alone, not mixed with the other kinds of materials. The fourth type is the media façades displaying contents, consisting of LED and other construction materials. For the types 3 and 4 which are used as the construction materials, the continuously changing colors were investigated by measuring the distance of each of the coordinate values according to the time in the color space with the CIE x,y color coordinate information measured per second to see the color system related to the changing contents.

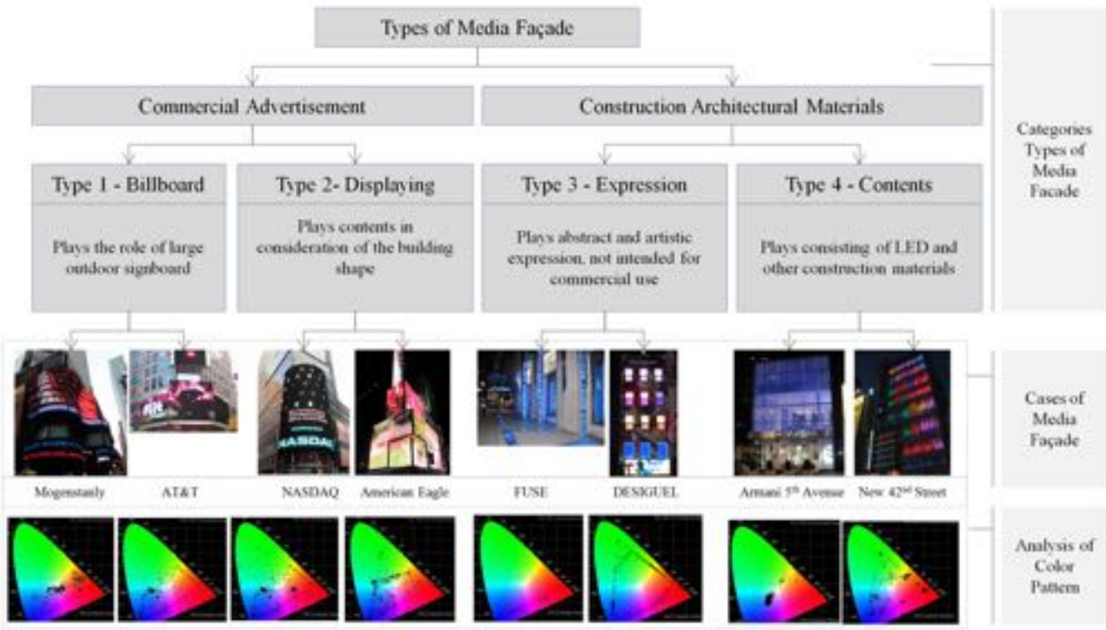

Figure 4. Categorizing Characteristics of Types of Media Façade

As a result of analyzing the CIE chromaticity coordinates distance value according to the time and the chromaticity area, the fourth type did show little difference in general in the distance values between each color coordinate. This means high purity colors in a similar system were used according to the change of time. On the other hand, the difference values of the third type were bigger than those of the fourth type. It means the change of colors of the third type is significant. The third type showed the changes of distance values in the range from 0.2 to 0.8. The maximum distance of the fourth type was 0.4. In addition, the x and y coordinate distance values of each type and the correlations of the chromaticity area were analyzed to see the relationship of coordinates according to the chromaticity area. As shown in Fig. 5, color distribution category of architecturally- integrated media-façade consecutively shows patterns in the range of same saturation level in case where colors around white area at the center or various colors on the CIE chromaticity diagram were used.

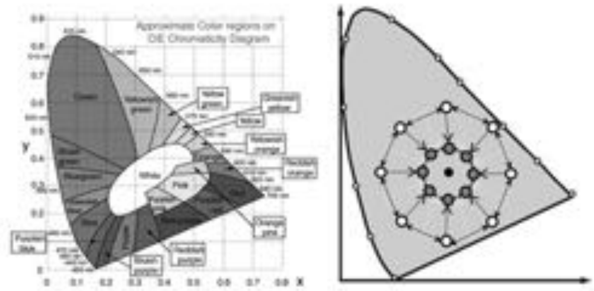

Figure 5. CIE x,y color region diagram and integrate architecture color pattern diagram

5. CONCLUSION

The conclusions of the study are as follows: First, categorization was carried out using characteristics of media-façade case studies. Second, media-façade made of materials from architecturally-integrated categorization enables comprehension of regular patterns in the color system. Identifying architectural materials is verified to be crucial in realizing colors of media-façade. In other words, new color system values are attainable by using reflection of color and materials. By considering formulation of color system, development of color design guideline is essential by reflecting new inventive color values. Due to continuous advancement of LED industry, media-façade could be utilized as building's exterior elevation materials in a cost effective manner. Therefore, it could be used as finishing materials in billboards and exterior elevations of the entire building. Functional ranges are forecasted to be further expanded as the background of commercial advertisement by adequately using as the background color of outdoor billboards to give an example of the range in practical use.

ACKNOLWLEDGMENTS

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REFERENCES

Janos, S., 2007, *Colorimetry, Understanding the CIE System,* John Willey & Sons, Inc

Juyeon, K., Jaewan, P., 2011, Study on the Chromaticity Coordinates Analysis in Accordance with the Classified Media Façade Types, *Journal of the Digital Design,* 33: 1-10

Mark, D. F., 2005, *Color Appearance Model*, John Willey & Sons, Inc

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Effects on Color Assessment Depending on Visual Ranges in Landscape

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ABSTRSCT
In this study, experiments were performed to quantitatively examine the effects on color assessment by considering three different visual ranges in the landscape. As results, small distance between the objects and the viewers had effects on the feeling of harmony and pressure with landscape. On the other hand, large distance between the objects and the viewers had effects on the feeling of conspicuity with landscape. From the above findings, it can be concluded that the assessment results differed depending on the distance between the objects and the viewers in the environment.

1. INTRODUCTION

It is generally believed that the humans' assessment of a particular color of an object in an environment differs depending on the distance between the object and the viewer. From the results of the previous studies, it is found that the chroma values decrease with an increase in the visual range by experiments to survey the relation between the "luminance" and the "chroma values". However, the effects on the humans' assessment of different colors in the environment, depending on the distance between an object and the viewer, were unknown. In this study, experiments were performed to quantitatively examine the effects on color assessment by considering three different visual ranges in the landscape.

2.EXPERIMENTAL METHODS

The experiments were performed in the historic preservation district of Kurashiki city in Japan. 21 participants were selected for these experiments. First, color panels of A1 size (594 mm × 840 mm) were hung at the height of the 13M position from the ground level. The participants assessed each color panel in the landscape from three viewpoints, i.e., from a distance of 25 m (close viewpoint), from a distance of 50 m (middle viewpoint), and from a distance of 100 m (far viewpoint). In figure 1, a scene from middle viewpoint was shown. The assessment indicators were constructed using 7 rating scales The rating scales had four indicators, namely, conspicuity, harmony, vitality, and pressure. After the participants viewed each color panel, they assessed the panels on the seven-point scale. In table 1, simulations of experiments were shown. Then, simulation patterns were created under the following conditions. The color panels showed the following nine hues: 5R, 5YR, 5Y, 5GY, 5RP, 5BG, 5B, 5PB, and 5P. They also showed values of 5 and 8. Further, they showed three types of chromas, namely, 1, 3, and 6. In addition, the panels showed neutral colors 5 and 8. The experimenter prepared a total of 56 color panels using different combinations of hue, value, and chroma. It should be noted that the experiment was completed in approximately 2 h.

Figure 1: A scene from middle viewpoint

Table 1: Simulations of experiments

FACTORS	LEVELS
Hue	5R, 5YR, 5Y, 5GY, 5RP, 5BG, 5B, 5PB, 5P and N.
Value	5,8
Chroma	1,3,6 (N was excepted)
Visual ranges	25 m (close viewpoint), 50 m (middle viewpoint), and 100 m (far viewpoint).

3. RESULTS AND DISCUSSION

From the results of the analysis of the variance, the following three points were quantitatively demonstrated with significant differences. In figure2, the effect on conspicuity was shown. It was demonstrated that 5R and 5RP have an effect on more conspicuity than 5Y and N; that chroma 6 have an effect on more conspicuity than chroma 1. In addition, when visual range was a far viewpoint, conspicuity tended to be appreciated. In figure 3, the effect on harmony was shown. It was demonstrated that 5Y and N have an effect on more harmony than 5RP; that chroma 1 have an effect on more harmony than chroma 6. In addition, when visual range was a close viewpoint, harmony tended to be appreciated. In figure 4, the effect on vitality was shown. It was demonstrated that 5R and 5RP have an effect on more vitality than 5Y and N; that value 8 have an effect on more vitality value 5; that chroma 6 have an effect on more vitality than chroma 1. In figure 5, the effect on pressure was shown. It was demonstrated that 5R and 5RP have an effect on more pressure than 5Y, 5GY and N; that chroma 6 have an effect on more pressure than chroma 1; besides that value 5 have an effect on more pressure value 8. In addition, when visual range was a close viewpoint, pressure tended to be appreciated.

Thus, small distance between the objects and the viewers had effects on the feeling of harmony and pressure with landscape. On the other hand, large distance between the objects and the viewers had effects on the feeling of conspicuity with landscape. It is interesting to note that the visual range had no effect on vitality.

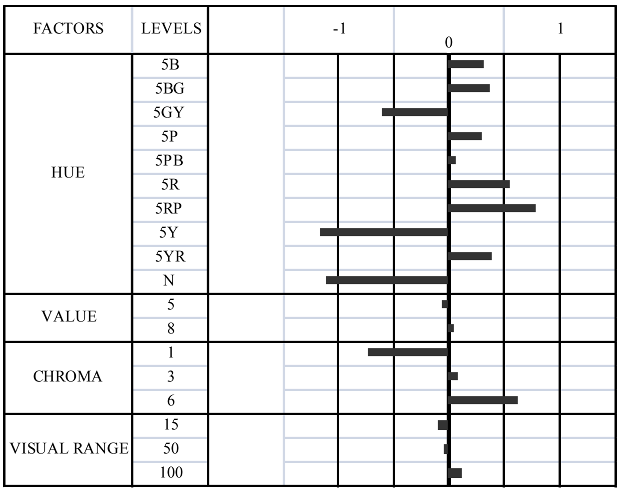

Figure 2: Effect on Conspicuity

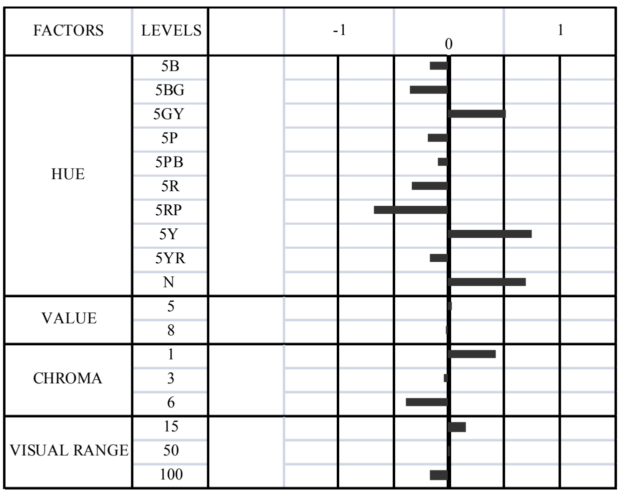

Figure 3: Effect on Harmony

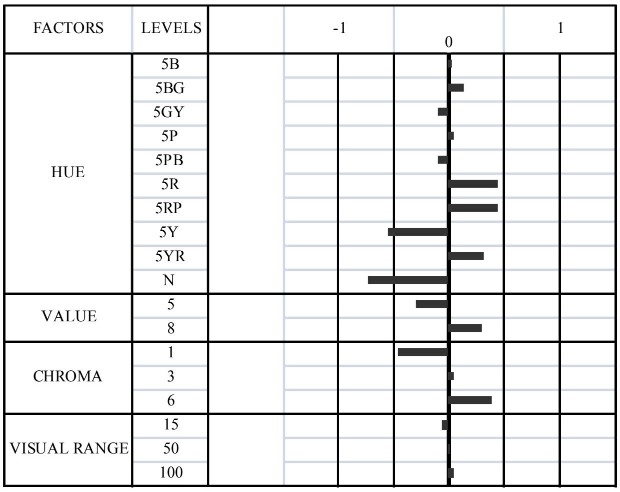

Figure 4: Effect on Vitality

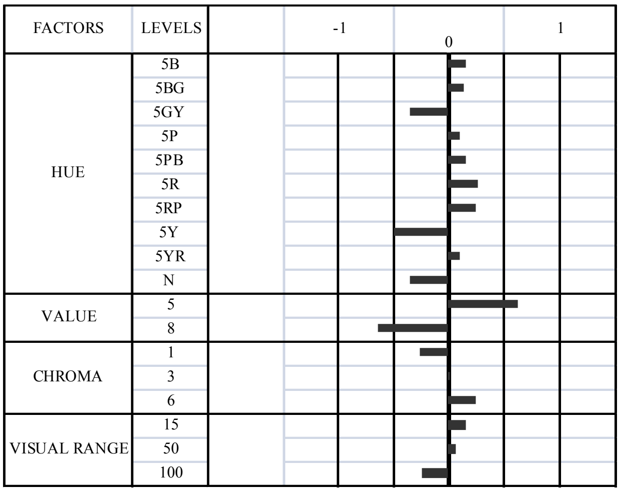

Figure 5: Effect on Pressure

4.Conclusions

From the above findings, it can be concluded that the assessment results differed depending on the distance between the objects and the viewers in the environment. In the case of the assessment from a close viewpoint, harmony and pressure should be considered carefully while designing a color environment. On the other hand, in the case of the assessment from a far viewpoint, conspicuity should be considered while designing a color environment.

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New uses of color in urban open spaces - the constitution of a tool generating discourses in the French city of Nantes

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ABSTRACT

This study is about understanding the emergence of a new kind of urban highly saturated polychromy, observable on many façades in the new quarters of French cities. We expose a graphic exploratory work at the scale of the French city of Nantes. Our purpose is the constitution of a visual tool able to generate discourses from urban project's actors on their use of color.

1. CONTEXT

Among the multiple aspects of the contemporary urban landscape, color seems to be an unavoidable component of architectural design. Our study focuses on the emergence of a specific polychromy applied to many architectural elements, which impose themselves visually by an unusual colored contrast that they maintain with their external environment.

The massive use of saturated and artificial colors displayed in frontage, transforms our perception of the urban landscape. The optical influences of these new shades go past the simple volumetric limits of buildings and radiate through several landscape scales, until having a repercussion on the image of the city. Covering up all types of programs, the "loud" color not only appears on new constructions but as well on existing buildings by thermal or visual refurbishments in double-skin.

Varied reactions appear concerning the intensive use of these colors and the quality of the urban spaces they border. Their verbal characterization is carrying negative connotations. « *Plus que jamais elles sont, pour les besoins du marketing, d'omniprésentes allumeuses [...] imposant avec elles un goût souvent grégaire, stéréotypé–celui du kitsch par exemple, des couleurs flaschy*. »[1] (Pinson, 2011, p.83). The fast development and the sudden way of their establishment ask many questions which this present research project proposes to discuss.

2. DEBATES AND HYPOTHESIS

Firstly, we can interrogate the origin and the factors of development of this phenomenon. As A. Picon (2010) highlights it, are we confronted to a crisis of the tectonic supporting the reinvention of the ornament, in particular thanks to the malleability of the computer tool in the communication and individualization society? Are we today answering to a frustration inherited from the large housing developments? Face to the economic ant tourist competition between the cities, is color playing a part in the marketing of its most contemporary architectural designs? Is this new polychromy launched by climatic challenges, calling on an affordable range of durable and performing materials with vast pallete of colors revivified by

[1] "More than ever, they are, for marketing's needs, omnipresent teasers […] imposing often with them a gregarious taste, stereotyped - the kitsch for example, of flashy colors."

petrochemical industry? In a second time, our study is about understanding and analyzing the reasons which motivated the urban project actors in their use of color. Which role do they allot to color: structuration, identity, harmony, visual domination, mimesis effect or palliative to an architectural weakness? We can interrogate the perceptive dimension of urban ambiances thus created, through the concepts of urban pleasure and appropriation of space by the users. Does color accompany the creation of new urban forms? How do we anticipate the aesthetic obsolescence of colors and the concept of the "disposable frontage"?

3. METHOD

Readings of colored samples on the Nantes urban area

In order to characterize our subject, we choose to approach it through the example of the urban area of Nantes, and through several modalities (sensitivity, regulations, geography, economy, etc…). The following images show one of the eight "colored sequences" carried out between October 2011 and January 2012. *Sequences* due to the phenomenon of the observer in movement, and *colored* to illustrate a certain freedom maintained in the chromatic choices (fig.1). These readings begin to constitute a notebook of "local colors", a colorful portrait through which the city can be identified. The various sequences were taking down along fractions of routes of public transport (tramway, bus-way, bus) or pedestrian precincts. The zones concerned by these examples enter within the framework of broad projects of town planning, and the landscape we take down today is already obsolete a few weeks later. These "urban frames" thus evolve quickly.

Method of readings and expected method of investigation

The experimental work under development is guided by a graphic arts vocational training.
The justification of the sketch is an aesthetic and methodical bias passing by the mobilization of the tools specific to the architect. By its malleability, the sketch facilitates the questions of framing, panoramic vision, contrasts of luminosity, contrejour… It favours the reading by proposing a landscape synthesis disregarding elements obstructing the vision. The choice of the medium takes part in the retranscription of the in-situ felt impressions. By the shift produced between reality and the drawn image, it brings a distance necessary to the value judgments.

Through the chromatic patterns (fig. 1), we synthesize every building in a square of a few centimeters across the colors used, their chromatic number and their associations. These colors are composed in the square in a schematic way. The definition of a colored pattern for every architectural objects proved thereafter to be a synthesis tool facilitating the study in terms of analysis programmatic, cartography (fig. 2), of color composition, chromatic association, colors redundancy. Because, a traveller in the tramway, a motorist, a pedestrian, or an inhabitant of the places holds a relatively different experiment of the site, the process of "fragmentation" (fig. 1) outlines a retranscription of the colored visual prints, broken up by layers according to a speed of movement and a landscape chromatic pallet.

This graphic approach gradually constitutes the bases of a tool, whose objective is, initially, to generate discourses from the urban project's actors. The notebook composes a matrix of prototypes conceived such as an inventory of concrete examples: site and visibility, colorimetric patterns (figures, proportions, contrasts), colored associations (marketing tendencies and aesthetic obsolescence), materiality (effects, virtuality of new materials, variations due to movement), color accents, rhythms and relationship between the object and its external environment (domination, signal buildings, search of uniformity, harmony, disharmony, etc.). We plan to use for the work of investigation several complementary methods including the method of the *Commented Routes* from J-P Thibaud (2001).

Figure 1. Colored sequence n°7, Island of Nantes

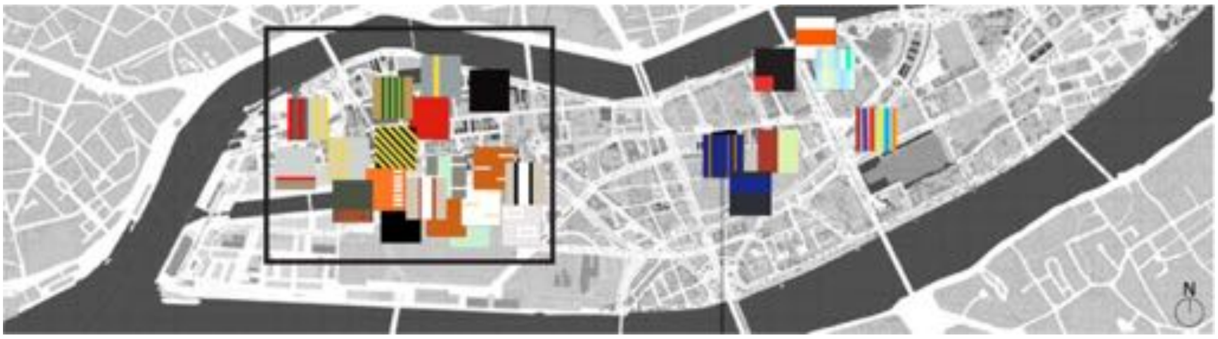
3. GENERAL OBSERVATIONS

According to the study initiated on Nantes urban area, we can from now make certain reports. We observe the redundancy of certain colored sharp essentially saturated and bright: acidulated color range, range of the greens tendencies, ochres, etc. We also perceive a great diversity of colors, colored associations, patterns and materials, and this, independently of the programs. It does not seem that we can define the recurrence of a range according to a particular kind of program.

In addition, one of the discernable aspects is the chromatic correspondence of the buildings according to their urban geographical locations (fig. 2). The “colored sequence n°7” located on l’Ile de Nantes illustrates this hypothesis (fig.1 and 2). Then, the mode of displacement influences the apprehension of the colored site (frequency of the borrowed road axes, temporalities of observation). A traveller of tram, a motorist, a pedestrian, or an inhabitant of the places, holds doubtless an experiment relatively different from the site.

To finish, a qualitative disparity in terms of colored treatments is identifiable according to the role given to color in the architectural design. Schematically, we could dissociate two zones in Nantes: the downtown area and the periurban zone. The downtown area, the show-window of the city, employs the “color-spectacle” and its rich associations of color-light-materials. In the periurban zones, the color appears to enliven the daily “greyness”. The built units seem to produce sometimes “chaotic” images which disturb existing balance and pose questions on the urban unity.

Figure 2. Cartography of chromatic patterns at the scale of Nantes (work in progress)



LIST OF BIBLIOGRAPHICAL REFERENCES

Lenclos, J-P., Lenclos D. and Rivière G-H. 1982, *Couleurs de la France : géographie de la couleur*, Paris : Le Moniteur.

Picon A. 2010, *Culture numérique et architecture*, Vol.217, Basel: Birkhäuser GmbH.

Pinson J-C. 2011, *Habiter la couleur* suivi de *De la Mocheté*, Paris, Ed. Cecile Defaut.

Thibaud J-P., Grosjean M. 2001, *L'espace urbain en méthode*, Marseille, Ed. Parenthèses.

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Do people prefer grey？A research on architectural color in changzhou

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ABSTRACT

Architectural color in urban has become one of the hot topics in China today.This research is a pre-survey for the urban color plan for Changzhou in 2011 of 253 square kilometers on the present color as well as the residential color bias. The questionare includes two aspects of the present and the future with unstructed type. The research group made an overall survey and evaluation on the present architectural color. Figure reveals that those get the higher scores lay in the colored building, while those grayish ones which prevail in the whole city get lower scores. Result reveals that the present façade color is mainly that of grey, while residents are inclined to the colored one.

1. BACKGROUND

Since March 2000[i], by the rapid development in Chinese city, the necessarity of urban color plan has been approved and many practices have been undertaken. However, worries arouse as most of them the grey color as the dominant hue. The project of *Changzhou Urban Color Plan* is a good chance to discuss the residential attitude and site color apperance.

2. METHODS FOR SURVEY AND SCALES FOR ANALYSIS

2.1 Methods for Survey

Methods includes: a, assume the Unstructured Questionnaire and Color Card (NC-1，Cascade 980) in interview; b, investigate each plot on site with the Color Card (A-6，NCS index 1950), assisted by color scan, drawings and graphics; c, analysis mainly from three aspects of brightness (blackness,S), chromaticness(C), and hue(Φ) by NCS color system.

2.2 Scales for Analysis

· Brightness(Blackness,S)：Set 5 scales.of high (0~10), mid-high (15~20), medium (25~35), mid-low (40~55), and low (60~90).

·Chromaticness(C) :Set 6 scales of high (80~90), mid-high(60~70), medium(40~50), mid-low (15~30), low （6～10）, and neutral (0~5).

·Hue(Φ)： According to the introduction of NCS index 1950, we take out the hue lower than 5 of grey (C=0), near to grey (C=02), and have little colors (C=05) as the neutrals seen as the grayish in urban space. And set 4 categories with the left according to NCS arrangement.

3 QUESTIONARE AND ANALYSIS

The questionnaire has 1065 effective from1086, which consists of two aspects of the attitude on the present and expectation for 6 aspects of residential, commercial, industrial, Administrative， and official business area with non-structure type and NCS Cascade 980 by the team of 4 persons lasting 10 days at Southern Street, Peoples Park, Cultural Palace Square and Plum Park at holidays from 4 parts of urban color attitude,the present urban color in city, the ideal for future urban color, and the ideal color for different functional architecture.

Figure shows there has 65% person concern it. The attitude on the present is positive (positive 60% ，negetive 30% ，neutral 10％). Most of the interviewees hope the urban color is green and clean, and next is the need for dynamic. Obviously, the bright façade color is welcome. And, chromaticness of medium and mid-low is selected more. There have few differences among functional architectures. Neutrals sit the first at administrative and commercial office buildings as well as industrial ones. Except for the administrative ones, others have little difference in hue. The residential, commercial and educational buildings have yellow selected more but most of them look like brick red. High brightness is the fist selected. Except for the medium and mid-low is the second, others almost desend to low gradually. The color selected is mainly of mid-low chromaticness in residential, commercial, and commercial office buildings, while neutrals in administrative office. And colorful instrial building is also accepted.

Fig 1 the relationship among hue, brightness, and chromaticness in different functions

	Hue(Φ)（%）					Brightnss(S)（%）					Chromaticness(C)（%）					
	G	**B**	**Y**	**R**	**N**	**H**	**MH**	**M**	**ML**	**L**	**N**	**L**	**ML**	**M**	**MH**	**H**
C	33.3	30.9	10.9	16.2	8.7	72.6	14.3	6.2	5.3	1.5	8.7	9.9	37.9	33.2	9.0	1.4
R	18.9	19.8	20.9	20.0	20.4	76.5	10.7	5.0	6.0	1.8	20.4	17.7	36.2	18.8	6.3	0.6
CM	10.2	18.3	28.5	21.4	21.6	63.8	13.3	7.8	9.5	5.6	21.6	14.2	29.2	24.	8.2	2.1
A	7.1	17.1	16.0	13.0	46.8	47.1	8.3	17.4	17.6	9.5	46.9	16.8	19.3	13.5	3.0	0.4
CMO	11.8	24.4	15.4	18.9	29.5	58.2	11.8	16.1	10.1	3.8	28.7	18.4	31.0	17.4	4.1	0.4
E	18.5	18.9	23.1	22.0	17.5	76.6	11.8	5.5	5.1	1.1	17.5	12.5	33.3	24.8	10.4	1.5
I	18.1	25.8	14.0	13.7	28.4	54.5	13.7	8.8	14.0	9.0	30.6	15.9	24.7	22.3	6.7	0.8

**Horizontal: G: green; B: blue, Y: yellow, R: red, N: neutral; H: high brightness, M: medium brightness, ML: mid-low brightness, L: low brightness; *Vertical: C: city, R: residential, CM: commercial, A: administrative, CMO: commercial office, E: Educational, I: Industrial.*

4 SITE SURVEY AND ANALYSIS

According the present color appearances, we designate and number the plot and determine, note and evaluate from color charaters, color combinations, and relationship between color and architural mass, style, and material, as well as special locations under 5 grades of best, better, medium, relatively poor and poor to evaluate under the basic five functions of residential, office, commercial, educational. Analysis devides the evaluation into 7 of good, better, faint good, medium, faint poor, poor, and bad according to the area amount of each grade from hue, blackness and chromaticness.

Figure shows the color quality in the whole city is faint good. There has little high chroma but grayish the most and green the least. Yellow and red has better quality. Contrast to the common idea of green is not suitable for facad, the better is the most. However, the absolute area for green is lower which has little affection to the whole city color quality.

Figure in different function shows: a, the colorful façade get higher score than neutral. Warm color is better than cool one. Except for that of residential building, in which cool color is also amazing.b, high brightness façade is the most. In official building and educational building, medium brightness is better; and c, Neutral is also the main in chromaticness. However, mid-low and mid-high is better than neutral and low one. Generally speaking, the positive possibility is increase with the value of chromaticness increase.

Fig 2 the evaluation among hue (Φ), brightness (S), and chromaticness(C) in different functional architecture and the whole

	Hue(Φ)（%）					**Brightness(S)（%）**					**Chromaticness(C)（%）**					
	G	**B**	**Y**	**R**	**N**	**H**	**MH**	**M**	**ML**	**L**	**N**	**L**	**ML**	**M**	**MH**	**H**
C	1.2	8.1	14.9	3.0	72.8	51.5	32.1	8.9	6.0	1.5	72.8	11.6	12.1	2.4	1.0	0.025
R	1.4	4.7	25.0	4.1	**64.8**	**43.8**	**26.8**	10.5	18.0	1.0	**64.8**	15.7	16.2	2.9	0.4	—
O	0.5	6.5	11.4	2.3	**79.3**	**50.8**	**27.6**	16.9	1.9	2.8	**79.3**	5.7	11.8	2.3	0.001	0.007
CM	0.6	16.5	16.8	4.0	**62.1**	**64.6**	19.2	8.0	5.0	3.1	**62.1**	15.8	15.1	4.3	2.7	0.05
E	6.0	11.4	19.2	7.6	**55.8**	**58.0**	25.2	6.9	6.6	3.3	**55.8**	6.6	25.6	9.5	2.5	—
I	0.8	9.5	7.2	1.8	**80.7**	**60.5**	24.8	9.0	4.2	1.5	**80.7**	9.0	7.7	1.1	1.5	0.0002

** Horizontal: G: green; B: blue, Y: yellow, R: red, N: neutral; H: high brightness, M: medium brightness, ML: mid-low brightness, L: low brightness; * Vertical: C: city, R: residential, CM: commercial, E: Educational, I: Industrial*

Rating legend good better faint good middle faint poor poor bad

5 CONCLUSIONS

·There has slight difference in hue in functions. Most people wish the façade colored not too light colored. Yellow is preferred in residential, commercial and Educational buildings which tallies the investigation reports.

·The bright façade is generally accepted, high brightness is always the main choice which tallies the site investigation. However, Figure reveals that brightness in low and medium in specific materials and colors, the quality is good but little in proportion. This shows that some good visual effect can't depend entirely on ordinary idea. But, compared to the current popular dark grey building for, the external walls of the bright more favorite

·In the chroma, we realize that usually assumed low saturation does not be recognized, on the contrary, medium and med-low is preferred which concise the figures in site investigation.

·Some value has special features, ie, the red family in commercial with R and Y80 of higher propotion has better scores. Blackness value of 5, 6,8,9,50,70 has better or faint better character.

6 DISSCUSION

·Large amount of low chroma and high brightness show the depressing. The usually idea of "urban color chaos with large amount of high chroma color seen everywhere" is debatable as the high saturated color is usually the abrupt advertisement and the high chroma proportion is very limited even less than 0.05%.

·Different function buildings has not always require difference color. The cool like green also get high scores in residential buildings. Saturation affects greatly the quality. The color with high bightness and low chroma makes it powder gas and run-down. Commercial building is not gray the good, steady volume and color can also become landmarks.

·The uncertainty in questionare leads to the evaluation results not meet with the questionnaire completely. However, covering more than 1000 people's interviews and 16 members' investigation can clearly see the common laws.

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REFERENCES

Gou AP, Wang JB, Research on the Location Characters of Urban Color Plan in China, Color Research and Application, Volume 33, Number 1, Feburuary 2008, page 68~76

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Consideration of the Area Effect in Color Reproduction of a Billboard

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ABSTRACT

This paper describes our attempt to quantify the area effect by a simple psychophysical experiment attempting to utilize the result in color reproduction of a billboard. The results of the experiment show that if the background of an object is dark and the visual angle is large, the colors of the object tend to look bright. On the other hand, if the background is bright, the colors of the object except blue tend to look dark. In terms of hue and purity, the area effect is strongest in case of blue and nil in case of yellow.

1. INTRODUCTION

A billboard (Figure 1) is usually produced based on a proof (printed matter, Figure 2), which is examined and approved by a customer and a proof (smaller than about 600mm width) is produced based on a color sample indicated by a customer. If a customer confirms the compatibility of colors between the color sample and the proof, an actual billboard is printed. However, the difference of color appearance between the actual billboard and the proof often brings a problem. This difference may be caused by several reasons, such as the difference of area of the object, the difference of distance between the view point and the object (N. Asami, Y. Matsuyama, and S. Yamashita. 2006), and the difference of lighting condition (illumination, color temperature, etc.) . The last influence by lighting condition may be predicted by the color appearance model, e.g., CIECAM02, while the first two problems are modeled as one problem of the difference of visual angle, which is called the problem of area effect.

The aim of this research is to quantify the area effect by a psychophysical experiment to utilize the result in color reproduction of a billboard.

Figure 1. A large-sized billboard. (16,000mm x 8,500mm)

Figure 2. A proof for a billboard. (600mm x 320mm)

2. METHOD

The relation between the size of a billboard and the distance from a view point to the billboard can be described by only one parameter, a visual angle that a billboard subtends at the eye. We simplified this situation and designed the following psychophysical experiment.

The geometrical condition of the experiment is shown in Figure 3. Square images with visual angle of 2, 10, and 20 degrees were displayed on the monitor instead of a billboard. Four test colors, yellow, red, blue and green with visual angle of 10 or 20 degrees were compared to the reference stimulus with visual angle of 2 degrees of the same color. White, Gray and Black are used as a background color of the square images. *Yxy* values of the test colors and the background colors are listed in Table 1 and Table 2 respectively. A subject adjusts *LCh* (lightness, chroma and hue) of the reference image of 2 degrees to be the same as the test color of the image of 10 and 20 degrees.

Visual angle of 2 degrees corresponds to 15mm square (reference image) on the monitor screen, visual angle of 10 degrees corresponds to 73mm square (test image #1), and 20 degrees to 146mm square (test image #2). The square of the test image #1 or #2 is displayed on the left-hand side of the screen, the reference image is displayed on the right-hand side with a spacing of 145mm. There was no partition between the test image and the reference image. In order to avoid the influence of the ambient light, the monitor was covered by a black enclosure.

Six subjects (five male and one female, from 37 to 71 years old, with normal color vision for all) participated in our experiment.

After adjusting the color of reference image, the *LCh* value of the reference color was converted to *Yxy*, then ΔY, the difference of *Y* between reference color and test color, and *xy* chromaticity coordinate were plotted for each background and for each visual angle.

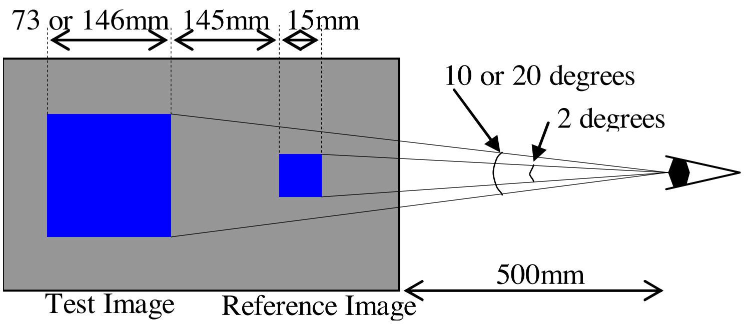


Figure 3. Viewing condition.

Table 1. Yxy value of test colors.

	Y	*x*	*y*
Red	11.8	0.652	0.314
Green	23.3	0.204	0.667
Blue	4.2	0.128	0.058
Yellow	40.6	0.428	0.498

Table 2. Yxy value of background colors.

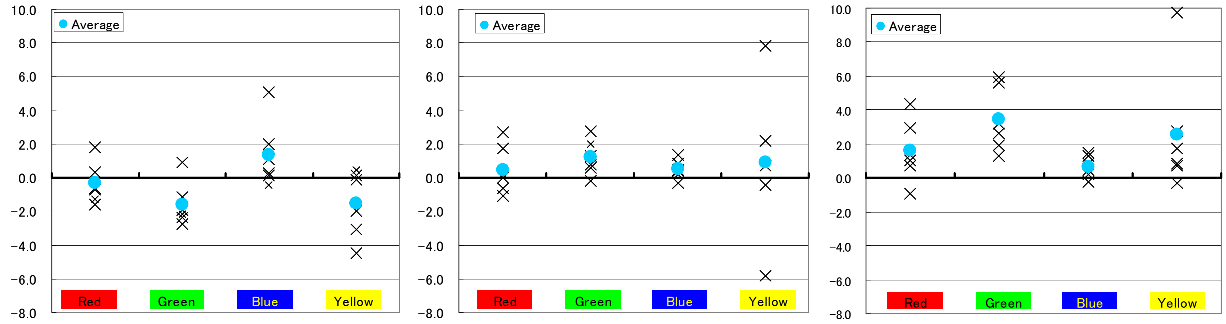
	Y	*x*	*y*
Red	57.2	0.3380	0.3471
Green	12.7	0.3407	0.3489
Blue	0.03	0.3264	0.3590

3. RESULT

The result of the experiment is presented in Figure 4, Figure 5, and Figure 6.

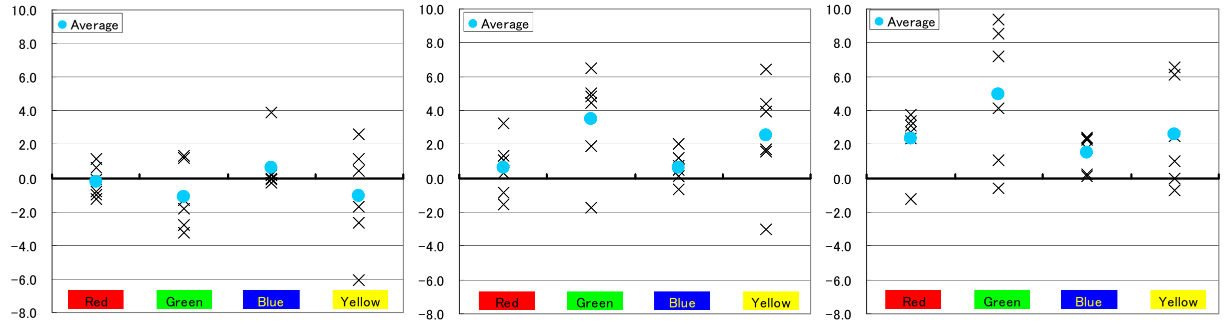
Figure 4 shows ΔY for visual angle of 10 degrees and Figure 5 shows ΔY for visual angle of 20 degrees. The light blue dots in each graph indicate the average difference, i.e., the difference of the average of *Y*'s of the reference colors for 6 subjects from *Y* of the test color.

In case of White background, for both visual angle of 10 and 20 degrees, ΔY's of Red, Green, and Yellow are negative, while ΔY of Blue is positive. Whereas, in case of Gray and Black background, for both visual angle of 10 and 20 degrees, ΔY's of Red, Green, Blue and Yellow are all positive. This suggests that, in a bright circumstance, a red or green or yellow image decreases its brightness according to the size of the image, while a blue image increases its brightness, but in a medium or dark circumstance, a red or green or blue or yellow image increases its brightness according to the size of the image.



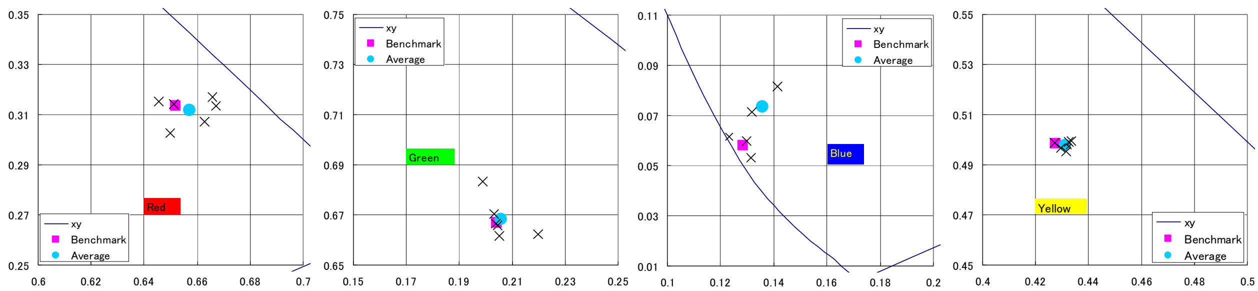
(a)White background (b)Gray background (c)Black background

Figure 4. Comparison of •Y for each color (10 degrees).

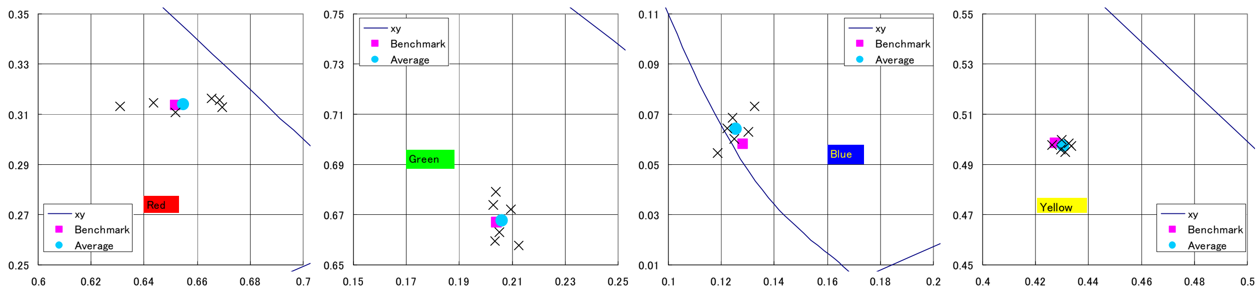


(a)White background (b)Gray background (c)Black background

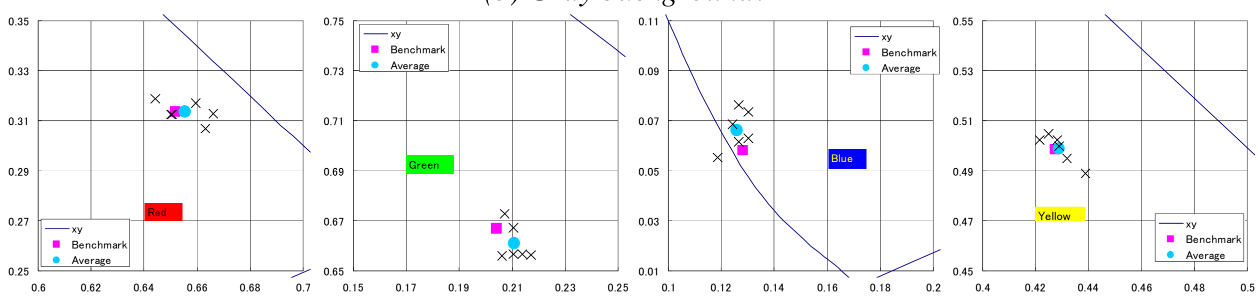
Figure 5. Comparison of ⊿Y for each color (20 degrees).



(a) White background.



(b) Gray background.



(c) Black background

Figure 6. xy chromaticity diagram of reference color with visual angle of 10 degrees.

Figure 6 shows the *xy* chromaticity diagram of reference color with visual angle of 10 degrees for each of three backgrounds. In each figure, the light blue dot indicates the centroid of *xy* coordinates for six subjects, and the pink dot indicates *xy* coordinate of the test color. The *xy* chromaticity diagram of reference color with visual angle of 20 degrees is omitted for the sake of saving space. The tendency of distribution of data is almost the same as the case of visual angle of 10 degrees.

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The observation of the diagrams, referring to the chromaticity of achromatic color, tells the following: in case of Red, with White background, the purity slightly increase, in case of Green, with Gray and Black background, the purity slightly decreases, in case of Blue, with White background, the purity slightly decreases, and with Gray and Black background, the hue slightly shifts, and in case of Yellow, there are no area effect. This is summarized in Table 3.

Table 3. Tendency of distribution of data in xy chromaticity diagram.

background	visual angle	Red	Green	Blue	Yellow
White	10°, 20°	purity+	---	purity-	---
Gray	10°, 20°	---	purity-	hue shift	---
Black	10°, 20°	?	purity-	hue shift	---

4. CONCLUSION

The relationship between visual angle and the color appearance of an object was clarified with a simple psychophysical experiment. The results of the experiment show that if the background of an object is dark and the visual angle is large, the colors of the object tend to look bright. On the other hand, if the background is bright, the colors of the object except blue tend to look dark. In terms of hue and purity, the area effect is strongest in case of blue and nil in case of yellow.

At the actual business situation, the difference of color appearance between the actual billboard and the proof often brings a problem. One way to solve this problem would be to share the knowledge of the area effect between the customer and the manufacturer. The results of our experiment can be applied to determine the parameters of color reproduction of an actual billboard.

REFERENCES

N. Asami, Y. Matsuyama, and S. Yamashita. 2006. *Shikyori no Henka ni tomonau Shikisai no Mie ni kansuru Kisoteki Kenkyu* (in Japanese). Japan Society of Civil Engineers Annual Academic Lecture Meeting 2006, Kyushu Sangyo University, 449-450.

N. Matsunobu, N. Asami, and Y. Matsuyama. 2005. *Yagai-Buttai ni okeru Mikake no Iro no Kyori-Henka ni kansuru Kisoteki Kenkyu* (in Japanese). Japan Society of Civil Engineers Annual Academic Lecture Meeting 2005, Kyushu Sangyo University, 409-410.

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New Experimental Data for Evaluating Colour Rendering Indexes

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ABSTRACT

A psychophysical experiment was conducted to evaluate the performance of colour fidelity based colour rendering indices. Ten observers assessed 22 colours under 19 light sources using the magnitude estimation method. The results showed that all CRIs gave similar performance.

1. INTRODUCTION

Colour Rendering Index (CRI) is one of the most important quality measures to evaluate sources in the lighting industry. The current CIE CRI [1], *CIE-*R_a, has been widely used in the industry for four decades. Manufacturers optimise the formulation of their lamps to achieve a high colour rendering index. However, the *CIE-*R_a has many drawbacks such as the usage of the outdated colorimetric tools and the poor estimation of narrow-band light sources such as light emitting diodes (LEDs) [2]. A CIE technical committee TC1-69 *Colour Rendition by White Light Sources* was established, having the term of reference as to investigate new methods for assessing the colour rendition properties of white-light sources used for illumination, including solid-state light sources, with the goal of recommending new assessment procedures. The TC members have been active and three CRIs were proposed: a colour fidelity based index (*CRI-CAM02UCS*) [3], Colour Quality Index (*CQS*) [4], and a colour memory based index (*MCRI*) [5]. There is a consensus from the TC members that the TC should first focus the colour fidelity based index, and to consider the other type of *CRIs* such as based on naturalness, attractiveness at a later stage.

More recently, a new index named *nCRI* based on *CRI-CAM02UCS* was also proposed. The main difference between the two is the test-sample set used, i.e. a set of mathematical test-sample set [6] was developed to avoid gaming.

This paper describes an experiment for assessing the colour fidelity quality of 19 sources. The experiment was conducted by assessing the change of colour appearance between a pair of sources.

2. EXPERIMENTAL

Table 1 sumamrises the engineering data of the 19 sources used in this study including luminance, correlated colour temperature (CCT), x,y chromaticity, and 4 types of CRIs. Telelumen®, an illuminator, includes 16 narrow-band LEDs across the visible spectrum to generate a light to match the spectral power distribution (spd) of a CIE reference source as used in the current CIE CRI. As shown in Table 1, their CCTs are close to CIE daylight illumination of 6500 and 5000 K, and Plankian Radiator of 4000, 3000 and 2500 K. They all had a high CIE CRI values ranged from 91 to 94.

Table 1. The engineering data of the light sources investigated

Sources	Light sources	Luminance	CCT	x	y	*CIE-R$_a$*	*CRI-CAM02UCS*	*CQS*	*nCRI*	*Average △E*
1	Filtered-Tungsten	327	7035	0.305	0.321	95	95	95	98	4.21
2	FB-F7	291	7203	0.303	0.319	96	96	98	99	4.67
3	FB-F8	401	5037	0.344	0.351	93	94	94	95	5.93
4	FN-CWF	313	4013	0.385	0.396	58	61	59	61	8.02
5	FT-4000K	176	4208	0.370	0.366	82	80	80	77	6.91
6	FT-3000K	138	2895	0.438	0.393	86	81	83	74	4.04
7	WLED 2700K	107	2610	0.468	0.413	89	88	88	90	5.09
8	WLED 3000K	104	2944	0.441	0.407	89	88	88	91	5.06
9	WLED 4000K	117	4071	0.375	0.367	93	92	91	87	5.84
10	WLED 5000K	100	5066	0.343	0.353	90	89	88	92	4.87
11	WLED LED 5700K-1	221	5815	0.326	0.336	87	86	84	89	5.04
12	WLED LED 5700K-2	261	5599	0.330	0.340	72	70	68	73	5.78
13	Energy-saving-F	318	5785	0.326	0.344	87	88	87	86	5.56
14	RGBLED-6500K	180	6556	0.314	0.311	25	37	50	42	10.98
15	**Telelumen-2500K**	**120**	**2522**	**0.467**	**0.401**	**91**	**91**	**95**	**97**	-
16	**Telelumen-3000K**	**169**	**3019**	**0.429**	**0.393**	**93**	**93**	**96**	**98**	-
17	**Telelumen-4000K**	**202**	**4050**	**0.376**	**0.367**	**94**	**95**	**96**	**98**	-
18	**Telelumen-5000K**	**204**	**5110**	**0.342**	**0.342**	**93**	**94**	**96**	**98**	-
19	**Telelumen-6500K**	**207**	**6745**	**0.311**	**0.314**	**94**	**94**	**96**	**98**	-

Note: FB, FN and FT are the broad-, normal- and tri- band fluorescent types, respectively. WLED and RGBLED are the phosphor and RGB LED lamps respectively. The 14 pairs of sources compared were: between Sources 15 (2500K) and 7; between Sources 16 (3000K) and 6, 8; between Sources 17 (4000K) and 4, 5 and 9; between Sources 18 (5000K) and 3, 10-13; between Sources 19 and 1, 2, 14.

Figure 1 shows the spds of the 19 sources studied. It can be seen that a large variety of sources were studied. Sources 15-17 and 18-19 are the 'reference' sources to match either the spd of Plankian radiators or CIE daylight illuminants, respectively. Sources 7-12 and 14 are the LED lamps, and the rest are different types of fluorescent lamps expect that Source 1 is a filtered tungsten.

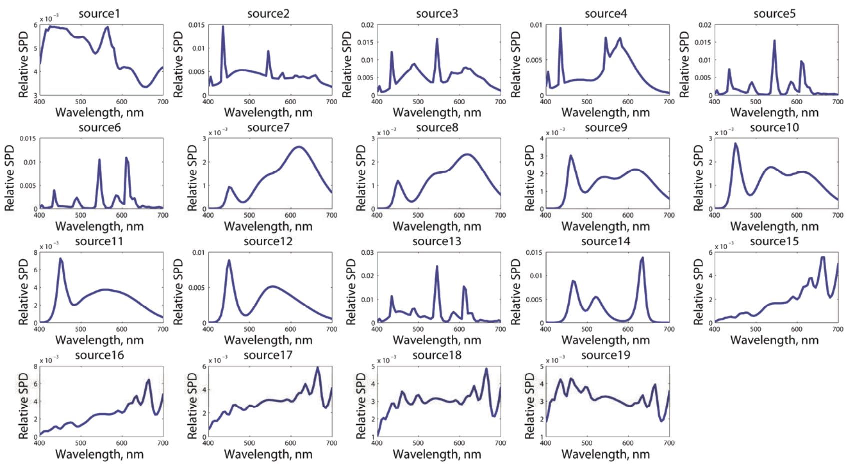

Figure 1: The spd for the 19 sources studied.

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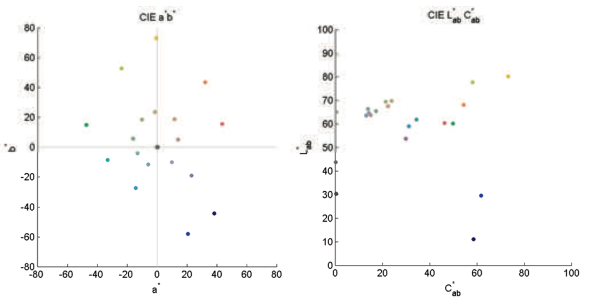
Twenty-two samples were selected to give a good coverage in colour space. Figures 2a and 2b show the sample distribution in CIELAB a) a^*b^* and b) $L^*C_{ab}{}^*$ planes respectively. Each sample had a size of 14.8 by 10.4 cm^2. Ten normal colour vision observers were first trained and then participated the experiment using the magnitude estimation technique [7]. For each sample, observers scaled the colourfulness and hue composition of each sample under each source as illustrated in Figure 3. Note that the short-term memory grey scale method was used to evaluate colour-difference in the earlier studies [8,9]. Observers estimated colour-difference of a colour between two sources based on memory. In the present study, observes were fully adapted under one source, with a natural viewing environment without switching two sources.



(a) (b)

Figure 2 Sample distribution in CIELAB (a) a^*b^* and (b) $L^*C_{ab}{}^*$ planes respectively.

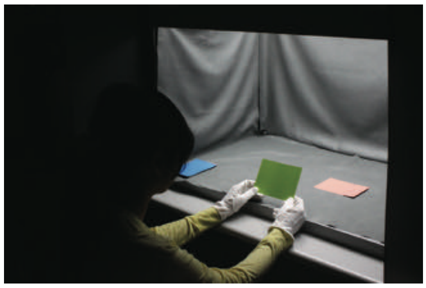


Figure 3 Experimental situation

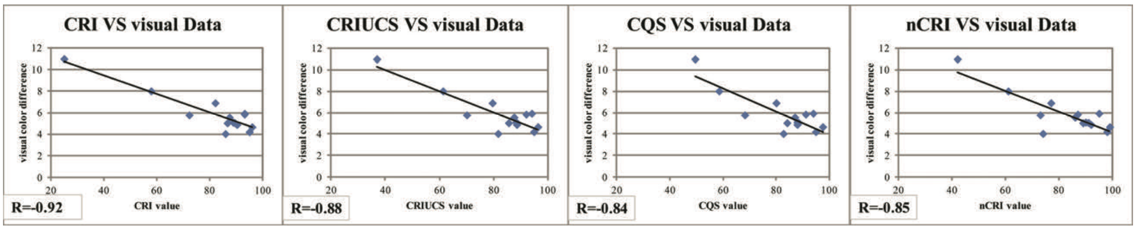
The raw data were analyzed to transform the hue scale into red (0), yellow (100), green (200), blue (300) and back to red (400). The hue and colourfulness results were then averaged for each Source. An additional experiment was conducted to relate the colourfulness scale in each phase to those of Source 19 (Telelumen 6500 K). This allows the colourfulness results to have the same visual scale.

3. RESULTS

The first analysis investigates observer uncertainty. It was first calculated the chromatic difference (hue and colourfulness) between the mean and each of individual observers for each colour. The average of the 22 samples across 19 Sources were used to represent inter-observer variability, which was about 7 CIECAM02 colour difference units.

The data analysis was based on the concept of 'colour fidelity', i.e. the colour appearance of an object to have the same appearance under a 'reference' illuminant, generated by the Telelumen. The procedure for each pair of sources is given below: 1) to calculate the mean colourfulness and hue composition visual results of each sample in each source, 2) to transform hue composition to hue angle via the reverse *CIECAM02* model [10], due to the former and the latter expressing hue appearance and difference, respectively, 3) to calculate colour-difference of corresponding samples of a pair of sources, which represents the degree of colour change between the reference and test illuminants, and 4) finally, to compute the mean colour difference for all the 22 test samples. For a perfect match between the two Sources, the mean colour difference should be close to zero. The mean ΔV value for each Source is given in Table 1.

Finally, the mean colour difference results were used to test the performance of the four colour rendering indices (*CIE-R_a, CQS, CRI-CAM02UCS* and *nCRI*). Their CRI values are also given in Table 1. Figures 4a-4d are the visual differences of all Sources plotted in Y axis against the predictions from each phase in X axis. For a perfect agreement, the data points should be located in the best fitted line. The results of correlation coefficients showed that all indices gave similar performance, i.e. correlation coefficients of -0.92, -0.88, -0.84 and -0.85, for *CIE-R_a, CRI-CAM02UCS*, *CQS* and the *nCRI*, respectively. The latter was designed to include test-samples for avoid gaming.



(a) *CIE-R_a* (b) *CRI-CAM02UCS* (c) *CQS* (d) *nCRI*

Figure 4: Performances of four colour rendering indices

4. CONCLUSIONS

A psychophysical experiment was conducted to evaluate the performance of colour fidelity based colour rendering indices. Ten observers assessed 22 colours under 19 light sources. The results showed that all four indices gave similar performance.

REFERENCES

1. CIE Publ. No. 13.3, Method of specifying and measuring colour rendering properties of light sources, Central Bureau of the CIE, Vienna, Austria (1995).
2. CIE Publ. No. 177, Colour Rendering of White LED Light Sources, Central Bureau of the CIE, Vienna, Austria (2007).
3. C. Li, M. R. Luo, C. J. Li and G. H. Cui, The CRI-CAM02UCS colour rendering index, Color Res. Appl., 37 (2012) 160-167.
4. W. Davis and Y. Ohno, Colour quality scale, Optical Engineering, 49 (2010) 033602-1.
5. K. Smet, W. R. Ryckaert, M. R. Pointer, G. Deconinck, P. Hanselaer, Correlation between color quality metric predictions and visual appreciation of light sources. Opt. Express 19 (2011) 8151-8166.
6. K. Smet and L. Whitehead, Meta-standards for color rendering metrics and implication for sample spectral sets, The Proc. Of the Color Imaging Conference 2011, San Jose, 76-81.
7. M. R. Luo, A.A. Clarke, P. A. Rhodes, A. Schappo, S. A. R. Scrivener and C. J. Tait, Quantifying colour appearance: Part I – LUTCHI colour appearance data, *Color Res. Appl.* **16** (1991) 166-180.
8. C. Li., M. R. Luo, G. H. Cui and C. J. Li, Evaluation of the CIE Colour Rendering Index, Coloration Technology, 127(2011) 129-135.
9. N. Sándor and J. Schanda, Visual colour rendering based on colour difference evaluations, *Lighting Research and Technology* **38** (2006)225-239.
10. CIE Publ. No.159, A colour appearance model for colour management systems: CIECAM02, Central Bureau of the CIE, Vienna, Austria (2004).

poster

A study on the evaluation of the color of a campus environment

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ABSTRACT

The purpose of this study was to analyze the importance of the image of the campus environment and to evaluate student's emotions triggered by the symbolic color of the campus.

The survey was divided into two parts. The first part surveyed the importance of the image of the campus environment.The second part of the evaluation focused on how the symbolic color of the campus affected the student's emotions. The target of this evaluation was Kansas State University (KSU), which actively promotes symbolic color of university. Fourrepresentative colors of the KSU campus were extracted from landscape pictures usingamosaic screen process in illustration program. The subjects were asked to evaluate the four extracted colors according to 14 adjectives. And the subjects evaluated their emotions using the seven-step Lickert'sScale. The subjects in all surveys included 30 students and professors whomajored in architecture, urban design or landscape with expertise in environment design in KSU. The subjects were composed of students from a variety of countries.And the pictures of the target were shown for the subjects for evaluation.

1. INTRODUCTION

Most universities select their own colors and use them in various ways for their PR activities. This research starts from the question of how the campus's symbolic color can affects the people's recognition of the universities.

2. PURPOSE AND METHODS

We tried to find out how much the environmental color is important in affecting the people's recognition of the university. So we conducted an experiment on the actual campus to find it out. The target of this research was Kansas State University (KSU), which actively promotes symbolic color of university.

The first part surveyed the importance of the image of the campus environment. The short question was "What elements constitute the image of the campus?"The second part of the evaluation focused on how the symbolic color of the campus affected the student's emotions.First of all we selected 20 graduated students of department of architeture in KSU as subjects and questioned them what colors represents KSU most. The subjects appointed four colors. 1) color of purple which is used in their sportswear, flag, cheering tool and lights. 2) color of ivory which is used for exterial of campus buildings; 3) color of gray which is used with purple in sportswear; and black which is used for bench, street lamp and signage. Fourrepresentative colors of the KSU campus were extracted from landscape pictures usingamosaic screen process in illustration program. The mosaic screen process is a way of averaging colors in picture.The subjects were asked to evaluate the four extracted colors according to the 14 adjectives.

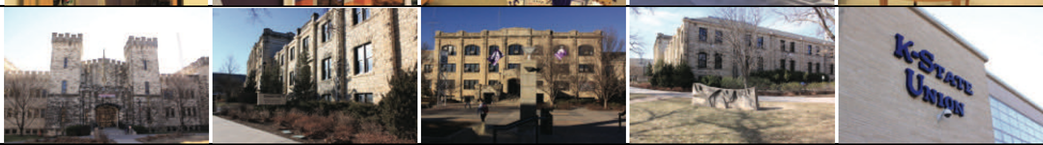
Table 1 shows the "adjectives" which are gathered for evaluaiton of images.

Table1. Evaluation adjectives

Dynamic	Strong	Passionate	Simple	Attractive	Friendly	Comfortable
Characterful	bright	Warm	Active	Calm	Historical	Peaceful

These adjectives described emotional responses and were chosen based upon related studies by preliminary experiments. And the subjects evaluated their emotions using the seven-step Lickert's Scale. The subjects in all surveys included 30 students and professors who majored in architecture, urban design or landscape with expertise in environment design in KSU. The subjects represented a variety of countries.The subjects were composed of students from five countries such as Saudi Arabia, India, China, US and Korea. And the pictures of the target were shown for the subjects for evaluation.Table 2 shows the objects which were shown to subjects for evaluation.

Table2. Evaluation Objects

Object1	
Object2	
Object3	
Object4	

3. RESULTS AND ANALYSIS

3.1 Result of research on the elements composing the campus image

As shown in Table 3, there are 9 elements constituting the campus image. Among them, the environment of campus was found out to be the most important factor followed by identity, tradition& history and international university ranking. The result of the questionnaire shows us that the campus' environmental color has relatively big influence on the image of the campus.

Table3. Result of questionnaires on elements constituting the campus image

"What elements constitute the image of the campus?"	
Elements	Number of responses
Identity, Tradition, History	24
Potential for development	7

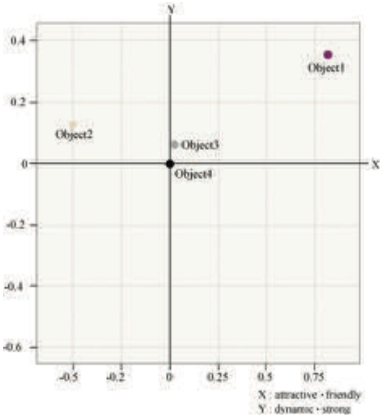
Welfare, Scholarship	2
Environment of the campus (Architecture, color, landscape, ect.)	25
Employment rate	4
Famous department	7
Location, Accessibility for transportation	4
National university ranking	16
other	2

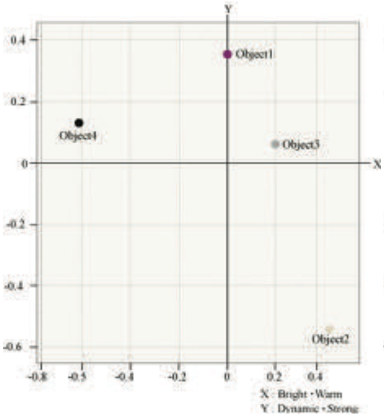
3.2Result of emotion evaluation for campus'environmental color

The PASW Statistics 17 statistical analysis package was used to analyze the factors. This resulted in 4 separate axes with the confidentiality level of 71.71%. Each axis was named as follows and the factor plots were drawn up based on the 4 axes.

Table3. Result of questionnaires on elements constituting the campus image

Factor	Evaluation term	Factor				Factor analysis
		1	2	3	4	
I	dynamic	.838	.084	-.187	.094	Dynamic · Strong
	strong	.784	-.137	.044	-.133	
	passionate	.741	.385	.217	-.027	
	simple	-.598	-173	-.191	.407	
Ⅱ	attractive	.162	.837	.180	.138	Attractive · Friendly
	friendly	.023	.748	.455	.069	
	comfortable	-.293	.699	.318	.346	
	characterful	.590	.597	-.053	.136	
Ⅲ	bright	-.090	.237	.790	.115	Bright · Warml
	warm	.175	.158	.760	.360	
	active	.481	.310	.596	-.298	
Ⅳ	calm	-.102	.036	.138	.774	Calm · Historical
	historical	.034	.172	.074	.771	
	peaceful	-.147	.270	.530	.596	
Eigen value		2.989	2.592	2.326	2.135	
Contribution rate		21.346	18.511	16.612	15.248	
Cumulative rate		21.346	39.858	56.470	71.718	





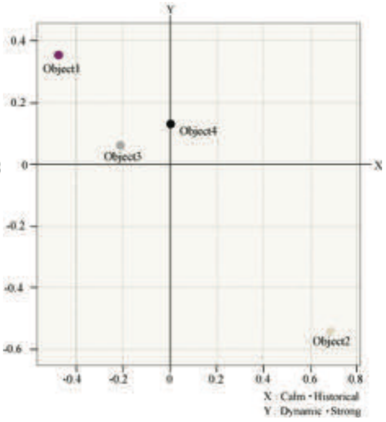


Figure1.Factor Plots (2-1axe)Figure1.Factor Plots (3-1axe)Figure1.Factor Plots (4-1axe)

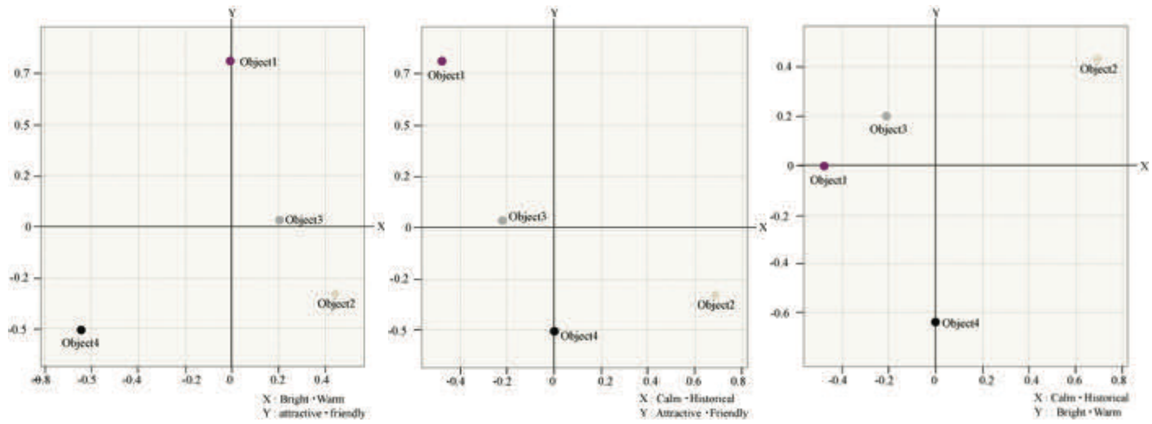


Figure1.Factor Plots (3-2axe)Figure1.Factor Plots (4-2axe)Figure1.Factor Plots (4-3axe)

Fig. 1-5 shows the result of evaluation of symbolic colors for KSU using the element plot diagram. The characteristics derived from evaluation of each factor axis are as follows; Purple was evaluated as giving “attractive-friendly, dynamic-strong and active” image; Ivory was evaluated as giving the “tender, bright-warm and calm-historical” image; Black was evaluated as giving the “strange and dark” image; but, the color of gray was evaluated as having no relatively big characteristics.

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REFERENCES

Park Jun. 2011. A Study on the Correlation between Configuration of Space and Cognition Determinant Factor Regarding University Campus: Focusing on the Space Syntax and Neural Networks, Mater’s paper, Chosun University, 45-48

Shin Gyeong Hee, 2002, Astudy on the Campus Image Elements and Cognitive character by Using Cognitive Mapping, Chonnam National University,master’s paper, 31-41

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poster

Supporting System for Color Coordination of Bridal Space Using Genetic Algorithm

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ABSTRACT

One of the most important issues for bridal coordinators is how to propose appropriate and satisfactory color coordination of a bridal space according to clients' needs and preference. This skill is highly depending on experiences or tacit knowledge of coordinators, however from social point of view, this skill should be shared within not only mature coordinators but also amateur coordinators. Therefore the computer supporting system for color coordination of a bridal space will be highly expected for especially amateur coordinators to be able to perform same as matures. In this study, a color coordination process was formalized as an optimizing problem and using genetic algorithm the supporting system for color coordination was developed. Finally, system evaluation was launched, as a result according to their impression as input data, the system presented appropriate color combinations as output data and effectiveness and validity of this system has been confirmed.

1. PORPOSE AND OVERVIEW

In this study, a color coordination process was formalized as an optimizing problem and using the genetic algorithm the supporting system for color coordination was developed. In this paper, Firstly for this purpose, 164 male and female aged between 20 to 30 years were required to evaluate their impression for over 200 photos of bridal spaces by 14 pairs of adjectives using the SD method and at the same time colors of 6 elements of a bridal space, i.e., ceiling, floor, wall, tablecloth, flower and chair, were measured by a colorimeter. After that, the results of the factor analysis on above evaluation and the cluster analysis (by Ward Method) on above evaluation and color measurement results of 6 elements, some statistical relationships are detected and a data space constructed, where impressions and physical features of bridal spaces are linked. The function of this supporting system is that can accept some adjectives presented by client's image and preference for a bridal space as input data and appropriate and satisfactory color combinations of 6 elements of a bridal space are proposed as output. This supporting system optimizes combination of colors of 6 elements using genetic algorithm, particularly the matching functions to evaluate combination of 6 colors were formulated by relations between impressions and physical features of a bridal space detected from above some experiments carried out in this study.

2. COLOR COORDINATION OF BRIDAL SPACE AND ITS IMPRESSIONS

To obtain the relationship between color coordination of bridal spaces and their impressions, some investigations by questionnaire and discussion were carried out. As a result, the specific 6 elements as elements of a bridal space were defined.

(1) Method

[Subject] 18 males and females (average age was 20.8) were asked to answer by free description method and 15 males and females (average age was 20.2) were to discussion
[Stimuli (adjective)] 51 adjectives showing images of bridal spaces
[Stimuli (image)] Photo images of bridal spaces located within the capital sphere (Tokyo)
[Evaluation Method] Questionnaires by free description method on interiors in bridal spaces were carried out for above 18 males and females. On the other hand, 15 males and females were asked to discuss on impressions of photo images of bridal spaces, and adjectives used in discussion were classified into some groups in which meaning of them are relatively similar to each others. And more, colorimetric values of stimuli (image) were measured by the colorimeter (CR-300 by KONICA MINOLTA).

(2) Results and Discussions
Adjectives were classified into 7 groups and some distinctive color combinations to bridal spaces were found out. Therefore the fact that impressions on bridal spaces highly depend on their color combinations was obtained. From this result, in this study we defined that a bridal space is constructed from specific 6 elements i.e., "ceiling, floor, wall, tablecloth, flower and chair", so we also determine that color measurements of only these 6 elements of a bridal space were required to find the color combination of a bridal space.

3. APPLICATION OF THE GENETIC ALGORITHM AND DATA SETS

The main purpose of this study, appropriate color combinations are generated and presented according to client's needs and preferences by a computational method, for realizing this function, in this study the GA was applied, in this section how to gain the data sets for GA procedures are clarified.

(1) Method
The data sets were gained by evaluation of impressions for photo images of bridal spaces.
[Subject] 164 females (average age was 21.46)
[Stimuli (adjective)] 78 adjectives explaining impressions of photo images of bridal spaces
[Stimuli (image)] 200 photo images of bridal spaces located within the capital sphere (Tokyo)
[Evaluation method] the SD (Semantic Differential Method) with 7 steps rating scale for 14 pairs of adjectives was adopted to measure impressions of above photo images as stimuli. At the same time, colorimetric values of above 6 elements of bridal spaces were measured by the colorimeter (i1Xtreme by X-Rite).

(2) Results and Discussions
The factor analysis by maximum likelihood procedure with promax rotation was adopted to detect some axes to construct of image spaces for formulation of evaluation function of GA. As a results, 3 factors are detected as follows; "light transparency factor" that include adjectives on bright, young etc., "valuate factor" that include adjectives on favorite, harmonious etc. and "commonplace factor" that include adjectives on humdrum, simple etc.. Subsequently, 200 photo images as stimuli were classified into 4 clusters by the cluster analysis with rating values of adjectives belonging to the light transparency factor assigned to independent variables. From these results, the degree of relationship between clusters and users' needs and preferences for bridal spaces were quantified and be used to define and formulate the evaluation function of the GA. Concretely, be more the number of adjectives as user's images of a bridal space belonging to a cluster, the evaluation value of the cluster be higher.

4. SUPPORTING SYSTEM FOR COORDINATION OF BRIDAL SPACES

Applying the GA mentioned in previous section, the supporting system for coordination of a bridal space was developed.

(1) Overview of the system
According to some adjectives as input to the system selected by users needs and preferences, this system presents 6 patterns of color combination of 6 elements of the bridal space which are expected to be appropriate and satisfactory ones for users. This system was implemented by the JAVA programming language. Further by using the color image scale (S. Kobayashi, 2001) and the language image scale, the relationship between 78 adjectives and colors are quantified, and by referring this quantified relationship the degree of occurrence of colors related to images of adjectives were defined and set as dataset of the database of this system. Finally the evaluation function of the GA was defined with 2 axes, one was a factor score of the valuated factor that means the general preference on images of bridal spaces, and the other was matching degree of user's image of a bridal space and color combinations defined as a sum of the number of clusters referring to adjectives as user's input and the number of occurrence of colors referring to these adjectives.

(2) Evaluation of the system
Some evaluations of the validity of system's behaviors were carried out as following method.
[Subject] 21 females (average age was 21.90)
[Stimuli] modified images to fit with the color combination as output of the system according to adjectives as inputs data for the system. These modifications of images were produced by using Adobe Photoshop Elements 8.0.
[Evaluation method] Subjects were asked to evaluate their degree of satisfaction how modified images fit with their needs or preferences of a bridal space and at the same time they were asked to answer their requirements for the system by free description method.

(3) Results and Discussions
2 examples of outputs of the system are shown in Figure 1, the left one is an output in case of that adjectives as input were "fancy, warm, poised, clean, natural" and so on, on the other hand, the right one is an output in case of that adjective as input were "antique, luxurious, high quality, relaxing" and so on. Average of the satisfaction degree of users for output images of the system was 63.33 (sd = 22.19). From these results, we can find that the system could output relatively appropriate and satisfactory color combinations according to user's needs and preferences. Also, a changing situation of values of the evaluation function in the GA implemented in the system is shown in Figure 2. We can easily find that the value of the evaluation function converges to the high score of matching degree with the increase of generation of GA operations. This fact shows that procedures of the GA work appropriately and effectively to realize our purpose in this study.

Figure 1. Output images of the system (after modification)

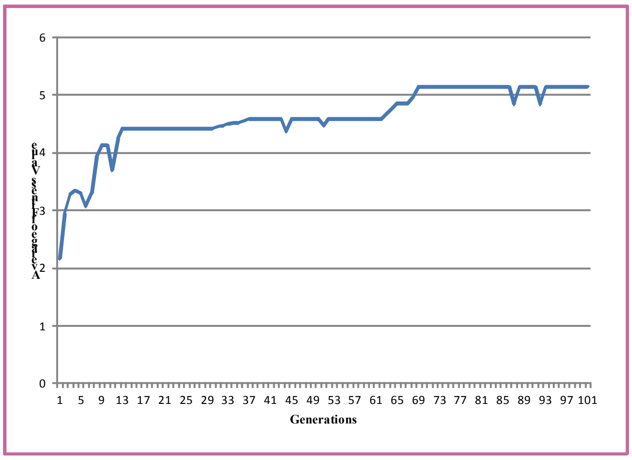

Figure 2. Changing situation of value of the evaluation function in GA

6. CONCLUSION

By using this system, we can confirm that impressions of bridal spaces are able to be visualized, so users' images and needs for a bridal space were able to be easily gathered. It will be one of the advantages for coordinators to find color combinations that they have not seen before. However at this stage of this study, considerable elements of a bridal space i.e., illuminations and so on were not implemented into the system, so increasing of elements of a bridal space will be an important future work to update the accuracy of output of this system. On the other hand, creating of meaning on different patterns of color combination presented by this system will be also an interesting future work from the color harmonious research point of view.

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REFERENCES

T. Matsui, Y. Tanemura, K. Muramatsu, K. Kojima, and M. Saito. 2012. Supporting System for Color Coordination of Bridal Space Using Genetic Algorithm. *Journal of the Color Science Association of Japan*, Vol.36, Supplement: 52-53.

S. Kobayashi. 2001. *Color Image Scale*, New Edition, Version 2. Japan: Kodansha.

N. Sannomiya, H. Kita, H. Tamaki, and T. Iwamoto. 1998. *Genetic Algorithms and Optimization*. Japan: Asakura-Shoten.

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Exploring Hues in Communication from Taiwanese Min-Nan Dictionaries

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ABSTRACT

This study aimed to explore the color terms clustering in the local Min-Nan language, which is a basic research of color in the local language. The study sample was eleven Min-Nan dictionaries from Taiwan and we discussed three dimensions of color that included word interpretation, science, and culture. The results show the following. (1) The number of commonly used color names was the maximum, a total of 3,041. Their distribution is: “black” (909), “cyan” (578), “red” (573), “white” (441), “gold” (294), “yellow” (162), and “purple” (84). The black word group is mostly of the black radical. The color image generated from the different scenarios could be divided to describe the weather change and the hue of the object (charcoal, ink). For the cyan(青) word group, cyan, blue, and green were most easily confused with each other. In the Min-Nan, the description of color usage, “cyan” with a grass green, so immature, panic can also be cyan representatives. The use of “green” is modified through natural objects, such as “beetle green” and “banana leaf green.” The usage of the word “blue” to describe the sky and water, such as the blue sky, is the same as in the Chinese characters. The red word group is mostly of the silk(糸) radical. The word usage is also from the observation of the natural environment and everyday life. (2) Color modifiers can be divided into the following categories: “neutral colors,” “warm and cold,” “to describe hue changes,” and “quasi-physical.” Future studies can investigate the lexical color category space in the Min-Nan language.

1. INTRODUCTION

1.1 Research Motivation

Because of situations of “have sound no word”, “confused uses” and “divergent interpretations”, usages of Taiwan language color words in business activities have some limitations, so color imagery of Taiwan language are confused and fuzzy when applied to advertising copywriting or in the course of communicating designs. On the other hand, the chromatics-related textbooks used in Taiwan’s color design education emphasize on adopting Western chromatics as teaching focus and learning model, but are less involved in the correlation between color and cultural aspects, and also the same case in the exploration of native language and color culture. Therefore, the motivation of this study is to observe what cultural aspects of colors are corresponded by Southern Min dialect of Taiwan.

1.2 Research Purposes

In order to establish the color vocabulary system of Taiwan language, this study used Taiwan language lexicographical works published before September 2005 to sort out vocabulary of words related to the description of colors, and adopted historical analysis method as the way for carrying out textual research, analysis, summarization and comparison of historical documents in the expectation of being able to sort out the traditional color system belonging to Taiwan native language. The purposes of this study are:

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（1）Exploring the use status of Taiwan language color words for color hues through collecting color vocabulary in Taiwan language lexicographical works published in Taiwan's modern era.

（2）Summarizing, sorting out and analyzing the describing methods of expressing colors in Taiwan language.

（3）Facilitating follow-up studies to carry out tests on the imagery of Taiwan language color words in order to understand the color gamut distribution of various colors.

2. LITERATURE REVIEW

2.1 Related researches on Taiwan Language Color Words

In her conference paper "Expression Research of Color Adjectives in Taiwan Language" , Hsiang-Lien Lee (1999) took color names of Taiwan language as scope, and conducted sorting and analysis from the classifications of nature and color group, found that in addition to retaining ancient Chinese pronunciation, the original meaning of Taiwan language color words have no much difference with their corresponding Chinese characters; some of them make actual description from original meaning of the word, or define the color from the color of a object and use sound-emulating word to enhance the color imagery. No great difference between the things represented by system color names and those represented by Chinese characters; while the colors described by conventional color names have more fun and real-life feeling than Chinese characters, and the overlapping of rhyme words adds some sense of beauty of Taiwan language. In addition, in the conference paper "Taiwan Language Expression Study of Color Adjectives – Using Expression Vocabulary of Red Color as an Example" of Hsiang-Lien Lee (2001), she analyzed and classified against the nature of color adjectives in Taiwan language to explore the color gamut value and intensity of red color, found that the use of modifiers can increase strong level of a message intended to convey, particularly when two, or three overlapping adjectives are used, it easily and clearly expressed the beauty of voice rhyme of Taiwan language, and the more the repetition times, the stronger the color feeling.

3. RESEARCH ANALYSIS

4.1 Research Analysis

According to collected lexicographical works, the color words can be divided into the烏(oo) word group, 紅(âng) word group, 白(peh) word group, 青(tshenn) word group, 黃(ng) word group, 金(kim) word group and 紫(tsí) word group (Table 3), in which the 烏(oo) word group has most number of words (23 words) and the 金(kim) word group has least (1). As for the number of extended sentences, the "烏(oo)" root has the highest number (909 sentences), followed by the "青(tshenn)", "紅(âng)", "白(peh)", "金(kim)", "黃(ng)", and "紫(tsí)" roots. In Minnan language the pronunciations of color names include classical sound and colloquial reading sound, the colloquial reading sound is mainly widely used and has more extended sentences. The description of color names is mainly based on conventional color names, covering popular usages such as animals and plants, place names, diseases, weather, proverbs ... and so on.

Table 1. Statistics of extended words of various color name word roots

Word root	烏(oo)	紅(âng)	白(peh)	青 (tshenn)	黃(ng)	金(kim)	紫(tsí)	Total number of sentences
Number of extended sentences	909	573	441	578	162	294	84	3041

(1) In the 烏(oo) word group, most words have a radical of black (黑), color imagery is generated from different scenarios described, for example, "黗(tòo)" is often used in describing the appearance of the dizziness of ink staining out, while "黗 (thûn)" represents the carbon smoke on the bottom of a pot. From the extended sentences of "烏(oo)", it can be found that the "black (黑)" is replaced by the word "烏(oo)" , and the modifier is mainly placed in rear, such as烏綠(oo-lik), 烏金(oo-kim), 烏白(oo-peh)... and so on; when the "gray (灰)" color is used to describer hue , the word "gray (灰)" is equivalent to the word "眒(phu2)", it is mainly used to describe colorless, mid-tones, and the change of light. The rest of the color names such as the single words "墨(bak)", "黔(kham5)", and 黗(tòo), most of them are used together and coordinated with the words "black (黑)" and "烏(oo)". Overall, the hue usages of black root color words mainly tend to describe existing color of objects, and can be roughly divided into two types of hues of the explicit color of weather changes and object (charcoal, ink), and use modifiers to show the subtle differences of mid-tones.

(2) The number of single words of the 紅(âng) word group is only less than the 烏(oo) word group, and mainly use the word 糸 as their radical, the performance of its single words also comes from the observations of natural environment and everyday life. As for the extended sentences of 紅(âng) word group, the number of sentences extended with the word "紅(âng)" is highest, followed by the word "赤 (tshiah)". So, the usages of 紅(âng) in Minnan language, one is a continuation of word usage in Chinese, another is colloquial usage of Minnan language (such as 水紅(tsuí-âng), 烏黗紅(oo-tòo-âng), 紅絳絳(âng-kòng-kòng)). While on the word usage of hue performance, there is no difference with Chinese character no matter in placing the 紅(âng) word root in front, rear, or matching two basic color names, and in the color combinations it is very common to see color mixing phenomenon of "朱(tsu), 桃(thô), 烏(oo), 紫(tsí)" with 紅(âng) word root.

(3) The 白(peh) word group has least number of single words, only 5. Total number of extended sentences is 441, highest number of these extended sentences is found in "Grand Taiwan Language Dictionary"; as for the words used to describe hue, the highest number recorded in lexicographical works is "白死殺(peh8 si2 sat4)", with a total of 6 works, its meaning is to describe the pale face of a person.

(4) In the 青(tshenn) word group, "青(tshenn), 綠(lik), 藍(nâ)" are most easily to cause confusion. In the usage of describing colors in Minnan language, the "青(tshenn)" indicates with a grass green color, so is immature, 青(tshenn) also can be used to represent panic; while the usage of "綠(lik)" is to be modified through a object, such as "金龜綠(kim-ku-lik) (cash turtles green) ", "弓蕉綠(king-tsio-lik)(bow banana green)", mainly reflected by nature and ecology; word "藍(nâ)" is described by sky and water, such as blue sky, water blue, usage is the same as Chinese character.

(5) In 金(kim) word group, a total of 294 sentences of extended words are recorded, among the works, "Lee's Taiwan language Dictionary" records highest. Its usages are divided into the two kinds of performances of the metal quality and glossy color, majority of the word combinations are of "kim (front) + noun", including three types of metal objects, customary beliefs and vulgar proverb.

(6) Not much sentences were recorded in the 黃(ng) word group (162 sentences), they are mainly used to describe withered yellow color, face, and plant. In the word usage of hue, the word 黃(ng) is mainly modified by a prefix word, such as "light", "heavy", "rot", "dry" and "green"; in addition to color representation method mentioned in the former, it is also used as a metaphor of pornography.

(7) In the紫(tsí) word groups, only 3 words are included, namely 紫(tsí), 茄(kiô) and 菫(kin2 or kin7). And the number of its extended sentence is also the least, only 84 sentences. In lexicographical works, the explanation of the word紫(tsí) is a color name, commonly known as "茄仔色(kiô-á-sik)" or "茄色(kiô-sik)" (eggplant color). Their usages for performing hue only have two kinds of "紫(tsí)" and "茄仔色(kiô-á-sik) or 茄色(kiô-sik)". In addition to being a kind of plant and used to quasi-physically express hue, "eggplant" also symbolizes the meaning of a male sexual symbol.

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REFERENCES

Lee Hsiang-Lien. (Expression Research of Color Adjectives in Taiwan Language) . 1999. *Proceedings of Academic and Practical Commercial Design Conference*. Taichung Institute of Commerce：109-118

Lee Hsiang-Lien. (Taiwan Language Expression Study of Color Adjectives – Using Expression Vocabulary of Red Color as an Example) . 2001. *Proceedings of Basic Modeling Exhibition and Visual Communication Design Academic Conference*. Jinwen Institute of Technology：119-131

Song Mei-hui. 1992. *Exploring the Phenomenon of Mixing Taiwan language In Newspaper Headlines from the Perspective of Sociolinguistics*. National Normal University Institute of English Language and Literature, Master Thesis

Wang Zhi-yi. 1999. *Discussion of Overlapping Phenomenon in Chinese from the Horizon of Cognitive Function Synta*. National Chung Cheng University, Institute of Linguistics. Master Thesis

Wu Tie-ping. (Discussion on Color words and Their Fuzzy Nature) . *Language Teaching and Research*. No. 2, Beijing: Language School Press. pp. 88-105

Zheng Ying, 1991. *Structure and Changes of Chinese Basic Color Words*. National Tsinghua University. Institute of Linguistics. Master Thesis

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COLOR IN IRANIAN LIVING ROOM

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ABSTRACT

The purpose of this paper is to find the colors which Iranians choose for decorating and furnishing their living spaces, and the interaction between cultures, history and everyday life.Twenty five samples of middle class Iranian homes in different cities were taken into account, observed and interviewed for this case study. For each sample, five preferred color schemes were found, and a color pallet was created. Three main pallets were found as the most popular colors in this survey:1- Brown scheme from the lightest cream to golden, copper and brown 2- Dark brown with pink and dusty red 3- Warm shades between orange, red and brown. Generally, avoidance of vivid color schemes was observed. Despite sharp and bright traditional colors, people use a small or a single piece of colorful furniture, such as a brightly toned rug, accent their homes. In this survey, two generations of Iranian couples below and above 35 years old, were studied. No meaningful differences were found between them, and it defines the need of wide research in the history of last century of Iran's interior design.

1. INTRODUCTION

Of all the constituent elements of the world, color is perhaps the first element that we register when we view something for the first time. They attach meaning and could directly affect people's lives, and play an important role in the way people feel and their reactions and responses to their surroundings (Lee 2010:6-10). Our cultural conditionings affect the meaning that we will naturally make associations based upon the colors we see, and these provide an idea of how we will think, react, or even judge objects or environments (Ambrose & Harris 2005). Therefore, the color people use in their home could affect visitor's feelings about the personality or characteristics of a person. Perhaps, most people do not care about others judgment when they are making their choices in personal objects and cloths, but when choices are presented in society, it will be more important.

One of these challenging decisions is furnishings the home, especially a space such as the living room. Colors, architecture features, and the arrangement of furnishings, create a sense of place in every home. However, out of these three ingredients, color will make the most impact (Cliff 2008).

A living room is generally considered as the most public space in a home, where strangers, as well as friends and family may be greeted (Lee 2010:106). Even though their choice of colors, paintings, fabrics, ornaments, furniture and lighting gives away their deepest emotions and will result in visitors' merciless verdict on people's taste, many people accept it and normally are far less worried about exposing their living rooms to the critical gaze of strangers (Stoeltie 1998:64). Thus, the living room conveys cultures points more in comparison to other living spaces.

Since in history of Iran, even in the most primary settlements, color was used to decorate the architecture and since the beginning, Iranians have manifested their interest in the bright and shining colors through the very application of them, the aim of this paper is to find the colors which Iranians choose for decorating and furnishing their living spaces, and the interaction between cultures, history and everyday life.

2. METHODOLOGY

Although the human eye is capable of distinguishing millions of color-nuances, most color-languages, in all cultures and throughout recorded history, included a vocabulary of eight to eleven basic terms. According to Berlin & key's hypothesis, black, white, red, green, yellow, blue, orange, purple, gray, pink and brown are the basic terms of color in languages (Gage 1993).

2.1 Color sample

According to these facts, all of the colors were categorized in ten main groups. The first group contains whites and greys, through to black and named "Black & white". The primary and secondary colors make other groups: "Yellow", "Red", "Blue", "Orange", "Purple", and "Green". To cover all the common color terms, "Brown" and "Pink" are added.

To support all the colors, three color dimensions; hue, value or lightness, and chroma or color purity, were used to make a table that contains all colors. In this table, the main hues is divided into nine subgroups that show value in rows; dark, normal, light, and chroma in columns; pure color, middle, and grey color. Each subgroup is a sample for that range of colors.

The last group contains a group of colors such as bone, cream, ecru, and beige, through khaki and mushroom, to sepia and espresso, called "Neutral", these colors are not specified to the special color terms, but it was added since these are common colors in interior design.

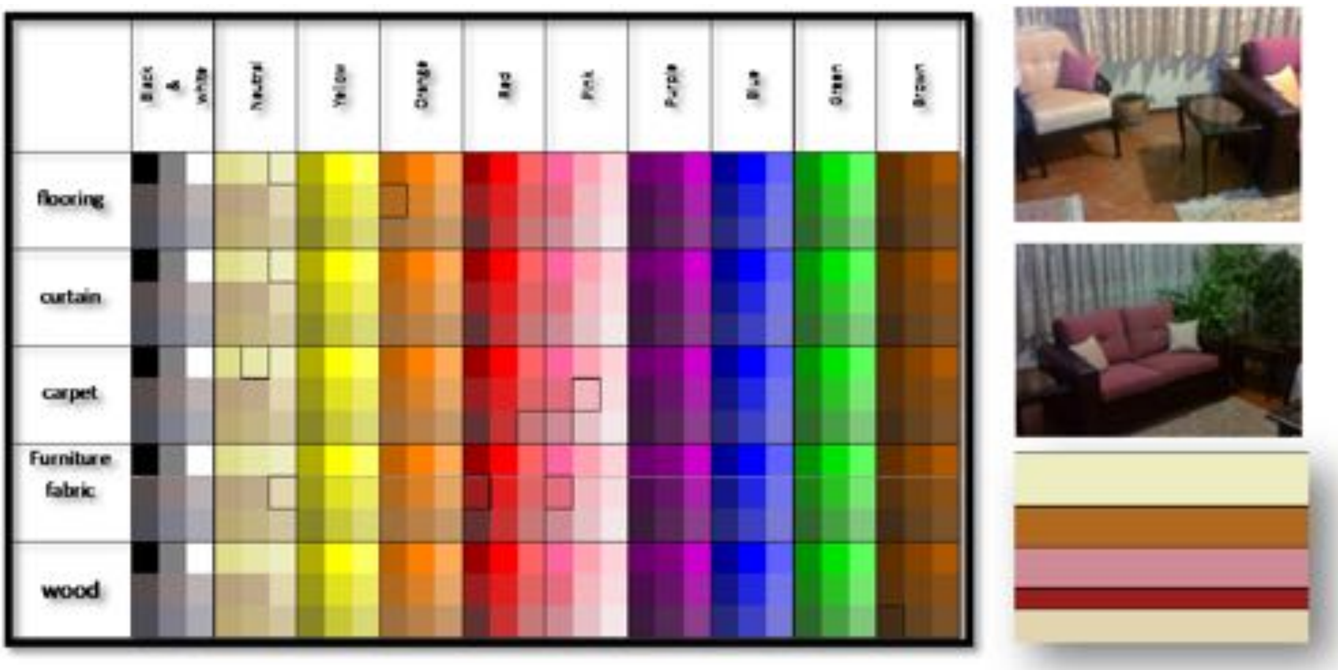


Figure1. Procedure

2.2 Participants

For this survey, 25 samples of Iranian homes from the middle class society in different cities were chosen, observed and interviewed. In this survey two generations of Iranian Families were studied and two groups of women below and above the 35 years old were interviewed.

2.3 Procedure

At first, the main six items (wall, floor, wooden furniture, curtain, carpet and furniture fabrics) in each living room were studied. Later, other considerable objects and decorative elements, such as table wears, were observed and discussed.

For each item according to hue, value, of three level, and chroma, of three levels, were recognized. And for each case, a table was created to show colors of all items. In each sample, five colors preferable as main schemes and a color pallet was created (Figure1).

3. DISCUSSION AND CONCLUSION

Through analyzing the results these points are founds:

- Distribution of hues shows the population of each hue in this order:

1- Neutral

Neutral colors were used more than the others because in Iran generally walls are painted in bone white, ceiling in white with some plaster decoration in beige or espresso. These tones allow detail to assert itself and provide the ideal background for the display of colorful or complex artifacts and furniture (Cliff 2008:25).

2- Brown

Since wood is brown, it has a wide range in usage which is not unexpected.

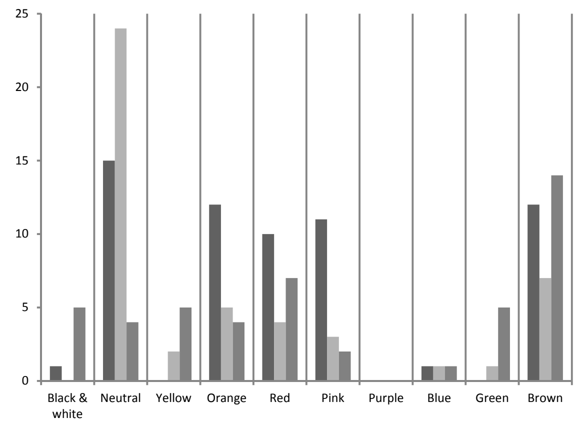
3- Red and Orange

As observed in the diagrams, between main hues, warm tones are the most popular; orange and red.

4- Blue and green were rarely used, and when used it was just in details.

5- Purple and bluish green were not seen anywhere.

Diagram1. Distribution of color value



- In contrast with Iranian art history, bluish-green was not observed anywhere and the use of blue was rare. However, small decoration parts in green theme were found.

- Three popular pallets were found in this survey:

1- Brown scheme; from the lightest cream to golden, copper and brown

A wholly brown interior gives a comfortable and enveloping feel to a room (Lee 2010:34).

2- Dark brown with pink and dusty red

The palette of pink, brown and dark red all share the common ancestry of red.

3- Warm shades between orange, red and brown

Shades that have an element of red in their composition are said to be warm. These warm schemes along with green plants, small green patterns in fabrics and carpets make a good contrast.

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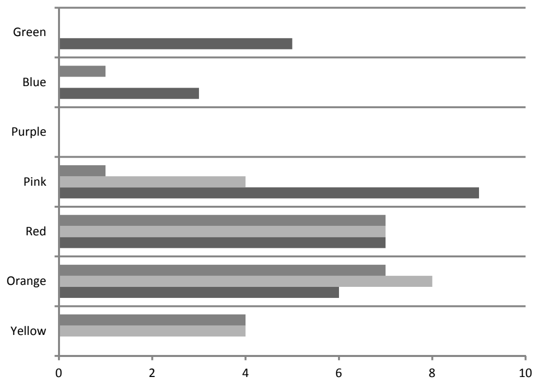
- Although it is evident that Iranian architecture through the time were decorated with vast areas of richly colored materials dependent to the importance of the building, a kind of avoiding strong color scheme is observed in this survey. In the past, they collected all the materials and techniques of ancient world and used them in a way they believe; colors were used in the bright and clear ways since in their culture all the good things are clear and bright (Rakei, 2011). But now, even the brightly red of traditional Persian rug is not popular anymore and people prefer to have dusty-pink ones.

Diagram2. Distribution of chroma



- In this survey two generations of Iranian couples were studied, but there is no meaningful difference between them (bellow and above the 35 years old) and it definitions the need of wide research in the history of last centuries in Iran's interior design.

REFERENCES

Ambrose, G., & Harris, P. (2005). *Basics Design: Colour* (Vol. 05). SA: AVA publishing.

Cliff, S. (2008). *The way we live with Color.* New York: Rizzoli International Publications, Inc.

Gage, J. (1993). *Color and Culture: Practice and meaning from Antiquity to Abstraction.* Berkeley and Los Angeles: University of California Press.

Lee, V. (2010). *The Colorful Home: Confident and Creative color Schemes for Every romm.* (S. Parkhouse, Ed.) London: Jacqui Small.

Rakei, S. (2011). Color in ancient Iran:architecture. In M. R.–D.–P. Milano (Ed.), *Colour and Colorimetry. Multidisciplinary Contributions. VII B*, pp. 253-259. Rome: Maggioli Editore è un marchio di Maggioli S.p.A.

Stoeltie, B. (1998). *timeless Interiors: Rooms Inspired by the past.* london: Frances Lincoln Ltd.

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Development of Browning Scale of Baked Foods Based on Color Measurement

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ABSTRACT

We measured the surface colors of plain cookies, sliced breads, and grilled fish (pacific saury) at various stages of baking and made their color charts (browning scales) based on color measurements. A large spherical dome with a diameter of 600 mm, whose inner surface was painted white, was used to illuminate large food samples uniformly by D65 fluorescent lamps. We placed food samples at various stages of baking in the middle of the dome and recorded their colors by a digital camera. Then, we derived color-corrected images using the X-Rite ColorChecker as the color standard. The baked color of each food was found to be dominated by the lightness, L*; color changes in a* and b* of each food during baking were well described by the regression equations with L*. Using these regression equations, browning scales of plain cookies, sliced breads and grilled fish have been developed.

1. INTRODUCTION

Color is one of the important factors in determining food quality. For example, we judge the ripeness of fruits by their colors. We check the doneness of cooked food by their browning. We know that properly browned toast, fish, steak, and other foods will stimulate the appetite. Producing delicious-looking food is one of the qualities required of cooking equipment.

Studying a food color, however, is difficult. It is partly because that conventional colorimetric apparatus is usually not used to measure a color of food with wet/oily surface, and partly because that foods are usually unevenly colored. For studying a food color, it is necessary to accumulate reliable measurement data of food colors and to develop reliable standard color charts for various foods.

For that purpose, we built a color image photographing system with a digital camera and measured the surface colors of plain cookies, sliced breads, and grilled fish (pacific saury) at various stages of baking. Then, their color charts (i.e., browning scales) were developed based on color measurements in the CIE L*a*b* space. We believe that the browning scales made in this study are very useful and necessary, for example, for doing sensory tests of food colors and for developing new cooking equipment (European Standard 2009).

2. EXPERIMENTAL METHOD

We selected three kinds of foods, a plain cookie, sliced bread, and grilled fish. They are typical foods cooked in the oven in Japan. Plain cookies were made from dough; cookie dough was prepared by mixing margarine, sugar, eggs, soft wheat flour and baking powder; then it was cut into square-shape (30x30 mm). Sliced bread (Shikishima Baking Co.,Ltd) and fish (pacific saury or "*samma*" in Japanse) were obtained on the market. We baked these foods in the oven and prepared samples from completely raw to overcooked and measured their colors by using a color image photographing system as describe below.

We prepared 10 stages for plain cookies and obtained 20 colorimetric data (averaged over each front and back surfaces). We prepared 14 stages for sliced bread and obtained 14 colorimetric data (average over each front surface without crust). For fish, which tends to be unevenly-colored by baking, we prepared 21 stages including raw state and measured color at 3 points with a diameter of 8 mm for each side of 20 baked stages (120 data); for raw state, measured average color for each side of the body (2 data) and obtained totally 122 data. Some examples of sample images used are shown in Figure 1.

Figure 1 Examples of sample images: (1) plain cookies, (2) sliced bread, and (3) fish. The size of ColorChecker is 57x82.5 mm

For measuring colors of food samples, we used a spherical dome with a diameter of 600 mm, whose inner surface was painted white (Figure 2). Food samples were placed in the middle of the dome and recorded their colors by the digital camera (Panasonic LUMIX DMC-G1). As the light sources, two D65 fluorescent lamps powered by a high-frequency inverter power supply were placed below the sample stage. Thus, the samples could only be illuminated by indirect light. A White Balance Card was used for shading correction and the X-Rite ColorChecker Mini (57x82.5 mm) was used for color correction. The color-corrected images have three values R, G, and B in sRGB format for each pixel. We converted these sRGB values to CIE 1976 L*a*b* values. The D65/2 deg. observer was assumed in calculation. The mean color differences between 24 ColorChecker's reference values and their measured values of L*, a*, b* were 0.91, 3.36, and 5.83, respectively.

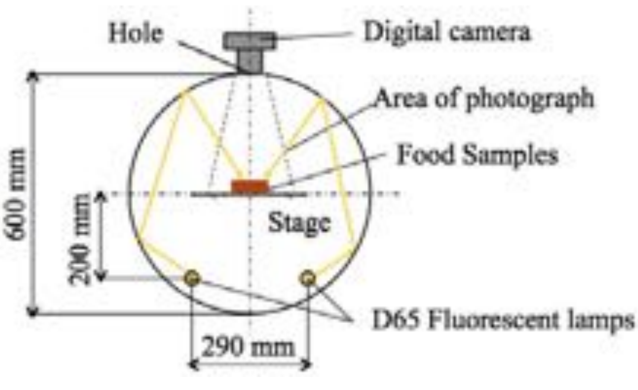

Figure 2 Color image photographing system with a digital camera.

3. DEVELOPMENT OF BROWNING SCALE

By using measured data at various stages of baking, and we made their color charts (browning scales). For plain cookies, we calculated the average over each front and back surfaces and obtained 20 colorimetric data. They are shown in Figure 3. The values of a* and b* change monotonically as a function of L*. In addition, there are abrupt changes for a* at L* is about 70, and for b* at L* is about 55. a* and b* are well correlated with L* and can be described by two linear lines as follows (also shown in Figure 3):

$$\begin{aligned} a^*_1(L^*) &= -0.90\,L^* + 77.03, && \text{for } 71.30 \le L^* \le 90.00 \\ a^*_2(L^*) &= -0.03\,L^* + 15.00, && \text{for } 30.00 \le L^* < 71.30 \\ b^*_1(L^*) &= 0.03\,L^* + 31.91, && \text{for } 54.86 \le L^* \le 90.00 \\ b^*_2(L^*) &= 0.73\,L^* - 6.49, && \text{for } 30.00 \le L^* < 54.86 \end{aligned} \qquad (1)$$

where coefficients in equations were determined by the least-square regression method.

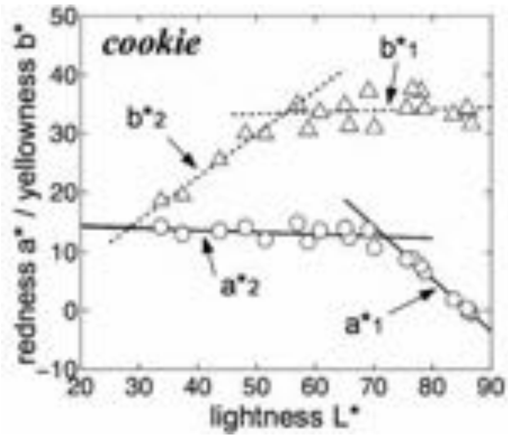

Figure 3 Color change of plain cookies during baking. Open circles represent a and open triangles represent b* as a function of L*. Two solid lines are regression equations of a*, and two dotted lines are those of b*.*

For sliced bread (toast), we calculated the average over front surfaces without crust and obtained 14 colorimetric data. They are shown in Figure 4. a* and b* can be well described by two linear lines as a function of L* as follows (also shown in Figure 4):

$$\begin{aligned} a^*_1(L^*) &= -0.66\,L^* + 56.22, && \text{for } 60.62 \le L^* \le 90.00 \\ a^*_2(L^*) &= -0.06\,L^* + 19.85, && \text{for } 20.00 \le L^* < 60.62 \\ b^*_1(L^*) &= -0.91\,L^* + 99.34, && \text{for } 60.84 \le L^* \le 90.00 \\ b^*_2(L^*) &= 0.68\,L^* + 2.60, && \text{for } 20.00 \le L^* < 60.84 \end{aligned} \qquad (2)$$

For a raw fish, we calculated the average over front and back body surfaces and obtained two colorimetric data. For baked fish, we picked up 3 points with a diameter of 8 mm for each side of the body at 20 baked stages and obtained 120 colorimetric data. Totally 122 data are shown in Figure 5. As a function of L*, there is a peak at L* is about 30 for a*. For b*, there is a broad peak at L* is from 50 to 60. Therefore, a* is described by two linear lines and b* is described by three linear lines as follows (also shown in Figure 5):

$$\begin{aligned} a^*_1(L^*) &= -0.32\,L^* + 23.60, && \text{for } 32.52 \le L^* \le 80.00 \\ a^*_2(L^*) &= 0.54\,L^* - 4.37, && \text{for } 20.00 \le L^* < 32.52 \end{aligned}$$

$$b^*_1(L^*) = -2.51\,L^* + 162.95, \quad \text{for } 65.32 \le L^* \le 80.00 \quad (3)$$
$$b^*_2(L^*) = -0.47\,L^* + 53.22, \quad \text{for } 45.60 \le L^* < 65.32$$
$$b^*_3(L^*) = 1.06\,L^* - 16.55, \quad \text{for } 20.00 \le L^* < 45.60$$

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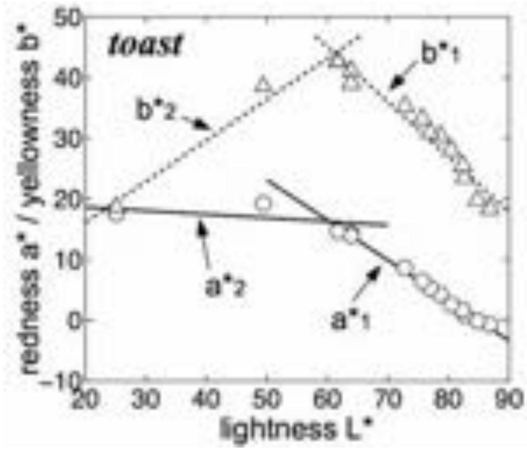

Figure 4 Color change of sliced bread during baking. Open circles represent a and open triangles represent b*. Two solid lines are regression equations of a*, and two dotted lines are those of b*.*

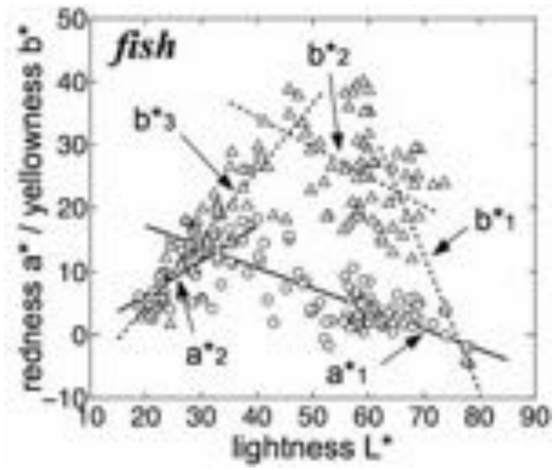

Figure 5 Color change of fish during baking. Open circles represent a and open triangles represent b*. Two solid lines are regression equations of a*, and three dotted lines are those of b*.*

Using these regression equations, browning scales of plain cookies, sliced breads and grilled fish have been developed.

REFERENCES

European Standard, EN 50304:2009+A1:2010, BS EN 60350:2009, Electric cooking ranges, hobs, ovens and grills for household use. Methods for measuring performance (2009).

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Color Tolerance of Copier Paper: A Comparison Study between Japan, Korea, and Thailand

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ABSTRACT

The focus of this paper is a cross-cultural comparison of the color tolerance level of recycled copier paper between Japanese, Korean, and Thai consumers. The aim of this study was to know the tolerances in terms of paper color and the influence of different cultural backgrounds on the consumers' awareness of recycled paper. A series of visual assessments was carried out using a color palette consisting of 266 color samples by thirty university students in each country. The assessments were carried out under the two hypothetical conditions: the paper was either recycled or not recycled copier paper. It was found that the results obtained in three countries were similar, that the color tolerance significantly increased ($p<0.01$) by the assumption of recycled paper.

1. INTRODUCTION

The amount of using recycled paper is globally increasing with the consumers' awareness of environmental sustainability. Recycled paper should be produced as an environmental load-reducing by comparison with virgin paper. Consequently, the inferior quality of recycled paper is related to the eco-friendly products. It is thus necessary to know the acceptable quality level of recycled paper in use. In our previous studies of consumers' color tolerance of copier paper e.g., Jung et al.(2008), Suk et al. (2009), Jung et al.(2012), we found that the use of recycled papers having lower whiteness than commonly-marketed papers are accepted by consumers.

The aim of this study was to know the tolerance in terms of paper color and the influence of the different cultural background toward the consumers' awareness of recycled paper through a series of visual assessments.

2. EXPERIMENT

The same experimental methodology was arranged in the three countries. A series of visual assessments was carried out using a printed color palette consisting of 266 color samples as shown in Figure 1, which were arrayed in nineteen columns of hue and fourteen rows of lightness level. In addition, the CIELAB color scale of the 266 color samples were measured by a spectrophotometer (CM-3600d, Konica Minolta) under D_{65} illuminant with the 10-degree field of vision. The subjects assigned an acceptable lightness level for each hue (the column of the color palette) as a usual paper color. Namely, the subjects were asked to point the border between acceptable and unacceptable colors in each hue column. To investigate an awareness of recycled copier paper, the assessments were carried out under the two hypothetical conditions that the each sample color is for a copier paper. The first assessment (O-Use) was conducted without mention of recycled paper statues, and the second assessment (Re-O-Use) was conducted with mention of recycled status. The subjects were thirty university students in each country.

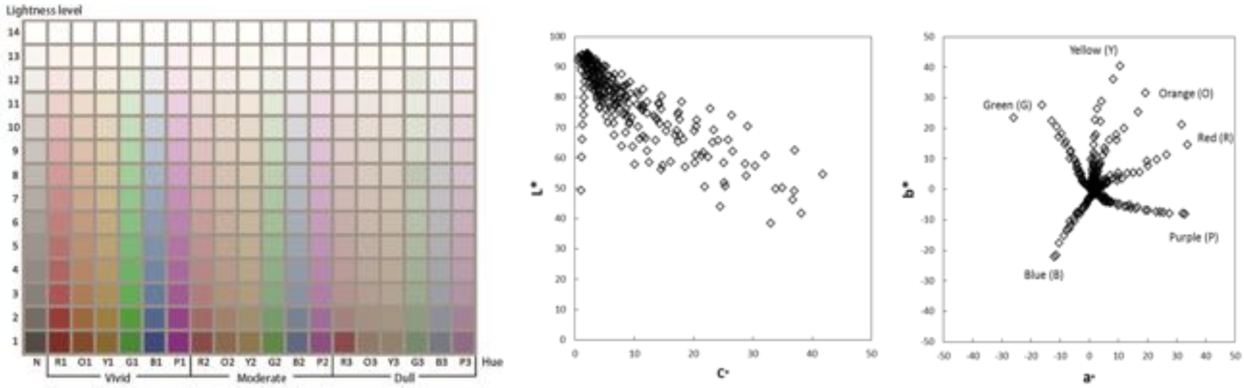

Figure 1. The color palette and the 266 color distributions on CIELAB color space

3. RESULTS

The means of the lightness level to each hue column were investigated as shown in Figure 2 by the response of assessment of each country: Japanese (JP), Korean (KR), and Thai (TH). Where a hue has a higher mean lightness level, it means that the hue is tolerated relatively lower than other hue columns. The result of comparison of O-Use (left of Figure 2) and Re-O-Use (right of Figure 2) showed the mean lightness levels of Re-O-Use are lower in whole. Therefore it is suggested the assessments were influenced by the hypothetical condition. Comparison among the subjects of three countries, the order of high mean lightness levels was Thai, Japanese, and Korean.

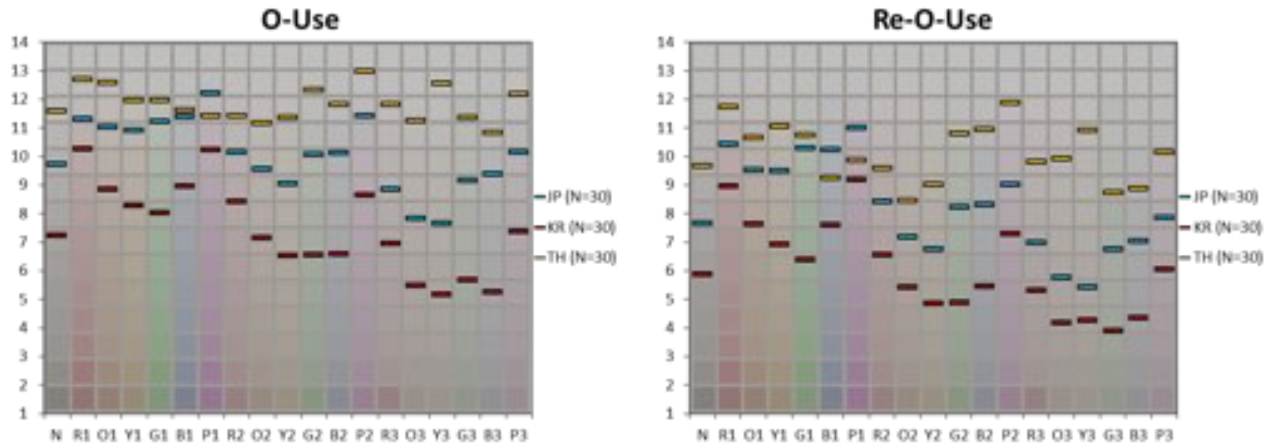

Figure 2. The means of lightness level to each hue column in each country: the results of O-Use (left), the results of Re-O-Use (right)

The color tolerance (*T*) for each color sample was calculated to investigate more details about the relationship between color properties (colorimetric values) and the subject responses. The color tolerance (*T*) was defined by the responses which were calculated for each color sample as percentage based on the frequency of choices of all the subjects. When all subjects responded the color could usable as a copier paper, the color tolerance of the color is 100. Accordingly, each color had different color tolerances by the hypothetical condition. In this study, the color tolerance of the first assessment (O-Use) is labeled "$T_{O\text{-}Use}$", and the color tolerance of the second assessment (Re-O-Use) is labeled "$T_{Re\text{-}O\text{-}Use}$".

The results of Student's t-test showed statistically significant ($p<0.01$) between the $T_{O\text{-}Use}$ and $T_{Re\text{-}O\text{-}Use}$ in each country: Japanese ($t(265)=16.161$), Korean ($t(265)=18.155$), Thai ($t(265)=13.63$). In addition, mean differences between the $T_{O\text{-}Use}$ and $T_{Re\text{-}O\text{-}Use}$ in each country are: 13.12 (JP), 9.99 (KR), 12.33 (TH).

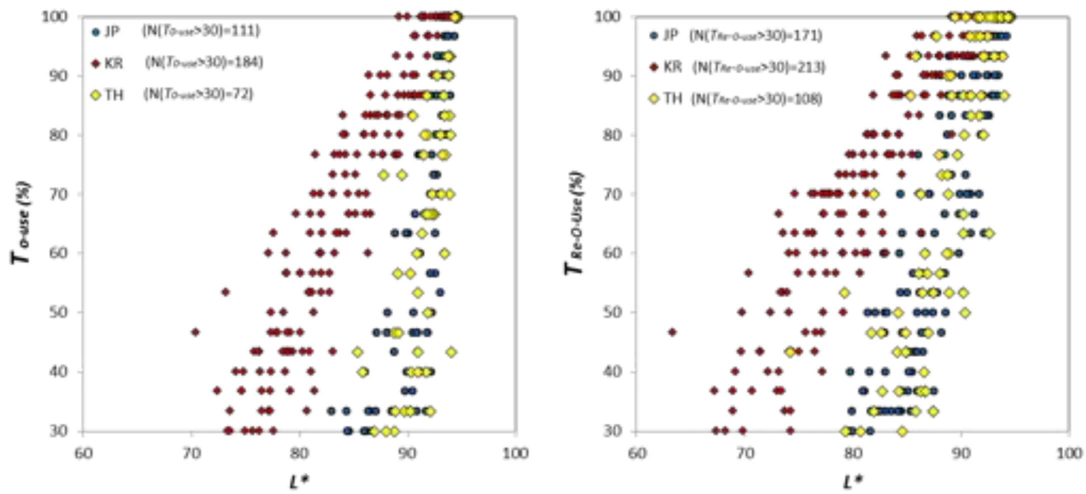

*Figure 3. The color tolerance against L*of color samples which have more than 30% color tolerance: the results of O-Use (left), the results of Re-O-Use (right)*

Table 1. Correlation coefficients (r) between color tolerance and colorimetric values (N=266)

	Japan		Korea		Thai	
	$T_{O\text{-}Use}$	$T_{Re\text{-}O\text{-}Use}$	$T_{O\text{-}Use}$	$T_{Re\text{-}O\text{-}Use}$	$T_{O\text{-}Use}$	$T_{Re\text{-}O\text{-}Use}$
*L**	0.77	0.87	0.93	0.96	0.68	0.78
*C**	-0.63	-0.75	-0.75	-0.79	-0.45	-0.52

Table 2. Calculated L values by the linear interpolation where $T_{Re\text{-}O\text{-}Use}$ is equal to 50%*

	Vivid						Moderate						Dull							
	R1	O1	Y1	G1	B1	P1	R2	O2	Y2	G2	B2	P2	R3	O3	Y3	G3	B3	P3	*M*	*SD*
JP	87.1	86.0	87.1	88.7	88.8	89.7	85.2	84.0	83.2	87.3	87.0	86.7	83.7	83.0	82.1	86.8	87.5	87.6	86.2	2.17
KR	75.8	76.5	77.5	74.1	74.6	79.3	73.1	73.0	72.5	72.3	77.4	79.1	72.1	71.3	71.9	69.7	65.7	77.3	74.1	3.50
TH	88.3	88.4	85.7	86.4	84.2	77.6	87.8	86.0	85.3	89.8	86.2	82.9	89.4	87.6	87.2	92.1	90.5	87.3	86.8	3.21

Since L^* of CIELAB is corresponding value of the lightness level, the color tolerance could correlate highly with L^* as shown in Figure 3. The results of correlation analysis show (Table 1) that the lightness, L*, contribution to the color tolerance was specifically higher in the case of the Korean subjects than the Japanese and Thai. The propensity of $T_{O\text{-}Use}$ of Korean is gradually-increased with L^* in comparison with Japanese and Thai one. Both figures in Figure 3 are suggested lower L* paper could be accepted to some of Korean which has 0% tolerance in Japanese and Thai.

L^*, a^*, and b^* values of each hue column were calculated by the linear interpolation which is known as a method for linear fitting, to know the difference of color dependence between countries. As shown Table 2 and Figure 4, where the color tolerance of Re-O-Use is 50%, the L^*, a^*, and b^* values are calculated because $T_{Re\text{-}O\text{-}Use}$ = 50% is a boundary of

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available/unavailable color. Through range of $T_{Re\text{-}O\text{-}Use}$ = 50% on *a*-b** diagram, it is indicated Korean subjects have higher tolerance over the entire hues even the lightness is lower than the Japanese and Thai. And also, the shapes of curve lines in Figure 4 differ according to country. Regardless of country, yellow direction is highly tolerated. However in terms of the hue, the highest tolerance hue directions in Korean and Thai assessments are green and purple respectively.

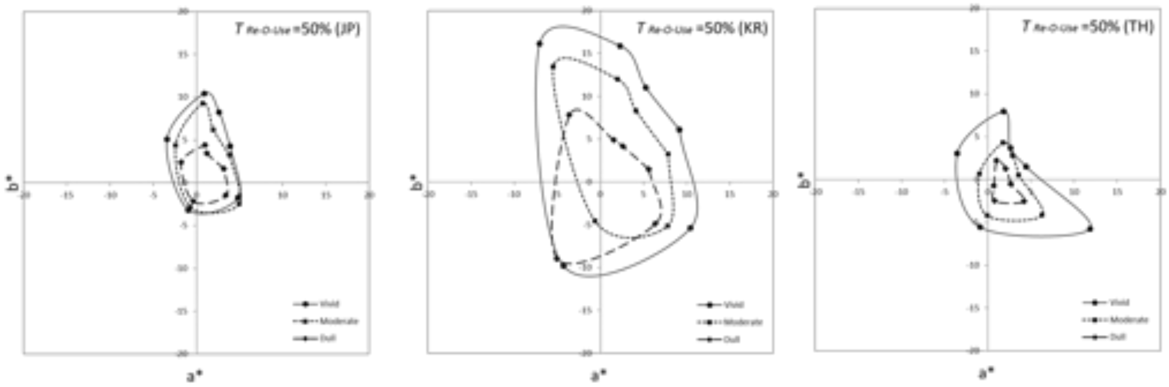

Figure 4. Calculated a and b* values by the linear interpolation to each hue column where* $T_{Re\text{-}O\text{-}Use}$ *is equal to 50%*

3. CONCLUSION

It was found that the assessments of subject groups in three countries was similar, that the color tolerance significantly increased ($p<0.01$) by the recycled assumption of copier paper. However, the degree of color tolerances of each color sample had different propensity in each country. The subjects of Korea had less tolerance in both conditions than Japanese and Thai. The features of color tolerance in each country are summarized as follows.

1) The assessments of Japanese subjects are strongly influenced by the awareness to a copier paper which is either recycled or not recycled.
2) Basically, Korean subjects have more tolerance to the whiteness of a copier paper than other two country subjects, even recycled or not recycled.
3) Thai subjects adhere to specific hues when they assess the color tolerance of a copier paper; purple is more toleranced hue but orange is less toleranced hue.

REFERENCES

Jung, H., T. Sato, A. Mori, and H. Yokura. 2008. Colour tolerance of recycled paper: how awareness influences choice. *In AIC 2008, Proceedings*, Stockholm, No. 170.

Suk, H., H. Jung, and T. Sato. 2009. How environmental attitude affects the consumers' tolerance of paper colors. *In IASDR, Proceedings*, Seoul, 437-446.

Jung, H., H. Suk, S. Kitaguchi, T. Sato, and K. Kajiwara. 2012. Color tolerance prediction for recycled paper based on consumers' awareness. *Color research and application*, 37(4): 272-280.

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A Colorimetric Analysis of Coloration Technique Used in Japanese Paintings by Itō Jakuchū

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ABSTRACT

This study describes a colorimetric analysis of splendid Japanese paintings titled *Dōshoku sai-e* by *Itō Jakuchū*, a Japanese painter in the 18th century. The paintings consist of a set of 30 hanging scrolls with motifs of bird-and-flower. We chose three paintings from *Dōshoku sai-e* and analyzed them. In *Rogan-zu*, a painting technique to emphasize the contrast of the border (Chevreul illusion) was observed. In *Shuro-Yūkei-zu*, the assimilation effect was observed in the part of combs of two roosters. In *Oimatsu-Hakuhō-zu*, *Jakuchū*'s unique technique representing "golden texture" was analyzed from the viewpoint of color composition. His trial for applying contrast and assimilation effects to his paintings was a century or more earlier than similar trials in Europe.

1. INTRODUCTION

Itō Jakuchū (1716-1800) was a famous Japanese painter born in Kyoto. He studied Japanese and Chinese paintings and established his own style. A set of paintings titled *Dōshoku sai-e* (E. Colorful Realm of Living Beings; Museum of the Imperial Collections 2006) is one of the most famous masterpieces of *Jakuchū*. The set was produced from 1757 to 1766 and consists of 30 hanging scrolls with motifs of bird-and-flower.

Last year NHK (Japan Broadcasting Corporation) planned to produce a special TV program (Japan Broadcasting Corporation 2012) for introducing *Jakuchū*'s extraordinary coloration technique applied in *Dōshoku sai-e.* We were requested by NHK to make a colorimetric analysis of his paintings.

In this paper, three paintings from *Dōshoku sai-e* are analyzed using a color analyzing tool SciColor (Suzuki and Kobayasi 2011) to reveal the effective and unique coloration techniques in *Jakuchū*'s paintings.

2. IMAGES FOR OUR ANALYSIS

High resolution images of the paintings were provided from NHK for our analysis. The images are captured by Super Hi-vision format (7680×4320 pixels; Japan Broadcasting Corporation 2012). As color profiles or color chart images are not included, we assumed that the definition of color signal in Super Hi-vision is the same as that of the HDTV standard (ITU-R BT 709-5 2002). Using Adobe PhotoShop CS5.1, every image was associated with a color profile "HDTV (rec.709) 16-235" and color values of images were converted to sRGB (IEC 61966-2.1 1999).

3. CHEVREUL ILLUSION IN "ROGAN-ZU"

In *Rogan-zu* (E. Wild goose and snow-covered reed; height 142.6cm, width 79.3cm), one of the scrolls, white color of snow covering the reeds is painted on dark gray background to emphasize the whiteness of snow. An area including the boundary between snow and background was sampled and measured. See Figure 1 and Figure 2. The lightness (Munsell value) of a row of pixels varies from left to right as follows: (1) decreasing (V=4→V=2.5) at background, (2) increasing (V=2.5→V=9) on the border between background and snow, and (3) decreasing again (V=9→V=7) at snow. This tells that *Jakuchū* emphasized the contrast of the border (Chevreul illusion) by placing the more blackish background close to the more whitish snow.

Figure 1. Rogan-zu and its close-up.

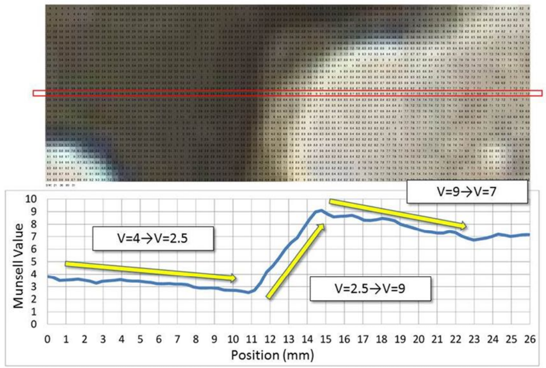
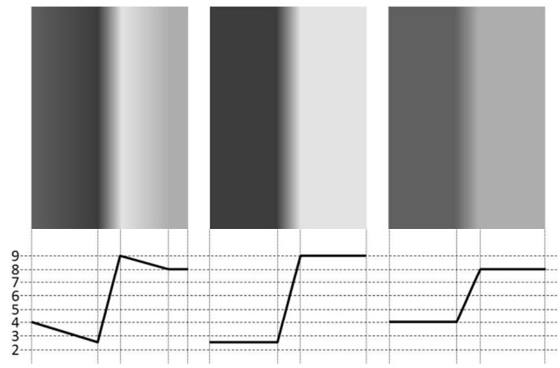


Figure 2. Transition of lightness.

To verify the effect of Chevreul illusion, we made three figures each of which shows a typical pattern of lightness transition and compared each intensity of Chevreul illusion by inspection (Figure 3). Figure 3(a) is the same transition to the original sampling data. Figure 3(b) omits decreasing part of the lightness at background and snow. Figure 3(c) suppresses the emphasis of the difference of lightness near the border. We can see that Figure 3(a) has the strongest effect of Chevreul illusion among these three figures.



(a) (b) (c)

Figure 3. Simulation of border-emphasis.

The same technique is also observed around snow-covered reeds in *Secchū-Oshidori-zu* (E. Mandarin ducks in the snow). We can find the attentive painting technique, emphasizing Chevreul illusion on the border between figure and ground, in many other paintings of *Jakuchū*. This fact suggests that *Jakuchū* already knew the phenomenon of contrast.

4. ASSIMILATION EFFECT IN "SHURO-YŪKEI-ZU"

In *Shuro-Yūkei-zu* (E. Roosters and hemp palms; height 142.7cm, width 79.7cm), the comb of the left rooster is painted as a combination of red background and white dots, while the comb of the right rooster is painted as a combination of red background and dark-red (blackish) dots. See Figure 4. Munsell color attributes of dots and background of two combs are listed in Table 1.

Color of each comb was measured by two different methods and compared. One method is a visual comparison of the comb as a unity with standard color chips. The comb and color chips were observed from 2 meters distance. Another method is a calculation of the average color of the background and the dots of the comb based on the additive color mixing model. The average color corresponds to the observed color from a far distance that dots and background are not distinctive.

Table 2 is the result. The observed color of left white-dotted comb looked different from the average color and brighter than the background color. The observed color of right blackish-dotted comb looked different from the average color and darker than the background color. In other words, *Jakuchū* painted the combs of the two roosters in a way that the difference of lightness between the two combs is emphasized when observed from a short distance. This result suggests that *Jakuchū* already knew the assimilation effect and applied it effectively in his paintings.

Assimilation effect will of course depend on the distance between an object and an observer. To investigate a relation between distance and assimilation effect is our future work.

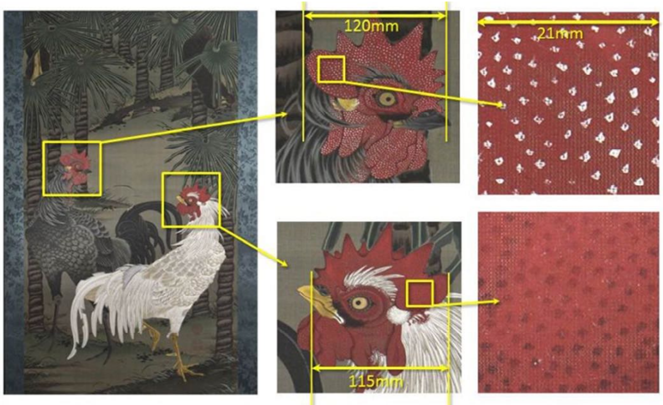


Figure 4. Shuro-Yūkei-zu and sampling points of combs of two roosters.

Table 1. Colors of dots and background of combs of two roosters.

rooster	dots	background
left (white dots)	7.3R 7.8/2.2	6.1R 4.0/6.7
right (blackish dots)	5.5R 4.1/7.6	5.7R 4.4/8.3

Table 2. Comparison between the observed color and the calculated color.

rooster	observed	calculated
left (white dots)	5.5R 5/6	5.5R 4.6/5.4
right (blackish dots)	5.5R 4/7	5.7R 4.4/8.1

5. REPRESENTATION OF GOLDEN TEXTURE IN "OIMATSU-HAKUHŌ-ZU"

Lastly, we introduce one more unique technique of *Jakuchū* representing golden color. In *Oimatsu-Hakuhō-zu* (E. White phoenix and old pine; height 141.8cm, width 79.7cm), the body of a phoenix appears to have “golden texture,” though any pigments of gold (gold powder, gold leaf, etc.) are not used. Only ochre is used to represent yellowness of "gold" (The Museum of the Imperial Collections 2008).

Munsell color attributes of the area with “golden texture” were measured (Figure 5). A gradation from dark gray to yellow (H≈5Y, V=4→V=5, C=1→C=3→C=2) is observed, which represents the characteristics of selective specular reflection on a gold surface. Plume of a phoenix is painted with bright white color (V=8~9). This white part gives us visual effect of glare which is always associated with gloss of metal.

6. CONCLUSION

Three paintings in *Dōshoku sai-e* are colorimetrically analyzed. Emphasis of Chevreul illusion and assimilation effect is observed in *Jakuchū*'s paintings. The color gradation from dark gray to yellow representing the selective specular reflection on a gold surface is also

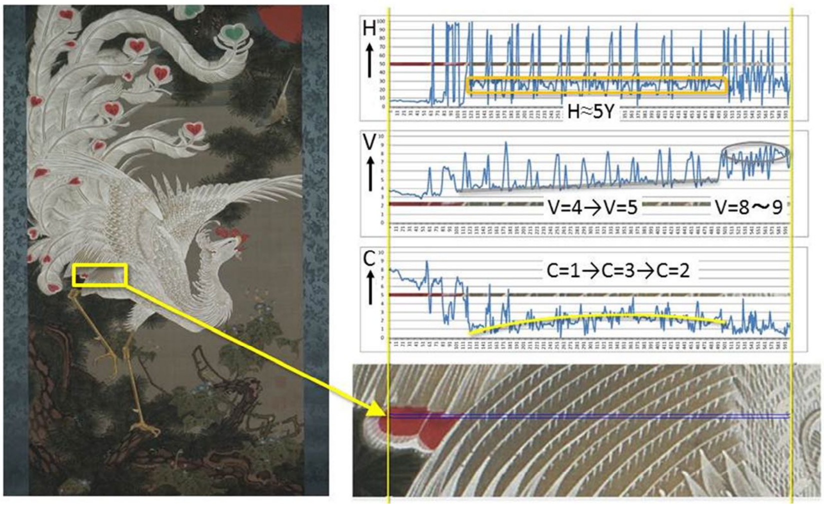


Figure 5. Oimatsu-Hakuhō-zu and color transition of an area with "golden texture."

observed.

It is interesting that the effective and unique coloration techniques of contrast and assimilation were devised in 18th century, preceding the publication (Chevreul 1839) by M.-E. Chevreul (1786-1889) and the establishment of pointillism by Neoimpressionists, e.g., G. Seurat (1859-1891).

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REFERENCES

M.-E. Chevreul. 1839. *De la loi du contraste simultané des couleurs, et de ses applications (E. the principles of harmony and contrast of colours)*, Paris.

IEC 61966-2.1. 1999. *Multimedia systems and equipment – Colour measurement and management – Part 2-1: Colour management – Default RGB colour space – sRGB*.

Recommendation ITU-R BT 709-5. 2002. *Parameter values for the HDTV standards for production and international programme exchange*.

Japan Broadcasting Corporation. 2009. *Super Hi-Vision* (a pamphlet), http://www.nhk.or.jp/digital/en/super_hi/NHKsuperHiV_english.pdf.

————. 2012. *Jakuchū's Miracle World – Kyōi no hikari no gaka* (a Japanese TV program by NHK BS Premium).

The Museum of the Imperial Collections (eds.). 2006. *Dōshoku sai-e – Jakuchū, byōsha no myōgi* (in Japanese), Kikuyō Bunka Kyōkai.

————. 2008. *Itō Jakuchū "Dōshoku sai-e" shūri jigyō hōkoku-sho* (in Japanese), The Imperial Household Agency.

Takuzi SUZUKI and Mituo KOBAYASI. 2011. *A color analyzing tool "SciColor" for research and education*, Conference Proceedings of AIC 2011 Zurich, pp.767-770 (Zurich, Switzerland).

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Colors and Designs of Pictograms Used on the Restroom Signs in International Cities.

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ABSTRACT

Nowadays, with the aim of creating aesthetically pleasing communities, various signs in our environment are used to promote attractive planning.

Visual displays installed in and outside buildings include traffic signals, signage, posters, advertising signs and various kind of signs. It is advisable that they have a high level of visibility and convey their meaning clearly.

This paper includes a survey concerning pictograms indicating restrooms depended on the aspects of the pictogram's visual impact: the colors of the target and it's background. They are used in public areas in Osaka, Japan, Seoul, Korea and San Francisco, USA.

Keywords; Pictogram, Restroom Sign, Visual Color Perception,

1. Introduction

The author considered it important for our living environment to use suitable restroom signs to maintain our living areas in normal situation that provide us looking for easily.

Recently, signs with not only words, but also pictures, have become more popular outside bus stops, restrooms etc. Some newer signs, however, have caused difficulties because it is not easy to find the bus stop or restroom from looking at the sign.

However, it is very difficult to improve the visual impact of these pictograms because such factors (the picture being too small, the color that it is hard to look at being used etc.) are not taken into consideration where they are designed.

In color planning, it is important to consider how colors will be perceived and how they can convey the points of pictograms easily. However I have considered that it is more useful to improve the visual impact of the pictograms than to just evaluate the colors which are used.

2. Method

1) Field survey

Here, I report the results of my survey concerning restroom signs. They relate to the visual impact of signs used in public areas in Osaka, Japan, Seoul, Korea and San Francisco, USA.

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Table 1 shows the locations in the three cities selected for survey. Data was collected in the daytime (9:00 to 16:00) from August to November 2010 and I checked that the sign's colors were not affected by strong direct sunlight. At each point, the data was recorded 3 times and the mean was taken. The data was recorded at big shopping centers, famous hotels, central stations and airports. Four aspects of each sign were investigated; 1.Color of the pictogram; 2.Color of the background of the pictogram; 3.Design of the pictogram; 4.Design of the background. The photographs were taken with the Nikon-COOLPIX P600 (IPHONE 3GS). The 2007 JPMA Standard Paint Colors (Munsell notation for each sample) was used to identify the colors. At the same time I recorded the size of signs and the materials they had been made from.

3. Result

Table 1 shows the points of measurements and the number of signs evaluated at 100 points in famous central stations, hotels and shopping centers in the 3 cities mentioned above. The data in this report relate to 40 points in Osaka, 30 points in Seoul and 30 points in San Francisco. Photograph 1 shows examples of the actual restroom signs installed in the 3 cities.

1 2 3 4 5 6

Photograph1, An example contains six samples obtained from three cities. Left to right; San Francisco (1+2), Osaka (3+4) and Seoul (5+6) .

Table 1 Measurement points

country	Korea	Japan	USA
Measurement City	Seoul	Osaka	San Francisco
Hotel	9	12	11
Airport, Station	10	16	7
shopping center	11	12	12
Total	30	40	30

1) Colors of the pictogram

Figure 1 shows how often achromatic or chromatic colors were used on the pictogram of the sign in the 3 cities.

It shows, firstly, that the incidence of achromatic colors in San Francisco (70%) were approximately 1.5 times higher than in Seoul and 3.4 times higher than in Osaka.

Secondly, the use of Red is 3.7 times higher in Osaka and Seoul than in San Francisco. PB is used 28% in Osaka, 3 % in Seoul and nothing in San Francisco. Other colors are rarely used in Osaka. Thus we can conclude that Red or PB colors (Munsell notation) are used for pictograms in Osaka.

2) Colors of the background

Figure 2 shows how often achromatic and chromatic colors are used for the backgrounds of the signs in the 3 cities. It shows that achromatic colors are used approximately 50% of the time in Osaka, 40% of the time in Seoul and 25% of the time in San Francisco. Of these achromatic colors, N9.5 is used 26% in San Francisco, 40% in Seoul and 50% in Osaka.

In term of chromatic colors, PB is used 50% of the time in San Francisco, and both Red and Green are used about 5% of the time each. In Seoul, R, YR and PB are each used about YR and PB are each used about 13% of the time. In Osaka, Y is used 12% of the time, YR and PB are each used about 10% of the time.

In San Francisco, most chromatic color value (V) was V3(50%) of the time. In Seoul, the most common was V5 (26%), the rest searched from V7 – V3. In Osaka, the values varied widely from V9 – V3.

In San Francisco, most chromatic color chroma saturating (C) was 6(35%), followed by 8(30%). In Seoul, C varied widely from 8 –3. In Osaka, chroma saturating 6 was 31% of the time and the rest varied widely.

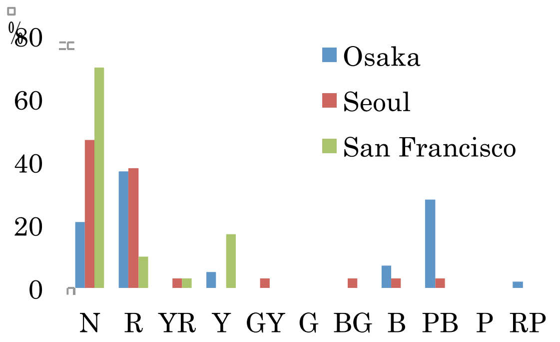

Fig.1 Results of Hue color of pictogram (%)

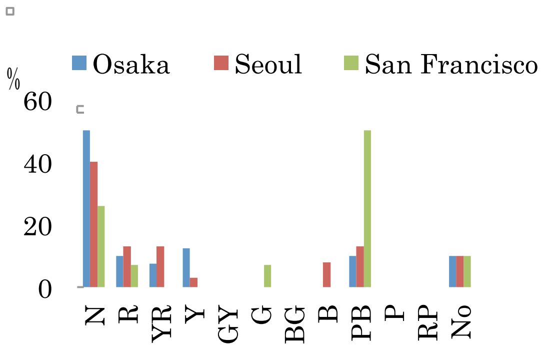

Fig.2 Results of Hue of background color(%)

I use the following abbreviations to indicate the Munsell colors. I am referring to Red(R), Yellowish Red(YR), Yellow(Y), Greenish Yellow(GY), Green(G), Bluish Green (BG), Blue(B), Purplish Blue(PB), Purple(P), and Reddish Purple(RP); and the achromatic is Neutral color(N).

3) Designs of the pictogram

Figure 3 shows how often different types of design were used on the signs in the 3cities.In San Francisco, signs with a pictogram and letters were the most popular (57%). Next was signs with only pictograms(20%) and third were signs only displaying letters (13%). In Seoul, signs only depicting a pictogram were most popular (60%), followed by signs displaying both letters and a pictogram (20%). In Osaka, deigns with either only a pictogram

(45%) or with a pictogram with letters (44%) were most common, with various other designs making up the remaining 10%. I thus conclude that in San Francisco signs with both a pictogram with letters are most common. In Seoul, a pictogram alone is most common and in Osaka both types of theses designs (pictogram, pictogram+ letters) are equally popular.

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4) Design of the background

Figure 4 shows the different types of backgrounds used in the 3 cities. In Osaka the most common form is a rectangle (85%), with various other shapes making up the remaining 15%. In Seoul is very similar to this. In San Francisco, however, the results were more varied, with rectangles being used only 40% of the time, circles 30% and triangles 17%.

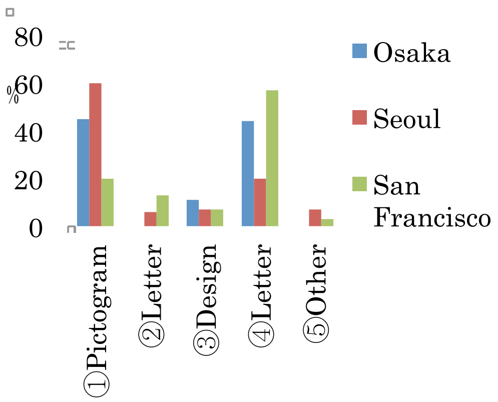

Fig.3 Displays of pictogram (%)

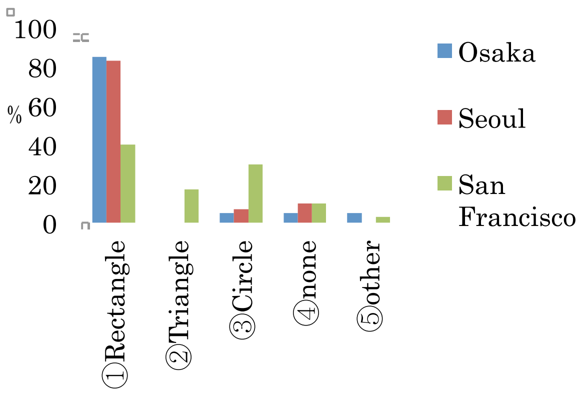

Fig.4 Background shape of pictogram (%)

4. Conclusion

The survey shows there is very little difference between Osaka and Seoul. But there is more of a difference between the Asian cities (Osaka and Seoul) and San Francisco.

The conclusions obtained from this survey will not easily be implemented. But we can suggest how to improve the current pictograms and how to achieve a better visual impact and visual perception.

ACKNOWLEDGMENTS

The author wishes to express her gratitude to the student Kim Kiyon at Otemae University. She contributed to the collection of data.

REFERENCE

1) FOMS: Design of the word by eye, Hall Yushi Co., Ltd., 2010.7
2) Architectural Institute of Japan: Dictionary of architectural term, Iwanami Shoten

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The Relationship between Color Harmony and Color Affective Feelings-Using 3D Color Configuration

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ABSTRACT

This study aims to explore the relationship between color harmony and color affective feelings on 3D color configuration. Thirty-two observers were invited to take part in a psychophysical experiment. Each observer was asked to assess 122 experimental samples on 6 scales, , including "harmonious-disharmonious", "active-passive", "heavy-light", "warm-cool", "soft-hard", and "complex-simple". The results showed that color harmony was modeled by "complex-simple" and "warm-cool". And the feeling of "warm-cool" was modeled by "active-passive", "heavy-light", and "soft-hard." In addition, four design techniques were found to have different effect on affective feelings.

1. INTRODUCTION

Many studies[1-8] have been devoted to the color harmony. It was found that these studies only used 2D shapes to study color harmony. This led the results impractical for product design, because the shapes of product are usually three-dimensional shapes. Lee *et al*.[9] explored the color emotion on 3D shape, furthermore, Lee *et al*.[10] studied color harmony on 3D configuration. However, for product design, designers seek not only color harmony but also the affective feelings to fulfill their design target. Hence, the current study carried out a psychophysical experiment using a series of color combinations applying on 3D color configuration to see the relationship between color harmony and color affective feelings.

2. EXPERIMENTAL PLAN

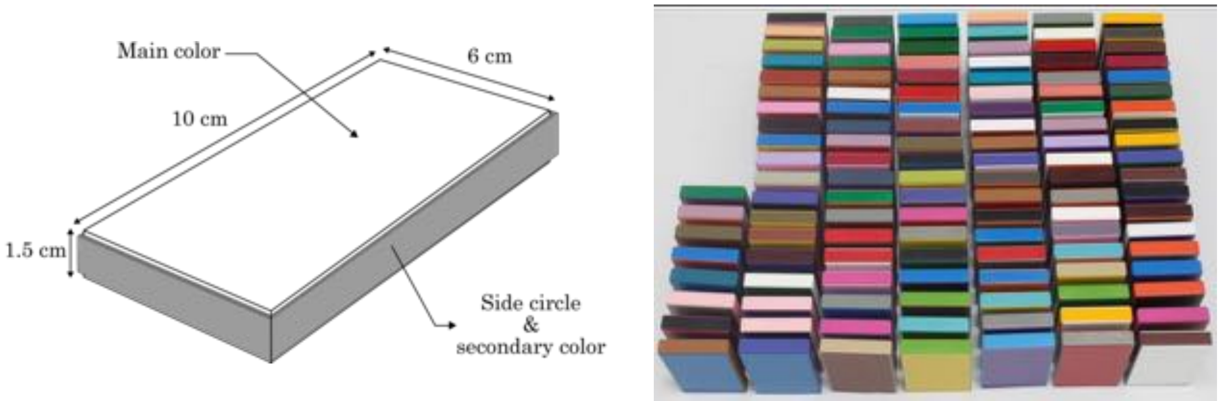
To explore the relationship between color harmony and color affective feelings on 3D color configuration, a psychophysical experiment was carried out. Thirty-two observers with an average age of 24 years old took part in the experiment, including 19 male and 13 female. Each observer was asked to assess 122 experimental samples on 6 scales, including "harmonious-disharmonious", "active-passive", "heavy-light", "warm-cool", "soft-hard", and "complex-simple". A 7-step categorical judgment method was used to collect data.

Cuboid with side circle shape was used to display color combinations. The main color was given on the cuboids shape, secondary color on side circle shape. The size of the experimental sample is illustrated in Figure 1(a).

In terms of color selection, Berlin and Kay's 11 basic color terms[11] (red, orange, yellow, green, blue, brown, purple, pink, white, black and gray colors) were used to be main color. Each basic color term was produced according to their boundaries in CIELab space proposed by Lin *et al*.[12-14] Four design techniques[15] were used to produce secondary colors, including "Tone in Tone"(TinT), "Tone on Tone" (TonT), and "Tonal"(T) together with "Achromatic-Chromatic color combination"(AC). The technique of "Tone in Tone" means the two colors having neighbouring hue and neighbouring tone. "Tone on Tone" indicates the two colors having same hue but different tones. "Tonal" means two colors having different hue but same tone.

“Achromatic-Chromatic color combination” means using achromatic and chromatic colors together. Totally, 122 color combinations were produced and applied onto the cuboids with side circle shape, as shown in Figure 1(b).

This experiment was conducted in a dark room. Each experimental sample was displayed one by one in a viewing cabinet and illuminated by a D65 simulator. The viewing distance was about 45 cm with a 0/45 illuminating/viewing geometry.



(a) (b)

Figure 1: *The experimental samples*

3. OBSERVER REPEATABILITY AND ACCURACY

In prior to analysis, the observer repeatability and accuracy were examined by RMS (root mean square). The former is to see whether the observers can repeat their judgment or not. The latter is to examine how well the individual observer agrees with the mean results. For RMS of 0, it represents a perfect agreement between two data array.

The results are illustrated in Figure 2. It can be seen that the observer repeatability and accuracy were ranged between RMS of 0.82 and 2.25. Three observers were found to have RMS value exceeding 2.0, indicating these three observers can’t provide consistent judgment and disagree with the mean results. Therefore, the data of these three observers were excluded from further analysis.

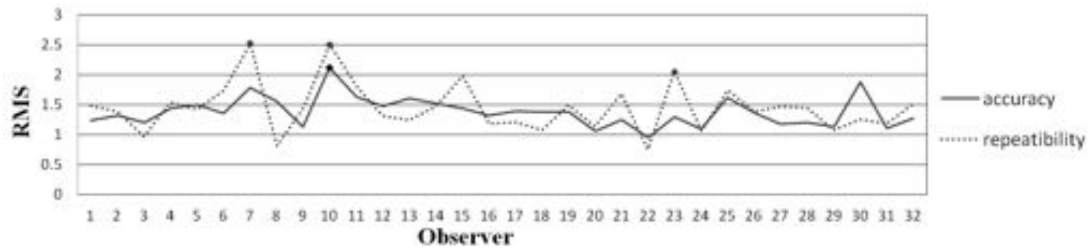


Figure 2: Observer repeatability and accuracy

4. THE RELATIONSHIP BETWEEN AFFECTIVE FEELINGS AND DESIGN TECHNIQUES

To understand if color design techniques had any impact on the color affective feelings, ANOVA analysis together with LSD post hoc test were used. The results are summarized in Table 1. It was found that

1. There is no significant difference between 4 techniques on “active-passive” and “heavy-light” scales.

2. The technique of “Achromatic-Chromatic color combination” was found to be “harder”, “cooler”, “simpler”, and “more harmonious” in comparison with other techniques.
3. The techniques of “tone in tone” and “tone on tone” were found to have similar effect on affective feelings. Both techniques prompted “softer”, “warmer”, “simpler”, and “more harmonious” feelings than other two techniques. This implied that two colors having similar hues make color combination “softer”, “warmer”, “simpler”, and “more harmonious.”
4. The technique of “tonal” was found to be “warmer”, “more complex”, and “more disharmonious” than other techniques. This reflected that two colors with same tone and different hues tend to have “warm”, “complex”, and “disharmonious” feelings.

Table 1: The results obtained from ANOVA and LSD post hoc test

	Active	Passive	Heavy	Light	Soft	Hard	Warm	Cool	Complex	Simple	Harmonious	Disharmonious
AC						*		*		*	*	
TinT					*		*			*	*	
TonT					*		*			*	*	
T							*		*			*

“*” indicates 95% significant difference.

5. COLOR HARMONY MODEL

In order to understand the relationship between color harmony and color affective feelings, a structural equation model was hypothesized. This model was verified by multiple regression analysis. The results showed that the performance of the hypothesized model was significant, as shown in Figure 3. It was found that color harmony on 3D color configuration was modeled by both “complex-simple” and “warm-cool”. “Complexity” had greater impact than “Heat” upon “Harmony”. And it can be see that the scale of “warm-cool” can be modeled by “active-passive”, “heavy-light”, and “soft-hard” scales.

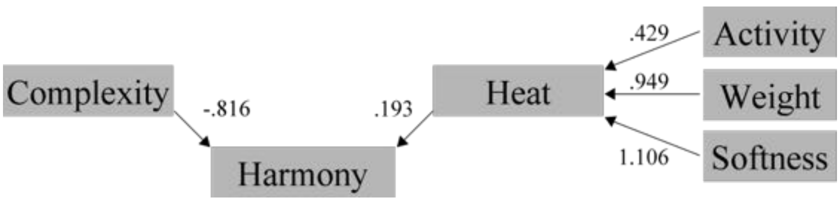


Figure 3: The color harmony model based on affective feelings.

6. SUMMARY

The current study conducted a psychophysical experiment to see the relationship between color harmony and color affective feelings. The results showed color harmony was modeled by “complex-simple” and “warm-cool”. And the feeling of “warm-cool” was modeled by “active-passive”, “heavy-light”, and “soft-hard.” In addition, the design techniques were found to have different effect on affective feelings.

Based on these findings, a comprehensive color harmony model was developed, as illustrated in Figure 4. This model tells us that the “harmonious” feeling can be prompted by “simple” and “warm” feelings, and avoided “complex” and “cool” feelings. In addition, this model reflected the technique of “tone in tone” and “tone on tone” can create “harmonious” feeling easier than “tonal” and “achromatic-chromatic color combination” techniques.

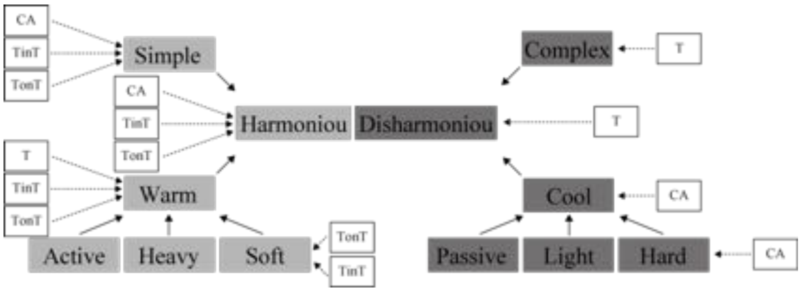


Figure 4: The color harmony model based on affective feelings and design techniques.

ACKNOWLEDGMENTS

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REFERENCES

1. Chuang M-C, Yeh C-L. Influence of an Integrated Color Interval of Object Colors on Color Harmony. Journal of Design 1998;3(2):113-130.
2. Chuang M-C, Ou L-C. Influence of a Holistic Color Interval on Color Harmony. Color Research and Application 1999(26):29-39.
3. Hård Anders , Lars S. A Theory of Colors in Combination: A Descriptive Model Related to the NCS Color-Order System. Color Research and Application 2001;26(1):4-28.
4. Kao S-L. A Study of the Effect of Changing Size and Shape of Colored Area on Cognition in Color Combination. Yunlin: National Yunlin University of Science & Technology; 2004.
5. Chen Y-f. The Effect of Color Areas on Color Image: National Cheng Kung University; 2008.
6. Haung Y-H, Lee W-Y. Color Harmony for Web Design. The 17th Annual Meeting of the Ergonomics Society of Taiwan; 2010.
7. Haung Y-H, Lee W-Y, Gong S-M. Area Effect on Color Harmony : Web Page as an Example. International Conference on Color Design. Taiwan; 2010. p 21-28.
8. Ou L-C, Luo MR, Andrée Woodcock, Wright A. A study of colour emotion and colour preference. Part II: Colour emotions for two-colour combinations. Color Research & Application 2004;29(4):292-298.
9. Lee W-Y, Luo MR, Ou L-C. Assessing the Affective Feelings of Two- and Three-Dimensional Objects. Color Research and Application 2009;34(1).
10. Lee W-Y, Huang S-J, Chang Y-W. Color Harmony on 3D Color Configuration. 2011 International Color Symposium, Color and Emotion; 2011. p 67-73.
11. Berlin B, Kay P. Basic Colour Terms: Their Universality and Evolution.: Basic Colour Terms: Their Universality and Evolution.; 1969.
12. Lin H, Luo M, LW M, AWS T. A Cross-Cultural Colour-Naming Study. Part III -- A Colour-Naming Model. Color Research and Application 2001;26:270-277.
13. Lin H, MR L, AWS T, LW M. A Cross-Cultural Colour-Naming Study: Part I-Using An Unconstrained Method. . Color Research and Application 2001;26:40-60.
14. Lin H, MR L, AWS T, LW M. A Cross-Cultural Colour-Naming Study: Part II-Using a Constrained Method. . Color Research and Application 2001;26:193-208.
15. Yano R. The Art of Designing. 柳曉陽, translator: Solutions Publishing CO.; 2008.

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Color Categorization of Color Deficiencies, effects of illuminance and categorization correspondence to normal trichromat

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ABSTRACT

We carried out a categorical color naming experiment using dichromats and normal trichromats as observers to investigate the effects of illuminance (three levels: 10, 100, 1000lx). A series of Munsell chips was used in the measurement, which was presented separately, and the observers were asked to categorize them into one of 11 categories (red, pink, orange, yellow, green, blue, purple, brown, white, gray, and black). The results showed that illuminance level affected color categorization especially to color deficiencies. The consensus on categorization between the dichromats and normal trichromats was declined, as the illuminance level was lower. We also found there were some color chips whose categorization was same regardless of observer group or illuminance in category blue, pink, green, orange and yellow.

1. INTRODUCTION

Basic color terms based on color category are often used to communicate. They are useful to designate or distinct objects then colors are widely used on application like signals, signs and so on. When we use color for the purpose, it is needed that the same surface (i.e., object) is always seen the same color category even if it is seen by various people and/or environment. It is pointed out that it sometimes does not stand up to color deficiencies caused by their different color characteristics and it is important to know how much color deficiencies can categorize color as well as normal trichromat by seeing. For the purpose, we carried out a categorical color naming experiment to evaluate the effects of illuminance that is one of the important factors of visual environment.

2. METHOD

2.1 Design

The experiments were designed to investigate the effects of illuminance on the color categorization for dichromats.

2.2 Illuminant and illuminance

D65 fluorescent (D-EDL-D65) were used for all measurement. Three levels of illuminance (10, 100, 1000lx) were employed as experimental condition to investigate the effects of the illuminance.

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2.3 Participants

Sixteen normal trichromats and seven color deficiencies (two-protanopia, five-deuteranopia) participated in the experiment as observer. All observers were aged in their 20 years and had enough visual acuity to make their dairy living without specific visual pathologies that affect the experiment. Color vision of dichromats was checked with anomaloscope. None of the normal trichomats have been pointed out their color vision abnormally during their life.

2.4 Stimuli and apparatus

A series of Munsell color chips was used as stimulus. The chips which fit for the hue, lightness and chroma listed as follows were chosen: the hue is either 5 or 10 in Munsell hue, the lightness is either 1, 2, 4, 6 or 8 in Munsell value, and the chroma is either 2 from 8 in every 2 in Munsell chroma. Totally, 332 chips were used. The measurement was carried on in a viewing box, which has adjustable illumination and N6 surface inside. The stimulus was presented in the box. Each chip was placed on the N9 background that extended 57 (H) x 42 (V) degrees in visual angle. Viewing was binocular from distance of approximately 30cm with natural pupil.

2.5 Procedure

Each color chips were presented separately. Observer was asked to categorize the chip into one of the 11 basic color terms - red, pink, orange, yellow, green, blue, purple, brown, white, gray, black (Berlin and Kay (1969)) in each trial. No time limitation was set to answer. Five-minute adaptation to the illuminant was carried out before each experiment.

3. RESULTS

The results showed that illuminance level affected color categorization especially to color deficiencies. The color categorization of normal trichromats was changed slightly by illuminance. As shown in Figure 1, the consensus of color categorization within the normal trichromats group was almost same between 1000 lx and 100 lx, slightly decline was found at 10 lx. Meanwhile the categorization of color deficiencies changed abruptly. Figure 2 shows that the ratio of color chips categorized with 70% consensus between the dichromats and normal trichromats. If the illuminance level affects the categorization of both the dichromats and normal trichromats group equally, the ratio has a constant value. The results were, however, the ratio declined for the color chips with Munsell value 4 or 6, and increased for Munsell value 2 as the illuminance was lower.

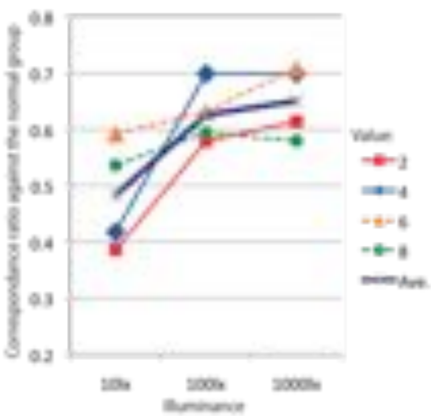

Figure 1. Consensus of color categorization within the normal trichromats group.

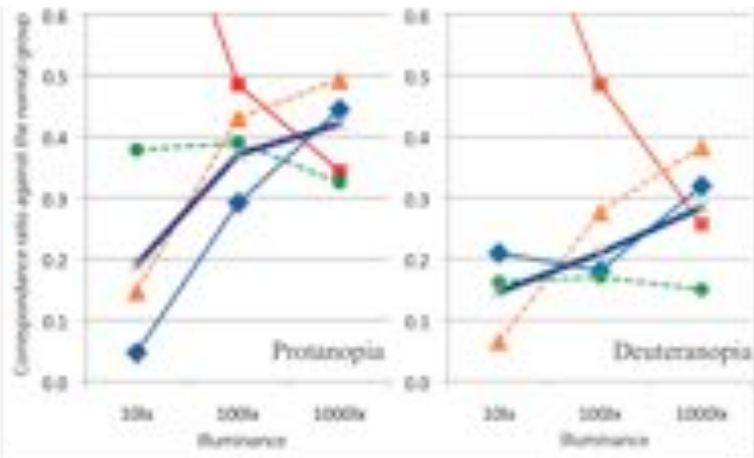

Figure 2. The ratio of color chips categorized with 70% consensus between dichromats and normal trichromats.

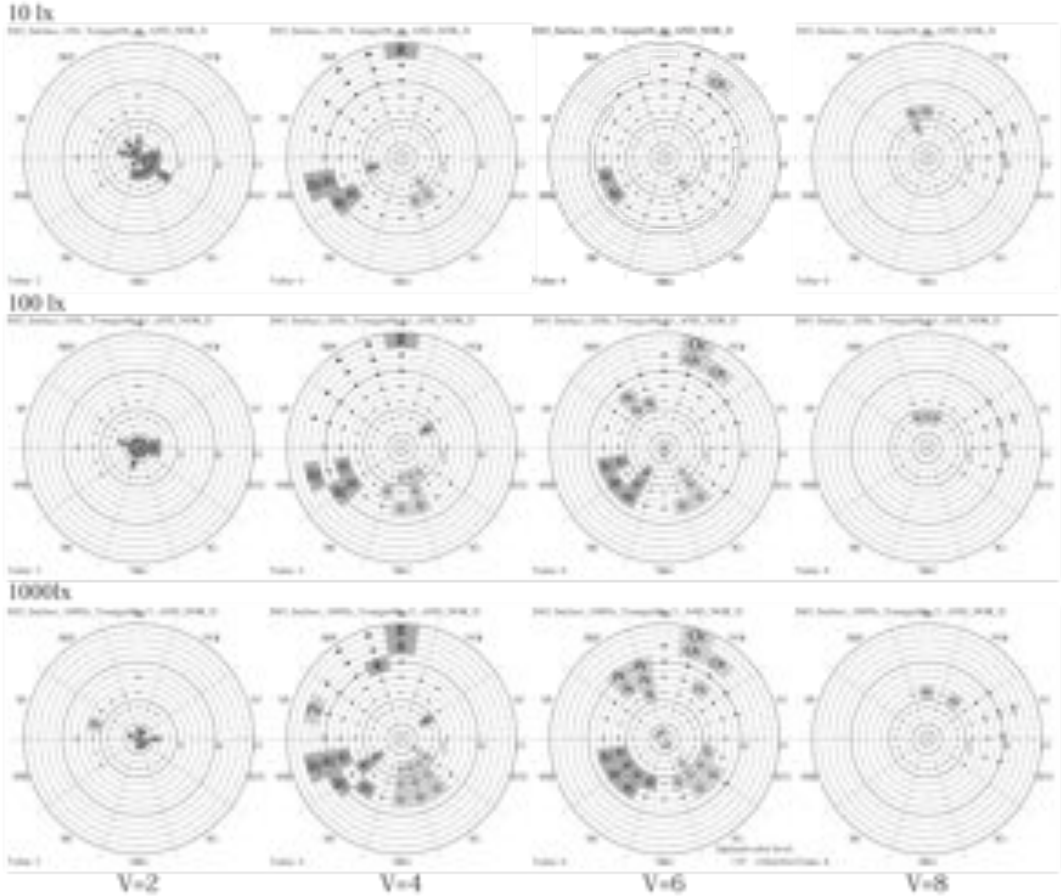

Figure 3. Common color categorization across the deuteranopia and normal trichromats. Symbols mean the coordinates of the chip which was obtained the consensus. The responses are indicated by initials - R: red, Or: orange, Y: yellow, Br: brown, G: green, Bl: blue, Pu: purple, Pk: pink, Gr: gray, W: white, Bk: Black. Dot means fewer than 70% consensus.

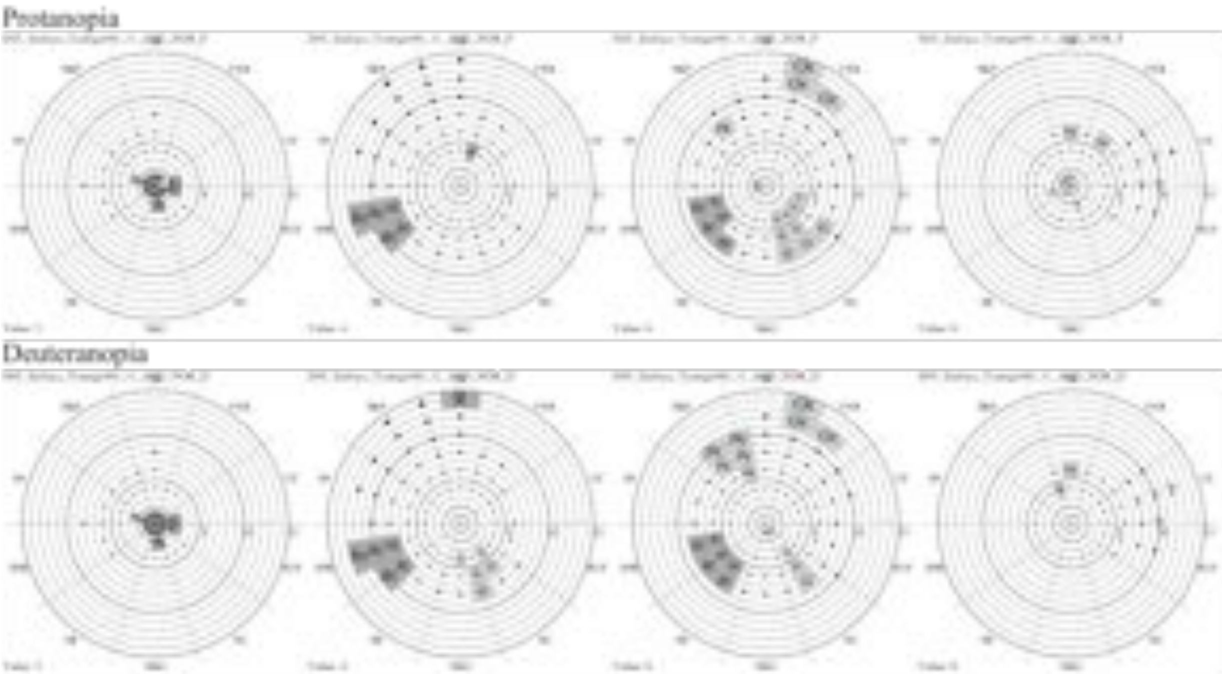

Figure 4. Common color categorization across the dichromats and normal trichromats all through the level of illuminance. Symbols mean the same as Figure 3.

Figure 3 shows that the common color categorization across the deuteranopia and normal trichromat group with 70% consensus. Chromatic categories were obtained in Munsell value 4 and 6, meanwhile achromatic category (black) was obtained in Munsell value 2.

We also have found that there were some color chips whose categorization was same regardless of observer group or illuminance. The each approximate centricity in Munsell space was 5PB4/10 and 10B6/8 for blue, 5RP6/8 and 5R8/6 for pink, 5G6/6 for green, 10R6/12 for orange, and 5Y8/10 for yellow (see Figure 4).

4. DISCUSSIION

The consensus of color categorization was declined as illuminance for both dichromats and normal trichromats group. We have obtained same results for young normal trichromats in our previous work. (Kawamoto *et al*. (2007)) The point is the effect was larger to dichromats than in normal trichromats. It means that dichromats are more affected by illuminance on color categorization than normal trichromats. It suggests that it is important to maintain illuminance level on indication like signals or signs by its surface colors. When the surface is used to communicate by its color category, the surface should be indicated in well-lighted space. Insufficient illuminance would more affect the categorization of color deficiencies.

We also obtained some color chips whose categorization was same regardless of observer group or illuminance. It can be utilized to consider visual environment from a perspective of color universal design. The five color categories mentioned above could be the safe colors for communication by color.

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REFERENCES

Berlin, B. and Kay, P. 1969. *Basic color terms*, California: University of California Press.

Kawamoto, K., Wake, T., and Yasuma, T. 2007. The difference of categorical color perception between young adults, elderly people and color deficiencies. In *AIC Color 2007, Proceedings,* ed. by Guanrong YE and Haisong Xu: Zhejiang University, 254-257.

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Analysis of Color Design of Broadcast Channel Identity: Focusing on color design of Korean women lifestyle channels

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ABSTRACT

Broadcasting companies, amidst increasing competition, have sought various strategies to differentiate their channels in an effort to sharpen the channel competitiveness. Using channel identity color is efficient tool in structuring the channel identity in such a way of imprinting the channel image. Korean women lifestyle channels define effective channel identities considering their own channel image, channel concept and target audience which are used in designing the logo and network in active manner. The color symbolizing the women is used as dominant color and particularly, they express the characteristics of modern women in color image using dominant color, highlight color and color matching. Color matching was seen to be differentiated depending on age of target audience by channel.

1. INTRODUCTION

In line with increase in number of channels, the audience who is the channel leader takes initiative in broadcasting, while broadcasting companies concentrate their efforts on enhancing the competitiveness based on their unique and differentiated image they are building. The color, among the visual factors, is recognized more quickly than others to convey the message and is the emotional element which determines the overall circumstance. Michell Pastoureau asserted the color rules the choice. Broadcasting companies use the color as effective means in structuring the channel identity. A color scheme harmonizing the channel image is consistently applied to network design elements including channel logo, title design, station break and typography. Particularly, when it comes to cable channel which has more distinctive channel characteristics, compared to the general service-providing channel, channel identity color incorporating the image of target viewers serves the effective differentiated strategy. This study is thus intended to compare and analyze the color design and channel image of Korean women lifestyle channels focusing on women audience.

2. METHOD

Among the objects for the analysis in this study are *Onstyle*, *O'live*, *FashionN* and *Channel Donga* and 8 important scenes of station ID of each channel were captured before analyzing the dominant color, highlight color, supplementary color and color matching band. Station ID, among broadcasting graphic elements, is the sort of promotional materials which represent better the channel concept, serving the catalyst for improving the image of broadcasting company and thus it shows the representative color of the channel.

As analysis method, representative colors from the captured screen were extracted and color matching band was configured considering the area, which was then arranged to IRI color image scale[1] for analysis of the channel image which the broadcasting companies wished to build through the colors.

3. RESULT

The major colors were extracted from station ID screen of 4 women lifestyle channels and the color marching band was configured depending on area which were compared and evaluated, together with channel logos (see Fig 1). All 4 channels used uniform color for logo color and station ID.

Figure 1. Captured station ID screens

Figure 2. Color matching band

3.1 Expression of women's symbolism

Dominant color and supplementary color which were consistently used in logo and station ID represented the women's symbolism (see Fig 2). Three channels, excluding *FashionN* channel, used purple in common, while *FashionN* adopted red as dominant color. Symbolic colors representing the women were frequently used, expressing their intent focusing on women.

Fig 3 is the color image scale indicating the major colors and adjectives by channel. *Onstyle* harmonized the feminine pink and luxury purple to create the soft and womanly image, *O'live* matched lively orange with luxury purple to create the fresh and cheerful image, *FashionN* mixed the dynamic red with modern black to create the passionate and intense image and *Channel Donga* stressed the diverse and mysterious image by harmonizing sweet pink and splendid purple.

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[1] A matrix to allocate the image of a single or matching color to each axis of the scale using objective statistical technique based on sensitivity from color image so as to serve the guideline of psychological sensitivity analysis.

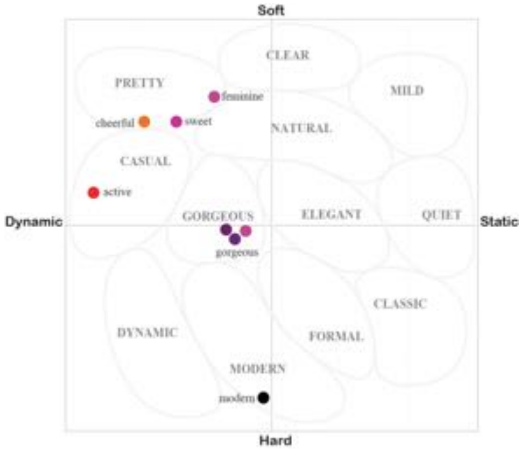

Figure 3. Color image scale

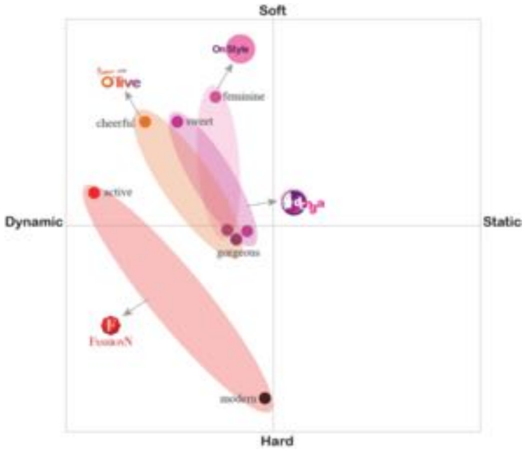

Figure 4. Distribution of color

3.2 Expression of modern femininity

As a result of analyzing the color image, dominant color and highlight color represented the modern femininity. Fig 4 indicates that dominant colors of 4 channels were all placed at the space of soft-dynamic color image due to a single color image scale, which was considered to represent the confident and active image of the women in modern society. Three channels, excluding *FashionN*, employed purple series which are individualistic and liberal as dominant color. Purple is conspicuous color differentiating her from others or vanity color which is favored by the women in her 20s or 30s. Thus it appeared to emotionally target the individualistic character of young women. When it comes to *FashionN* using red and black as dominant color, they showed the passion and aggressiveness of the women today through strong and dynamic color arrangement.

3.3 Difference in color matching depending on target audience bracket

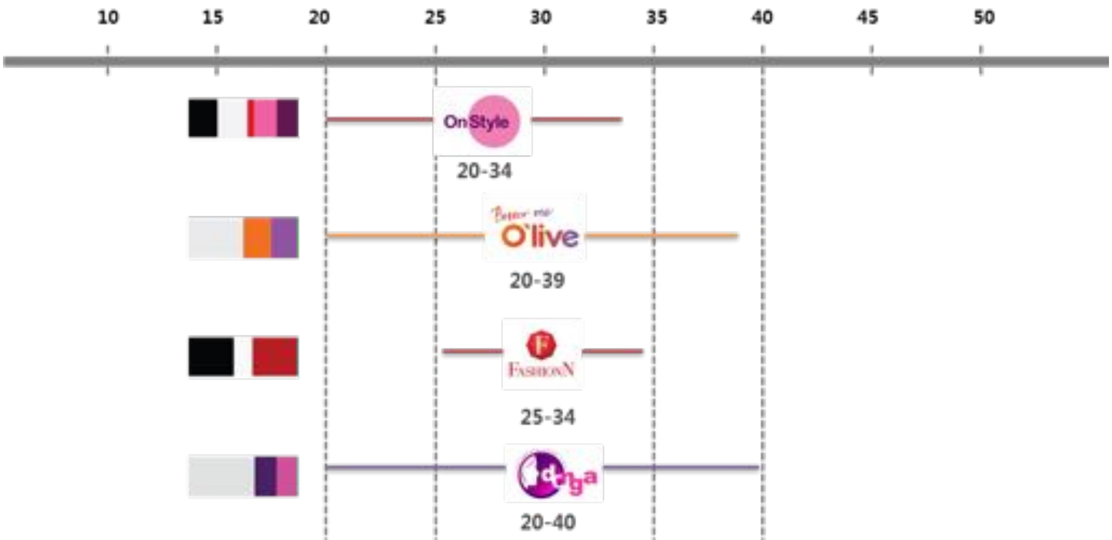

Figure 5. Difference in color arrangement depending by target audience

Fig 5 shows the difference in color arrangement depending by age group of the target audience. When it comes to *O'live* and *Channel Donga* who have the audience whose age bracket is broader (20 to 39 and 20 to 40, respectively), they adopted achromatic color having high brightness to display the mild background view. They attempted to show flexural attitude to accommodate the comprehensive age brackets using grayish color with high brightness symbolizing the soft and mild image. Then in case of *FashionN*, in contrast, which has the audience of narrow age bracket (25 to 34) selected the strong color matching using the red and black. Matching the red which is noticeable and expresses the passionate image with the black which is urbanely and refined image is rather stimulating and contemporary. Such a dynamic color arrangement appeared to have focused on unmarried women who have been emerged as the best customers.

4. Conclusion & Discussion

Color code which has been consistently applied in a bid to establish the unique channel image must be the efficient marketing tool which could enhance the identity and competitiveness. The outcome of the analysis of Korean women lifestyle channel colors is as follows.

First, four channels used such colors as Pink, Purple, Red and Orange representing the symbolism of the women in common as dominant color or highlight color. Second, they mainly used the color in the space of soft-dynamic color image as dominant color in a bid to represent the femininity which is confident and active in modern society. Third, there's a difference in color matching image among the age bracket of the target audience. The broader the age bracket of target audience the softer the color matching using grayish color having high brightness as background color, and the narrower the age bracket of the target audience the stronger the contrast in color as background design.

The analysis indicated that each channel has applied their identity color consistently which is expected to make commitment to enhancing the brand competitiveness through differentiated colors.

References

Chung, D., Kim, J. 2009. *Broadcast Network Design.* Seoul: Jipmoondang.

Heller, E. 2002. *Wie Farben auf Gefuehl und Verstand wirken.* Seoul: Yedam.

LoBrutto, V. 2002. *The Filmmaker's Guide to Production Design*. New York: Allworth Press.

Park, Y., Eun, H. 2005. A Study on colors in the Korean broadcasting for a raise of identity. *Journal of Korea Society of Color Studies* 19 (1): 1-12.

Yoon, H. 2005. *Channel brand strategy*. Seoul: Communication Books.

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The Effects of Surround Luminance on the Color Perception of Outdoor LED panel

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ABSTRACT

In this study, a psychophysical experiment using magnitude estimation technique was conducted to investigate the effects of the surround luminance on the perception lightness, colorfulness and brightness in LED panel. A total of eighteen test colors with various lightness level and chroma produced on LED panel were assessed by 12 observers in dark, average and bright ambient conditions. The color space CIELAB were used and the color coordinates of the test colors were measured by PR650 TSR. The observers were asked to assess the test colors in terms of lightness, colorfulness and brightness. The experimental results indicate that the lightness and brightness are largest when viewing in dark and least when viewing in bright sunny day. The accumulated data set was also used to test color appearance model CIECAM02 and mobileCAM proposed by Park YK. et al.

1. INTRODUCTION

Large size LED display panels are increasingly popular to use as outdoor for advertisement in public area for the energy saving. However, it is found that the perceived color appearance produced on LED panel is significant different viewing in bright sunny day and in dark night. It is necessary to investigate how the color appearance changes with the surrounding luminance level. According to the results, the light of the RGB-LEDs can accurately be adjusted that the color appearance looks the same in various luminance environments to save energy efficiently.

The color appearance model CIECAM02, providing methodologies to predict the color appearance in different viewing conditions, has been successfully applied in many fields. The color appearance prediction in different luminance levels, ranging from dark, dim and average, can be obtained by CIECAM02. However, the color appearance prediction in bright illumination is not included. There have been many researches to investigate the color appearance under high surround luminance level using various media. JM Kim et al.[1] found that the images of mobile display in the outdoor are perceived darker and less saturated than in average surround and proposed algorithm to improved the quality of the perceived image adaptive to an outdoor environment. The psychophysical data set of the perceived brightness on mobile in varied surround luminance levels from dark to over-bright is systematically accumulated by Park et al.[2] and mobileCAM, refined the surround parameters in CIECAM02, is proposed based on the visual data tests. The perceptual brightness contrast on LCD under various luminance levels from dark to over-bright is studied by Baek al et.[3] and the surround parameters are derived to good performance for the corresponding visual data. Choi et al.[4] conducted a psychophysical experiments using 42-inch Plasma Display to investigate the changes in color appearance under various surround ambient conditions. In this study, the color appearance in full-color LED panel under different luminance level environments, including dark, average and bright is studied. The visual data set was obtained from a series of psychophysical experiments, using magnitude estimation technique. The data were used to evaluate the performance of the color appearance model CIECAM02 and mobileCAM proposed by Park YK. et al.

2.EXPERIMENTAL

2.1 Experimental setup

In this study, a 32*24 cm^2 RGB-LED panel is composed of 64*48 full-color LED chips, in which the diameter of each chip is 3 mm and the space between the center of chip is 5 mm. The maximum luminance of R, G, B LED are tuned by computer to mix reference white D_{65} with luminous of 1646 cd/m^2. A psychophysical experiment was carried out to investigate the perceptual color appearance produced by the RGB-LEDs in various environmental luminance levels. A test color patch of 32cm*32cm produced by 16*16 RGBLED chips and surrounded grey paperboard was presented in the front of the observers, with a distance of 150 cm . A reference white with 5cm*5cm was placed on the left of the test color patch to provide for assess the lightness attribute. The CIELAB color space was used to select the target test color patched for neutral with different lightness (L*=20,40,60,80) and Red, Green, Blue, Yellow with different lightness or chroma. Total eighteen test colors, spreading in CIELAB space, were used.

2.2 Environment luminance

The test patches were assessed viewing in three different luminous levels, including dark, average and bright. According to CIE, the surrounding condition can be defined by the value of surround ratio S_R, which is the ratio of the luminance of reference white in the stimulus to the luminance of white area in the surround. The surrounding is dark for S_R □0, dim for 0< S_R <0.2 and average for 0.2 <S_R □1, which are the surrounding conditions considered in CIECAM02 color appearance model and for S_R >1, the surround is called bright. In this study, the luminance of the surround, the reference white in LED display and the background were measured. The surround ratios S_R, background ratios and veiling glare, involved in this study, were calculated and shown in Table 1. The surround ratios of dark, average and bright were 0, 0.35 and 3.3, respectively.

Table 1 The surrounding parameters for dark, average and bright

Surround	Surround white / white of LED Display in cd m^{-2} (S_R)	Y_b (%) (Background)	Veiling glare (%)
Dark	0/1646 (0)	0.17 (Black)	-
Average	613/1748 (0.35)	24.4 (Gray)	6.2
Bright	7298/2196 (3.3)	22 (Gray)	33.4

2.3 Observer assessment

The magnitude estimation technique was used and observers sit on the front of the test LED-color patch, subtended a viewing angle of 6^0, and were asked to assess the test colors in terms of lightness, colorfulness, brightness and hue. Twelve observers took part in the experiment for three phases, including dark, average and bright ambient conditions. Each phase consists of 18 test colors assessments and a total 7776 assessments were implemented. The average color appearance attributes of the test color in each phase were calculated and used to compare with the predictions of CIECAM02. The predictions obtained from mobileCAM were also utilized to analyse the effect of the medium.

3. RESULTS

3.1 Observer accuracy

The coefficient of variance (CV) between individual and mean visual value in each phase were calculated to indicate the observer's deviation. The total means, shown in Table 2, were 27.8, 32.9, 26.2 and 9.4 for lightness, colorfulness, brightness and hue, respectively. The lower value of hue indicates hue attribute was easier to be assessed than other attributes. However, all of the mean CVs are larger than those found in previous studies. It indicates that the accuracy of the color appearance assessments for LED is worse. The reason maybe due to the high luminance of the LED colors. Comparison the CVs with various surround, it found the CVs of bright are largest for all perceptual attributes except hue. The high surround luminance and veiling glare affect the perceptual color assessments.

Table 2 Values of CV of lightness,colorfulness,brightness and hue for dark, average and bright

	Dark	Average	Bright	Total mean
Lightness	19.7	27.1	36.5	27.8
Colourfulness	34.3	29.3	35.1	32.9
Brightness	22.2	20.2	36.2	26.2
Hue	10.9	9.0	8.4	9.4

3.2 Effect of surround luminance

The visual assessment for lightness, colorfulness and brightness in various surround luminous were individually plotted against the L*, C* and L* to investigate the effect of surround on the color appearance attributes. The visual lightness and brightness are obvious larger viewed in dark than in average surround, and least viewed in bright. This is consistent with the findings of JM Kim.

The predictions of color appearance model CIECAM02 were used to compare with the visual data obtained from the psychophysical experiment. In the CIECAM02, three surround luminance levels (average, dim, dark), are considered and the values of surround parameters *c*, *F*, *Nc* for various surround are defined. The surround parameters for bright were set the same as those for average to evaluate the performance of CIECAM02 in this study. The predictions of lightness, colorfulness and brightness were individually plotted against the corresponding visual assessments in dark, average and bright. Figure.1 shows the values of lightness predicted by CIECAM02 under dark and average conditions are lower than the visual results in LED. For the colorfulness, CIECAM02 has better predicted performance, however, for the brightness, it gave bad predictions for all the conditions, especial the over-evaluated values under bright surround.

The color appearance attributes predicted by MobilCAM, which is based on the accumulated visual data on small size LCD displays, were also plotted against the corresponding visual assessments in LED panel to investigate the effect of medium and size. According to the results, the lightness values predicted by MobileCAM are lower than the corresponding visual data on LED panel, high intensity and large size, under dark and average surrounds. For the brightness, the colors in LED panel look brighter than in mobile display under dark surround. However, the brightness in LED is less than predicted by MobilCAM under bright surround.

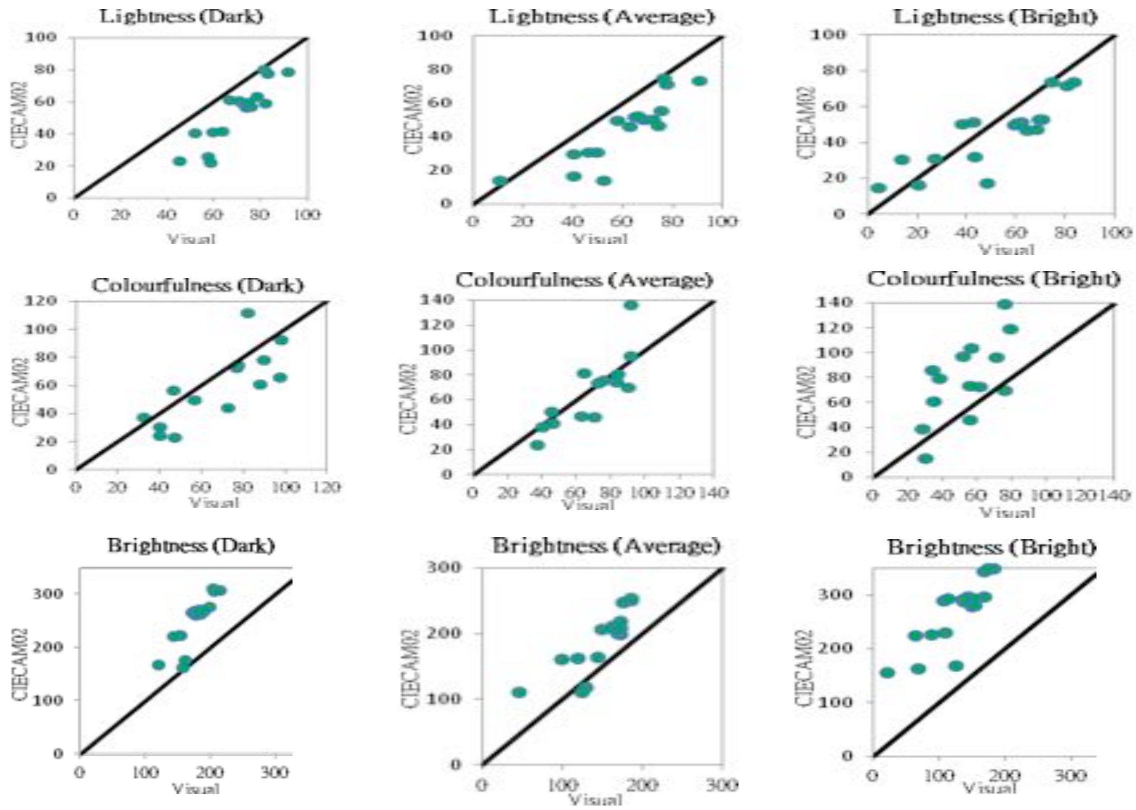

Fig.1 CIECAM02 predictions plotted against the corresponding visual data for different surround conditions (left: dark, middle: average, right: bright)

REFERENCES

[1] J.M. Kim, K.H. Park and O. S. Kwon. 2005. Illuminant-adaptive color reproduction for mobil display. *Preceedings of SPIE-IS&T* 058.

[2] Y. Park, C. Li and M. R. Luo. 2007. Applying CIECAM02 for mobile display viewing conditions. 15th *Color Imaging Conf*: 169-173.

[3] Y. S. Baek, A. Kim, H. S.. Kim and S. O. Park. Nov. 2011. Brightness contrast under high surround luminance levels: psychophysical data vs CIECAM02. *Preceedings of SPIE-IS&T* 7866:487-711.

[4] S. Y. Choi, M. R Luo, M. R. Pointer, C. Li, P. A. Rhodes. 2010. Changes in Colour Appearance of a Large Display in Various Surround Ambient Conditions. *Col. Res Appl* 35: 200-212.

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Gender difference in judging facial attractiveness based on skin tone

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ABSTRACT

A Psychophysical experiment was conducted to investigate gender difference in judging facial attractiveness by skin tone. Two original young Caucasian faces (a male and a female) were used for generating 22 face images varying in skin tone. Eighteen British observers participated in the experiment. The results show that gender difference was much stronger in judging female faces (r = -0.44) than in judging male faces (r = 0.58). Low-chroma, yellowish female skin tone appeared most attractive to female observers, whereas those of high-chroma, reddish hue were most attractive to the male.

1. INTRODUCTION

Skin tone has been a significant visual cue for facial attractiveness and physical health (Frost 1988). Skin was most attractive with evenly distributed tone and texture (Fink et al. 2006) and there was a high correlation between healthy-looking skin and perceived facial attractiveness (Lewis 2011). Evidence has shown that the preference for paler skin tone of female faces was consistent across races including African, Caucasian and mixed black and white (Wade et al. 2004 and Lewis 2011). Studies of preferred skin colour have reported that the preferred skin tones in face images were significantly different than actual skin tones. For instance, Zeng and Luo (2011) found that the preferred skin tones for Oriental and African faces were more reddish than real skin tones. The common flaw of these studies, however, was in the method of generating visual stimuli, i.e. the visual stimuli were selected or created without controlling any factors that might affect the visual results, such as age, facial features (e.g. eye size) or emotional facial expressions. Without any control of these factors, it would be hard to justify whether the results were based solely on skin tone or whether they were impacted by the other factors. In addition, little was known regarding the gender difference in judging facial attractiveness that might be affected by skin tone.

To address these issues, the present study used young Caucasian face images of both genders to investigate the observer's perception of facial attractiveness. Comparisons of the experimental results were made between male and female observer groups, revealing strong gender difference in judging female faces, as discussed in more details in the following sections.

2. METHODS

Two original young Caucasian face images, including a female and a male (see Figure 1), were used to generate image stimuli. Each original image was manipulated into 11 face images using MatLab by varying CIELAB a* and b* values for each pixel by equal amount while L* values remained unchanged. The 11 skin tones were selected to cover a wide range of preferred Caucasian skin tones on the basis of a recent study by Zeng and Luo (2011). The mean CIELAB values are shown in Table 1. A total of 22 manipulated face images were created as visual stimuli used in this study.

Figure 1. Original faces used in the study: (b) Caucasian female and (c) Caucasian male for Exp2

Table1. CIELAB values (pixel average) for text images used in Exp2

Skin tone manipulation	1	2	3	4	5	6	7	8	9	10	11
a*	15.9	11.5	13	9.7	20.3	23	17.1	19.6	18	13.4	10.6
b*	14.6	10.5	8.6	12.2	18.7	15.3	21.6	9	11.9	16.9	18.8
C^*_{ab}	21.6	15.6	15.6	15.6	27.6	27.6	27.6	21.6	21.6	21.6	21.6
h_{ab}	42.6	42.6	33.6	51.6	42.6	33.6	51.6	24.6	33.6	51.6	60.6

The experiment were conducted using a cathode ray tube (CRT) monitor (with a peak white of 64.9 cd/m^2) situated in a darkened room. Eighteen British Caucasian university students, aged from 18 to 21, including 9 males and 9 females, all passing Ishihara's test for colour deficiency, participated in the experiment, with a viewing distance of 50cm. The test images were presented individually on the CRT monitor in random order. The observers were asked to rate each image in terms of the attractiveness, on a six-point force-choice polar scale (on which 1 means "a little", 2 "moderately", and 3 "a lot"). Figure 2 shows a screen layout in the experiment.

Figure2. Screen layout of the experiment

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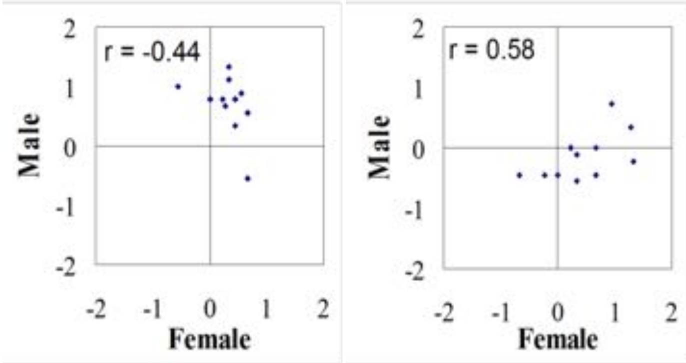
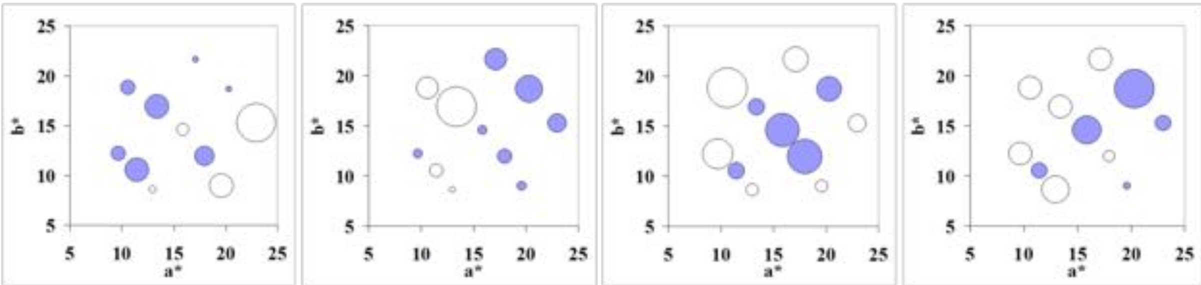
3. RESULTS

The gender difference in judging facial attractiveness affected by skin tone was examined by comparing female data and male date using correlation coefficient (r). Figure 3 demonstrates the comparison results of the experiment, showing a correlation coefficient of -0.44 between female and male data in judging female faces (see Figure 3a), and 0.58 in judging male faces (r = 0.58, see Figure 3b). This suggests that skin tone had a strong influence on gender difference in assessing female facial attractiveness.



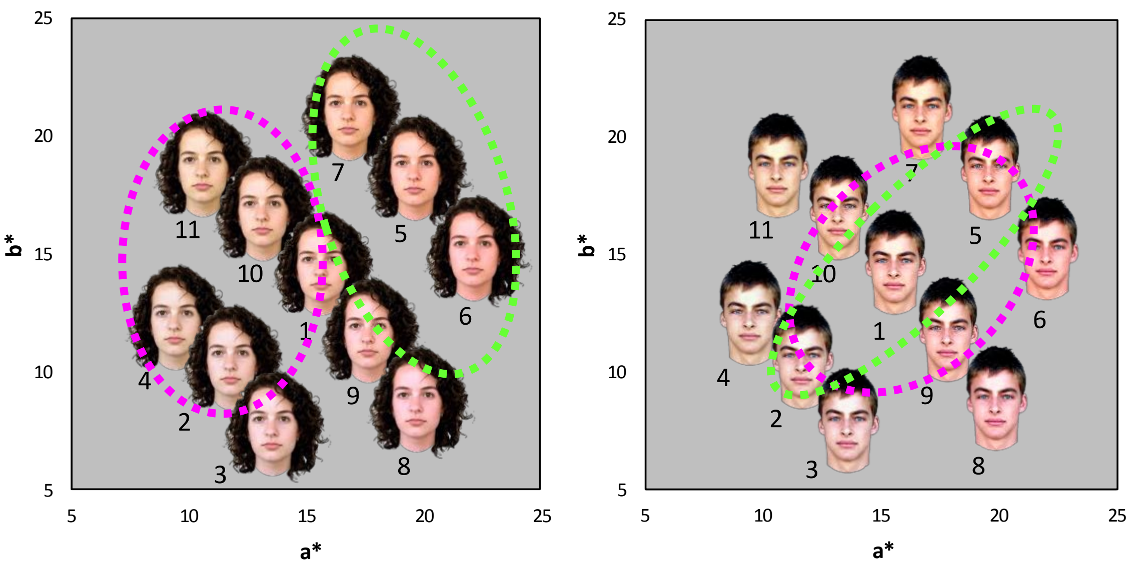
(a) *(b)*

Figure 3. Female response plotted against male response to (a) Caucasian female faces, (b) Caucasian male faces



(a) female response *(b) male response* *(c) female response* *(d) male response*

Figure 4. Response of (a) female observer to female faces, (b) male observer to female faces, (c) female observer to male faces, (d) male observer to male faces



(a) *(b)*

Figure 5. The 11 skin tones in CIELAB space for (a) female and (b) male faces used. Skin tones attractive to female observers are marked in pink to male observers marked in green.

To see how skin tone influences the differences between male and female data in judging Caucasian face images, comparisons were made by plotting male and female responses in bubble charts based on CIELAB a*-b* space, where the bubble size represents the observer response, as shown in Figure 4. It is clear that among female faces, female observers were most attracted by faces with skin tone in the low-chroma, yellowish hue region, whereas male observers were most attracted by faces with skin tone in the high-chroma, reddish hue region. Among male faces, the female observers were attracted most by faces with a skin tone at a hue angle of around 33° to 42°, with a chroma value of around 20; for male observers, the male faces with high chroma and hue angle around 42° were most attractive, and the higher the chroma is, the more attractive the male face appeared. Figure 5 (a) and (b) demonstrate a graphical visualization for the range of skin tones being the most attractive to female observers (marked in pink) and to male observers (marked in green).

4. CONCLUSION

The experimental results show strong evidence that male and female observers rated differently for female face images varying in skin tone. Female face images with skin tone in the low-chroma, yellowish hue region looked most attractive to the female observers, whereas those in the high-chroma, reddish hue region were rated most attractive by the male observers. The outcome of the current study may be applied in customizing image processing of facial skin tone based on user gender.

5. ACKNOWLEDGEMENT

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REFERENCES

Frost, P. 1988. Human skin colour: A possible relationship between its sexual dimorphism and its social perception. Perspectives in biology and medicine. 32 (1), pp.38 - 58.

Fink, B., K. Grammer, P. Matts. 2006. Visible skin colour distribution plays a role in the perception of age, attractiveness, and health in female faces. Evolution and human behavior. 27, pp.433-442.

Lewis, M. 2011. Who is the fairest of them all? Race, attractiveness and skin colour sexual dimorphism. Personality and individual differences. 50, pp.159-162.

Wade, T., K. Irvina, M. Cooper. 2004. Racial characteristics and individual difference in women's evaluations of men's facial attractiveness and personality. Personality and individual difference. 36, pp.1083-1092.

Zeng H., M. R. Luo. 2011. Colour and Tolerance of Preferred Skin Colours on Digital Photographic Images. Color Research and Application. Published on line, Sep. 2011.

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Studies of Blackness Preference and Perception

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ABSTRACT

This study investigates preference for, and perception of, blackness using psychophysical experiments. A total of 29 black samples (varying in hue, value and chroma) were evaluated for colour perception and colour preference. The results indicate little effect of gender or nationality on observers' perception of blacks. However, there is evidence of a cultural effect on colour preference, with gender being more important.

1. INTRODUCTION

There is a need for methods than can optimise the colour of black ink in printing systems and also that can optimise the use of black in product design. A research project at Leeds University is exploring the effect of hue, value and chroma on observers' preferences for and perception of different blacks. Psychophysical experiments to consider the effect of hue [1] and of value and chroma [2] revealed that neither nationality nor gender influenced blackness perception; however, colour preference of blackness was influenced by gender and, to a lesser extent, nationality.

The previous studies [1, 2] used an incomplete paired-comparison psychophysical method. This research seeks to validate and extend the previous findings using a ranking method.

2. METHODS

A set of 29 colour samples (Figure 1) was taken from the Munsell system. The set comprised of three samples (Munsell V/C = 1/2, V/C = 1/4 and V/C = 2/2) for each of ten Munsell hues (R YR Y GY G BG B PB P RP); the exception was for the hue Y where only two samples were available. Representations of the 29 samples were displayed on a CRT.

The ranking method was used in this study. The colour samples (3 cm × 2 cm) were displayed on a CRT GUI (written in MATLAB) with neutral grey (R=G=B=133) background. Observers viewed the samples in a darkened room from approximately 90 cm and were asked to sort them according to one of two criteria. Firstly, the observers were asked to arrange all

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colour samples in order from like to dislike (blackness preference); secondly, they were asked to put them in order of which one is the closest to a pure black (blackness perception). Observers were able to move the samples on the GUI using the mouse.

In this study 26 observers, 14 Chinese (5 male and 9 female) and 12 UK (5 male and 7 female), participated. All of these observers passed the Ishihara Test for colour blindness before participating in the experiment. The rank-order data were collected and used to calculate interval scale values.

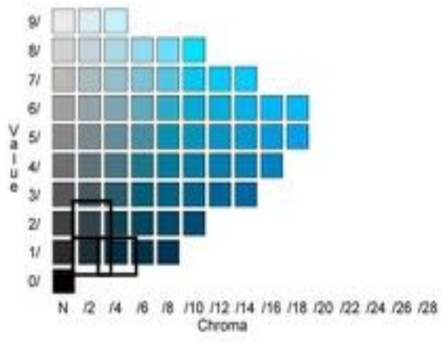

Figure 1. Colour Samples from the Munsell System.

Figure 2. The GUI used in the experiment.

3. RESULTS

3.1 Blackness Preference

In this section the results of the blackness preference phase are analysed. Figure 3 indicates the general order of preference of colour samples in different nationality groups. More positive scale values indicate that the samples were more preferred. As indicated in Figure 3, 5PB1/4 and 5P1/4 are strongly preferred by both nationalities. A previous study [1] also indicated that observers of both nationalities preferred blue and purple colours. Yellowish blacks were least preferred in general as they were in a previous study [1]. However, there were some small differences between UK and Chinese responses. Chinese observers ranked 5Y1/2, 5YR2/2 and 5Y2/2 as the least preferred colour samples whilst 5YR1/2, 5G1/2 and 5GY2/2 were least preferred by the UK observers. In terms of chroma and value, a previous study [2] had found that Chinese observers preferred V1C2 and disliked V2C2, and UK observers preferred V2C2 and disliked V1C2. However, in this study no difference was found between the nationalities; both groups preferred V1C4 and disliked V1C2.

Figure 4 indicates the differences between male and female responses. Both females and males like blue and purple tones and dislike yellow tones. In terms of chroma and value there were some marked differences between the male and female results. Males strongly preferred V1C4 and disliked V2C2 colour samples whereas females preferred V2C2 and disliked V1C2 colours. Generally, the female results are very similar to those obtained in the previous studies [1, 2] but there were some disparities in the male observers' results. For example, in the second study [2] males disliked V1C4 but V1C4 samples have high scores in each hue group in this study.

The correlation coefficients (r) for nationality and gender are 0.78 and 0.59 respectively. There is thus some indication that gender has more influence on preference than nationality.

Figure 3. Scale values for colour preference scaling for UK (blue bars) and Chinese (red Bars) observers.

Figure 4. Scale values for colour preference scaling for Male (blue bars) and Female (red bars).

3.2 Blackness Perception

In this section the results of blackness perception (which colour sample is judged to be closest to a pure black) are analysed.

Figures 7 and 8 show the scale values of each colour sample that results from four groupings of the observers (Chinese, UK, male and female). The greater and more positive the scale values the more the sample was judged against the criterion of being pure black. It shows that 5PB1/2 has the highest scale value (3.32 for UK and 3.16 for China) of all the samples. This result indicates that people considered 5PB1/2 to be the nearest color to pure black and this is consistent with the two previous studies [1, 2]. Samples 5R1/4 and 5YR1/4 were considered to be the least black of all the samples.

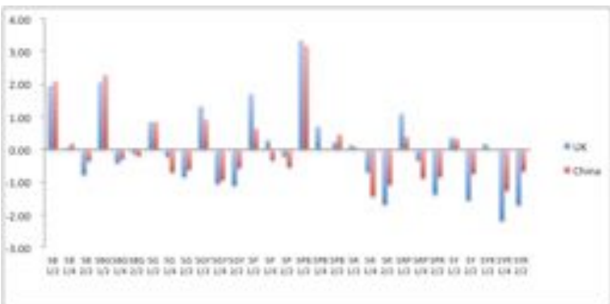

Figure 7. Scale values for colour perception scaling for UK (blue bars) and Chinese (red bars) observers.

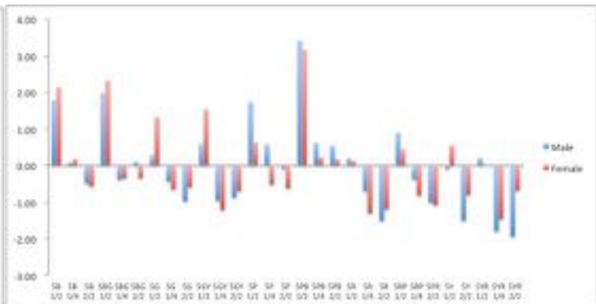

Figure 8. Scale values for colour perception scaling for male (blue bars) and female (red bars) observers.

Figure 7 shows the scale results according to nationality (China and UK) and indicates that there are little differences in blackness perception between the UK and China populations.

Samples 5PB, 5B and 5BG have higher scale value and 5R, 5Y and 5YR have low scale values; on the other hand, V1C2 is considered to be the most black in each hue group. This result indicates that people considered V1C2 to be the nearest colour to pure black.

Figure 8 show that responses from male and female observers are similar. For both groups samples 5PB, 5B and 5BG are considered to the three blackest samples whereas neither male nor female observers rate 5Y, 5YR and 5R highly. Both males and female also give V1C2 a high score.

The correlation coefficients (r) for nationality and gender are 0.91 and 0.88 respectively.

4. CONCLUSIONS

The main purpose of this research was to investigate blackness preference and perception with respect to differences in gender and nationality. The results indicate that neither nationality nor gender significantly influence blackness perception. However, there is some evidence that cultural factors (nationality and gender) could affect blackness preference. Purplish and bluish blacks are generally preferred by all observers. The results are broadly consistent with those from two previous studies [1, 2].

REFERENCES

[1] Tao L, Westland S and Cheung V, 2011. Blackness: Preference and Perception. *Proceedings of the IS&T/SID's Nineteenth Color and Imaging Conference*, 270-275, San Jose (USA).

[2] Tao L, Westland S and Cheung V, 2012. Blackness: Preference and Perception (Chroma and Value), *Proceedings of the Sixth European Conference on Colour in Graphics, Imaging, and Vision*, 253-258, Amsterdam (The Netherlands).

[3] Thurstone LL, 1927. Psychophysical analysis, *American Journal of Psychology,* 38: 368-389.

[4] Morrissey JH, 1955. New method for the assignment of psychometric scale values from incomplete paired comparisons, *Journal of the Optical Society of America,* 45: 373-378.

poster

Implicit attitude toward colour: Trials for analyzing colour preference using Implicit Association Test (IAT)

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ABSTRACT

In a history of research concerning color preference, preference judgment has been measured via explicit behavior, such as verbal report and so on. In many recent psychological studies, however, it has been indicated that expressed attitude measured with explicit method often differs from underlying implicit attitude. In the present investigation, we tried to analyze implicit attitude toward color. Using implicit association test (IAT), we measured strength of association between preferred color/hated color which was explicitly selected, and pleasant-unpleasant (experiment 1) or self-other (experiment 2). Data obtained from two psychological experiments with 26 participants indicated that preferred color significantly associates with concepts of pleasant or self. Furthermore, implicit association between preferred color and pleasantness turned out to be weakened in the participants with lower color stereotype and lower color consciousness. Thus, it can be concluded that participant's cognitive styles on color in daily life affects the implicit attitude toward color.

1. INTRODUCTION

Colour preference has been one of the biggest concerns of the researchers in colour sciences for long years. The colour preference has been measured by various methods in accordance with the researcher's interest. In most cases, the methods in measuring colour preference would be based on the participants' explicit behavior, such as verbal report and so on. Typically, an investigator may simply ask the participants to select their most preffered or hated colour from a set of candidate colours .

In many recent psychological studies, however, it has been indicated that expressed attitude measured with explicit method often differs from underlying implicit attitude. Thus, in the present investigation, we tried to analyze implicit attitude toward colour, using implicit association test (IAT; Greenwald et al, 1998). IAT is recognized as one of the most conventional method in measuring implicit attitude in psychological studies. In IAT, participants discriminate target word into two criteria. In the condition where the psychological concept which are implicitly associated are paired in discriminatory criteria, the participant's reaction is facilitated (reaction time is reduced), vice versa in the condition where the psychological concepts without implicit association are paired. IAT utilizes differences of reaction time in categorical judgment in order to measure participants' implicit attitude, independent of participant's conscious and arbitrary indication. In experiment 1, the participants executed IAT measuring implicit associations between preferred colour/hated colour, which was explicitly selected, and psychological concept of pleasant-unpleasant. In experiment 2, IAT measuring implicit association between preferred colour and psychological concept of self was executed with the same participants as experiment 1.

2. EXPERIMENT 1

2.1. Methods

Twenty six undergraduate volunteers participated in the psychological experiments. They participated IAT trials for measuring their implicit association between preferred-hated colour and pleasant-unpleasant. Before executing IAT, the participants selected their most favorite and most unfavorite colours from 12 candidate colour names (white, black, grey, red, pink, orange, brawn, purple, blue, green, lime green, yellow), which were used in the IAT trials.

In IAT trial, a target word belonging to the following four categories was presented; preferred colour, unpreferred colour, pleasant and unpleasant. Preferred and unpreferred colours were presented as one of three possible Japanese characters (Kanji, Hiragana and Katakana). Pleasant and unpleasant words were presented as nouns which represent the target concepts (e.g., happiness, peace or fortune for pleasant, and misery, pollution or evil for unpleasant words). The participant was asked to discriminate and categorize the word, and make a response with a correspondent key as soon as possible. On top-left and top-right of the display, there were labels of the categories in order to help the participant's response. Figure 1 schematically indicates visual display employed in the IAT trial. Laptop PC with 14.1 inc. LCD display was employed in the experiment. Methods for executing the IAT trial in the present experiment conformed the previous studies (Greenwald et al, 1998).

The participants also answered inquiry which asked the participant's cognitive styles on colour in daily life (colour consciousness [six items] and colour stereotype [four items]) with conventional six-point psychological scales. An example of items is as follows: "I'm always aware of colours of my friend's cloths and belongings" for colour consciousness, and "There should be a colour which can represent a certain country or region" for colour stereotype).

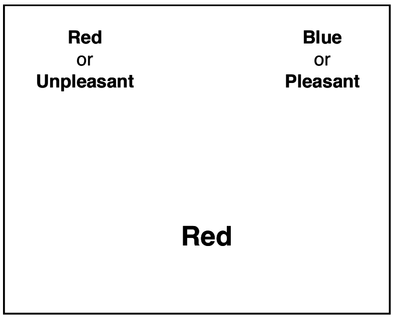

Fig.1 Schematic presentation of visual display used in the experiment. Japanese characters were used in a real display

2.2 Results and Discussion

IAT score was calculated based on modified method proposed by Greenwald et al (2003). Positive IAT score indicates that there is an implicit association between the participant's preferred colour and psychological concept of pleasantness (or association between hate colour and unpleasantness). The participants were divided into four groups in accordance with the medians of two scores for their cognitive styles against colour (high/low colour consciousness × high/low colour stereotypes). Figure 2 shows averaged IAT scores for each participants group. Implicit association between preferred colour and pleasantness was relatively stronger in the participants with lower colour stereotypes and higher colour consciousness, as compared with the participants with lower colour stereotypes and lower colour consciousness. Two-way analysis of variance (ANOVA) revealed that there was a significant main effect of the colour consciousness ($F(1,22)=8.61$, $p<.01$) and significant interaction between the factors ($F(1,22)=7.53$, $p<.05$), although main effect of the colour stereotype did not reach significant level ($F<1.0$). Post-hoc multiple comparisons using Tukey's HSD test revealed that there were significant differences of IAT scores between the participants with low colour stereotype/low colour consciousness and the other participant groups. Furthermore, single tailed t-tests with Bonfereni correction indicated that IAT scores had significantly positive values (significantly greater than 0) in the three participant's group other than the low stereotype/low consciousness. The result of experiment 1 showed that there was mostly significant implicit association between preferred colour and pleasantness, although its amount was varied with the participant's cognitive style on colour. In other words, experiment 1 succeeded to obtain the participant's colour preference with the implicit methods.

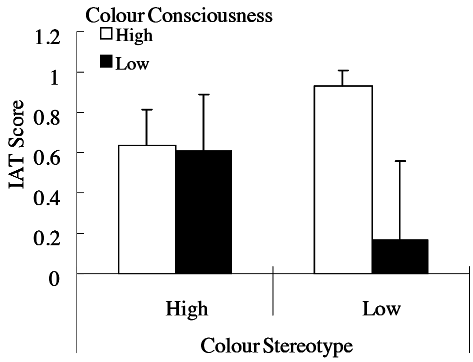

Fig.2 IAT scores under each participant's group (preferred colour-pleasantness: exp 1) Error bars indicate standard deviations

3. EXPERIMENT 2

3.1 Methods

Experiment 2 was carried out in order to examine implicit association between the preferred colour and concept of self. It has been reported that psychological images of preferred color and self, measured by explicit way such as semantic differential method, become resemble with each other (Charles & Moyer, 1992). Experiment 2 aimed to measure relationship between colour preference and self image implicitly.

Methods were almost same as in experiment 1. Target words relevant to "self" and "others" replaced the words concerning to pleasantness-unpleasantness employed experiment 1. Twenty six participants who participated in experiment 1 also took part in this experiment, with inter-experiment interval more than six months.

3.2 Results and Discussion

Figure 3 indicates averaged IAT score obtained under each participant's group. Two-way ANOVA indicated that there was no significant main effect and interaction.

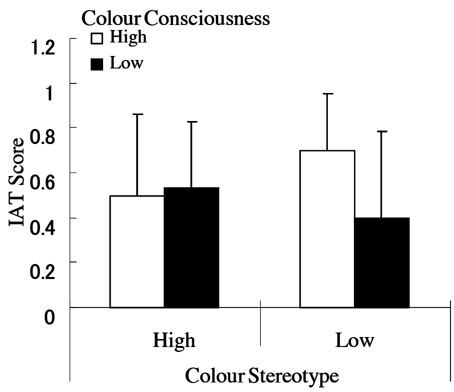

Fig.3 IAT scores under each participant's group (preferred colour-self: exp 2) Error bars indicate standard deviations

Single tailed t-tests with Bonfereni correction indicated that IAT scores for all participant groups had significantly positive values, which indicates that the preferred colour is implicitly associated with psychological concept of self (or hated colour is associated with concept of other). The result was consistent with the previous investigation which indicated that mental image of preferred colour which was explicitly measured with semantic difference method was similar to the one of the self.

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4. GENERAL DISCUSSION

The results of the present investigation indicate possibilities of implicit measurement of colour preference, that is, measurement based on participants' non-subjective behavior. Fazio et al. (1995) suggested that participants' attitude measured with explicit method (explicit attitude) can predict their verbal responses, whereas participants' attitude measured with implicit method (implicit attitude) predicts their non-verbal behavior well. Thus, it can be considered that implicit attitude toward colour is more adequate in predicting one's purchasing behavior and so on. Establishing method for measuring implicit colour preference can contribute colour marketing from new point of view. Further experiments will be carried out in order to assess psychological process underlying colour preference, with examining factors which can affect the implicit colour preference.

REFERENCES

Charles, M., and Moyer, W. W. Correspondence of self-referent statements and color preference. *Perceptual and Motor Skills*, 74(3), 993-994.

Fazio, R. H., Jackson, J. R., Dunton, B. C., and Williams, C. J. 1995. Variability in automatic activation as an unobstrusive measure of racial attitudes: A bona fide pipeline? *Journal of Personality and Social Psychology*, 69(6): 1013-1027.

Greenwald, A. G., McGhee, D.E., and Shwarz, J.L.K. 1998. Measuring individual differences in implicit cognition: The implicit association test. *Journal of Personality and Social Psychology,* 74(6): 1464-1480.

Greenwald, A. G., Nosek, B. A., and Banaji, M. R. 2003. Understanding and using the implicit association test: I. An improved scoring algorithm. *Journal of Personality and Social Psychology*, 85(2): 197-216.

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A Study on People's Preference and Imagery of House Color

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ABSTRACT

What effect does color have on people's feelings and imagery with regard to their immediate living environment? This study analyses people's preferences of outside wall color of single houses. In order to find out about people's preferences for colors of the outside appearance of a house, their imagery of preferable and aversive house colors, and the relations between color preferences of houses and cultural and demographic variables, a computer-based experimental survey has been conducted with 123 subjects of Chinese Culture University, Taipei. A series of images made from a 3D-model with 30 different texture colors were chosen to ask for color preferences. Eight semantic scales consisting of 8 bipolar word-pairs (Dislike-Like, Ugly-Beautiful, Hard-Soft, Cool-Warm, Vulgar-Elegant, Discreet-Loud, Masculine-Feminine, Unpleasant-Pleasant) were used to derive imagery and rate the colors with a 7-step Likert scale. Results show that people favor the colors S-3020-R70B, S4030-Y60R, and S3020-Y80R, but dislike S3040-Y, S2010-G90Y, and S5000-N (NCS notation) for their house color. No significant interaction has been found between demographic variables and color preference of house colors.

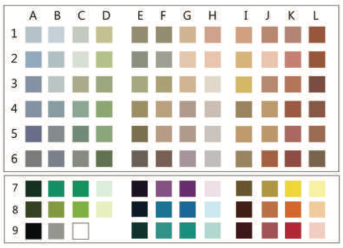
1. INTRODUCTION

The interest in understanding people's individual color preferences and architecture can be rooted back to early age in Western culture: The Roman architect Vitruvius (1st century A.C.) has written one of the first treatises on natural colors and pigments, and how to find and apply them. The Italian Architect Alberti followed the perspective of Vitruvius, offering the earliest descriptions of how color relates to aesthetics and color preferences. From his point of view, pure and clear colors can add holiness to people's life, and let it become more joyful. Alberti has also established a system of color brightness and color classification, and for the first time concluded an emotional value of colors (Caivano, J. L., 2006). Color has a great effect on people's feelings: different colors give people different imagery and value. Regarding archi-tectural design factors, the application of colors can change moods, and even influence the perception of a place, like the level of comfort and the kind of atmosphere of the surrounding space (Nissen, Faulkner & Faulkner, 1999). The architecture of big cities and its colors are not only factors that transfer a certain impression on people, but they also psychologically influence the life of the cities' inhabitants: color imagery is an impression that color has on people's perception. This study aims to investigate the preference of house colors and the psychological effect evoked by color imagery.

2. METHOD: SURVEY-TYPE EXPERIMENTAL RESEARCH

2.1. Stimulus

Due to the scale and feasibility concerns of the study, a computer-based survey experiment was set up using the stimulus of a 3D-model of a single house, with texture mapping and colors applied on the wall, followed by a questionnaire, to survey subjects' color preference and feelings with semantic scales. A pilot study was conducted with a focus group of architects, scholars and students, to determine proper colors and semantic scales. A color chart of an outside wall paint company was used to choose a total of 30 colors, and the colors were matched with of the Natural Color System (NCS) notation later.



排序	色票	NCS代碼	排序	色票	NCS代碼
1		S 5000-N	16		S3040-Y50R
2		S2010-R80B	17		S2020-R80B
3		S2002-R	18		S4005-R80B
4		S5005-R50B	19		S3010-Y80R
5		S6005-Y50R	20		S3020-Y80R
6		S3502-Y	21		S5020-Y80R
7		S2010-Y60R	22		S3040-R
8		S3020-R70B	23		S2005-B20G
9		S4005-G50Y	24		S2010-G90Y
10		S4010-Y10R	25		S1510-Y70R
11		S1505-Y80R	26		S3030-Y30R
12		S3020-Y30R	27		S4030-Y60R
13		S3030-Y90R	28		S3020-G30Y
14		S5010-Y50R	29		S4010-B90G
15		S3040-Y	30		S4020-R70B

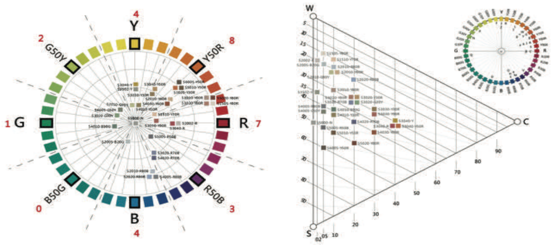


Fig. 1-a: Color chart from a wall paint company

Fig. 2: Color distribution in the NCS color space

Fig. 1-b: 30 chosen colors by focus groupmatched with NCS color notations

Meanwhile, a single house was selected to be the object for the survey. In order to replace the color of the wall, a 3D-model was created based on the photograph of the original house.

Fig. 3-a: Original photograph of a single house

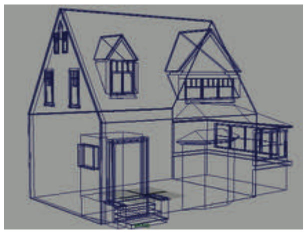


Fig 3-b: 3D-model based on the selected single house photograph

2.2. Survey

The monitor displayed questionnaire consisted of the appearance of a single house architecture and a set of semantic scales. Pictures of the 3D-model were shown to every subject, with the wall colors changing in timely intervals, keeping only grey roofs and white doors and window frames. Subjects were asked to respond and give their feelings toward semantic scales. The data were collected for future analysis.

2.3. Semantic Scales

By combining Lee's (2001), Osgood's (1964), and Taft's (1997), previous studies, this study formed a set of semantic differential scales with eight bipolar word-pairs. They are: Dislike-Like, Ugly-Beautiful, Hard-Soft, Cool-Warm, Vulgar-Elegant, Discreet-Loud, Masculine-Feminine, Unpleasant-Pleasant.

2.4. Subjects

123 students of Chinese Culture University, 45 male and 75 female, participated in the survey. After the Ishihara test and sorting out two incomplete, a total of 120 questionnaires had been analyzed. Demographic variables encompassed gender, living region, attendance of color studies or not, personality, main leisure activity, blood type, and age.

Fig.4: Samples for 3D-model of single house with different texture mapping of wall colors

Fig. 5: Display of questionnaire with a 7-point Likert scale

3. RESULTS AND DISCUSSION

3.1. Color Preference

Along the Like-Dislike scales, it was found that the most liked colors were S-3020-R70B, S4030-Y60R, and S3020-Y80R, and the most disliked colors were S3040-Y, S2010-G90Y, and S5000-N. A factor analysis was conducted and two factors were derived from the data set: the first one was defined as Evaluative factor, containing the scales Dislike-Like, Ugly-Beautiful, Hard-Soft, Cool-Warm, Vulgar-Elegant, Unpleasant-Pleasant; and the second one as Potency factor, containing the scales, Loud-Discreet, and Feminine-Masculine. Regarding the Evaluative factor, Fig. 6-a and Fig. 6-b present the top-three colors rated of the Evaluative factor scales

Fig. 7-a and 7-b display the top three color ratings of the Potency factor, containing Loud and Feminine.

Evaluative Factor: Scale \ Ranking	1	2	3
Like	M S3020-R70B	Y S4030-Y60R	K S3020-Y80R
Beautiful	K S3020-Y80R	Y S4030-Y60R	M S3020-R70B
Soft	K S3020-Y80R	G S2010-Y60R	S S3030-Y90R
Warm	a S3040-Y50R	Y S4030-Y60R	S S3030-Y90R
Elegant	M S3020-R70B	S S3030-Y90R	K S3020-Y80R
Pleasant	K S3020-Y80R	H S2020-R80B	S S3030-Y90R

Fig. 6-a: Most liked colors

Evaluative Factor: Scale \ Ranking	1	2	3
Dislike	Z S3040-Y	F S2010-G90Y	U S 5000-N
Ugly	Z S3040-Y	P S4005-G50Y	C S2002-R
Hard	U S 5000-N	J S3502-Y	P S4005-G50Y
Cool	J S3502-Y	U S 5000-N	C S2002-R
Vulgar	Z S3040-Y	P S4005-G50Y	J S3502-Y
Unpleasant	Z S3040-Y	U S 5000-N	P S4005-G50Y

Fig. 6-b: Most disliked colors

Potency Factor: Scale \ Ranking	1	2	3
Loud	ß S3040-R	S S3030-Y90R	K S3020-Y80R
Feminine	S S3030-Y90R	ß S3040-R	K S3020-Y80R

Fig. 7-a: Feminine perceived colors

Potency Factor: Scale \ Ranking	1	2	3
Discreet	C S2002-R	U S 5000-N	J S3502-Y
Masculine	U S 5000-N	J S3502-Y	P S4005-G50Y

Fig. 7-b: Masculine perceived colors

3.2. Imagery

Color Imagery is an impression that color has on people's perception. The scores from each semantic scale have been presented as an Imagery Map below:

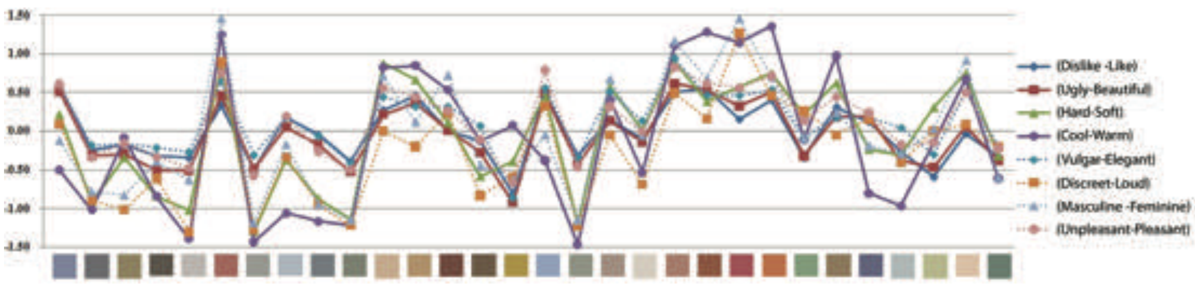


Fig. 8: Color Imagery of 30 chosen house colors plotted against the eight semantic scales of color feeling

3.3. Demographic variables

No significant interaction has been found between demographic variables and color preferences and feelings.

4. CONCLUSION

The results show clearly that as long as a person likes the specific color, it will be felt as beautiful, soft, warm, elegant, and pleasant; while if one dislikes the specific color, it will be treated as hard, ugly, cool, vulgar, and unpleasant. Among the three top-rated colors of the Evaluative factor group, a weighted ranking shows that S3020-Y80R, S3020-R70B, S3030-Y90R, and S4030-Y60R are the most frequent colors showing positive feelings and are found to be the favorite colors for house walls, while S3040-Y, S 5000-N, S3502-Y, and S4005-G50Y are the most aversive ones.

Another finding is that the scores of the Evaluative scales were all influenced by hues, but not by saturation, blackness and whiteness.

Interestingly, subjects who thought themselves as extravert personalities tend to rate with wider range while people thinking themselves as introvert tend to rate within a narrow range .

K S3020-Y80R	M S3020-R70B	S S3030-Y90R	Y S4030-Y60R	a S3040-Y50R	G S2010-Y60R	H S2020-R80B
11	7	5	4	3	2	2

Fig. 9-a: Most liked colors in weighted range

Z S3040-Y	U S 5000-N	J S3502-Y	P S4005-G50Y	C S2002-R	F S2010-G90Y
12	8	6	6	2	2

Fig. 9-b: Most disliked colors in weighted range

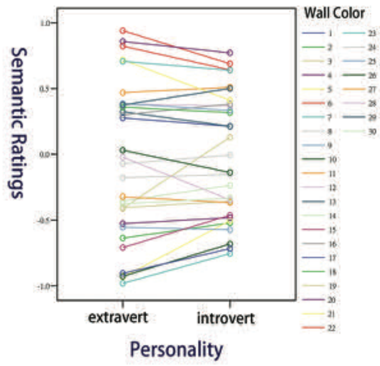


Fig.: 10: Range of extravert / introvert personalities' color choice

Acknowledgements

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References

Caivano, J. L., 2006, *Research on Color in Architecture and Environmental Design: Brief History, Current Developments, and Possible Future*, Color Research and Application, 31(4): 350-363.

Cubukcu, Ebru I. K., 2008, *Hue, saturation, lightness, and building exterior preference: An empirical study in Turkey comparing architects' and nonarchitects' evaluative and cognitive judgments.* Color Research & Application, 33(5): 395-405.

Faulkner, LuAnn Nissen, Sarah Faulkner, 1994, *Inside Today's Home,* Cengage Learning, Inc., Belmont, CA, U.S.A.

Nemcsics, Antal, 2007, *Experimental Determination of Laws of Color Harmony. Part 1: Harmony Content of Different Scales with Similar Hue*, Color research and application.

Osgood, Charles E., . Suci, George J, Tannenbaum, Percy H., 1957, *The Measurement of Meaning*, University of Illinois Press.

Taft Charles, 1997, *Color Meaning and Context: Comparisons of Semantic Ratings of Colors on Samples and Objects*, Color for Interior Architecture.

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Color preferences: a British/Indian comparative study

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ABSTRACT

A gender difference in color preference among British participants has been repeatedly reported in independent studies (Bonnardel *et al.*, 2006; Ling et *al.*, 2006, Bonnardel & Lanning, 2010). While both males and females showed a preference for blue-green colors, females additionally expressed a preference for pink-purple colors. To investigate the robustness of gender difference in color preference in a different culture, we tested 81 young adult Indians from a School of Design and compared them to 80 young British students in Psychology. Results confirm a gender difference in color preference of the same nature in the Indian and British samples with a preference among females for pink and purple colors. Cultural differences were only observed among females; in contrast to Indian females, the Bristish females prefered lavender to orange colors.

1. INTRODUCTION

In context-free situations, people are willing to rank colors in order of preference or to indicate a preferred color when given several different options. Results on color preference are not unanimous on the subject of gender differences. Eysenck (1941) emphasised the strong agreement between males and females in color choice, in contrast, McManus *et al.* (1981) reported a greater preference for red among females. More recently, Ling *et al.* (2006) tested 171 British participants (92F) and 37 (18F) Chinese participants using 8 different hues presented in pair on a color monitor. Plotting the proportion of trials in which a given color was chosen provided a color preference curve for each subject. Data were subjected to Principal Component Analysis (PCA) with 3 Components accounting for 79% of the total variance. Due to the resemblance of the two first components to the theoretical color-opponent mechanisms (blue vs. yellow and red vs. green) data were interpreted in terms of b-y and r-g mechanisms which could account for 70% of the total variance. A gender difference was observed across British and Chinese samples. In average, females had positive weight on the r-g mechanism (preference for reddish vs. greenish) while males showed the reverse pattern. Furthermore, while the same pattern was obtained within the Chinese sample, there was an overall increase in preference for reddish colors for the two genders. Finally, an overall preference for blue was reported across participants . In an experiment by Bonnardel *et al.* (2006), 103 participants were tested (50 young and 53 older adults) in a triadic task in which 3 of the 21 Munsell samples were presented on each trial. Color preference curves and Multidimentional Scaling analysis revealed a gender preference confirming females' preference for pink-purple colors, although gender difference was less prominent among elderly people. Using Bimler and Kirkland's (2009) triadic test made of 16 printed Munsell samples, a similar gender difference in color preference was replicated with 80 young adults (Bonnardel and Lanning, 2010). To extend the robustness of the gender difference in color preference observed in British context the present study replicated Bonnardel and Lanning's experiment with 81 young adults from India.

2. METHOD

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Subjects. Participants in the experiment were eighty (43 F) first year Psychology students at the University of Winchester (U.K) (average age =23.8 yrs, sd = 4.9) and 81 (42 F) students from the National Institute of Design, Ahmedabad (India)(average age =25.8 yrs, sd= 4.8) All participants had a normal trichromatic color vision as assessed by Ishihara pseudo-isochromatic plates (24-plate edition for UK and 38-plate edition for India).
Material. Sixteen stimuli based on the Farnworth D15 color Vision Panel test were used. Ten stimuli (5Y:'brown', 2.5YR: 'tan', 7.5YR: 'coral', 5RP: 'pink', 10P: 'purple', 5B:'blue', 10BG:'turquoise', 10G: 'green', 5G: 'dull green' & 5GY: 'olive green') had a Munsell value of 5 and a chroma of 4. The other six stimuli, or 'pastel' samples -noted with an asterisk- (10B*:'light blue', 5BG*:'light turquoise', 10GY*: 'light green', 10YR*: 'beige', 2.5R*:'light pink' and 5P*:'lavender') were lighter and less saturated with a Munsell value of 6.5 and a chroma of 3. The stimuli designed by Bimler and Kirkland (2009) were printed in triads on 4 x 4 cm neutral grey background cards.
Procedure. The color preference task consisted of the presentation of 75 triads resulting from a Balanced Incomplete Design. Subjects were asked to indicate their preferred color out of the three samples comprising each card, with their choice recorded by the experimenter. In Winchester, cards were presented on a large table of uniform grey (Munsell Neutral Value N/5), illuminated by a D65 ceiling lighting panel providing a reflected light intensity of 150 cd/m^2. In Ahmedabad, the same set of cards was used but participants were tested in a light booth (Macbeth Judge II) with a uniform grey surround (Munsell Neutral Value N/6.75) under the D65 fluorescent illuminant. The experiment was approved by the Ethic Committee of the University of Winchester and the NID Ethic Committee.

3. RESULTS

*Color preference curves***.** Each subject preference ranking was plotted as a function of the color samples ordered from light blue (10B*) to lavender (5P*). Inspection of the 161 individual color preference curves revealed that 24 Indian participants systematically associated the highest or the lowest ranks to the 6 pastel samples irrespective of their hue. The remaining 57 Indian participants exhibited a color preference pattern similar to that expected when hue is the criterion for choice, as was the case for the 81 UK participants. Since our objective was the comparison of color preference between two culturally different samples with all being otherwise equal, including the criteria on which preferred color choices were made, data from the 24 participants were processed separately and are not presented in this paper.

In both the Indian and the British samples, males' preference is limited to blue and green colors whereas females show an additional taste for pink and purple and exhibit more clearly marked maxima and minima (Figures 1a & 1b). Across cultures (curves not shown) females compared to males have higher ranks for turquoises (10BG & 5BG*), pink (5RP) and purple (10P) and a lower ranks for olive green (5GY), brown (5Y) and beige (10YR*).

British females' preferred color interval- running from pink (5RP) to light green (10GY*)- is interrupted in the Indian females by a relative disliking for the two pastel colors; light blue (10B*) and lavender (5P*). Indian and the British females shared the brown color (5Y) as their least preferred color (Figure 2c). In males, the Indians differ significantly from the British in respect to their taste for the olive green (5GY) (Figure 1d).

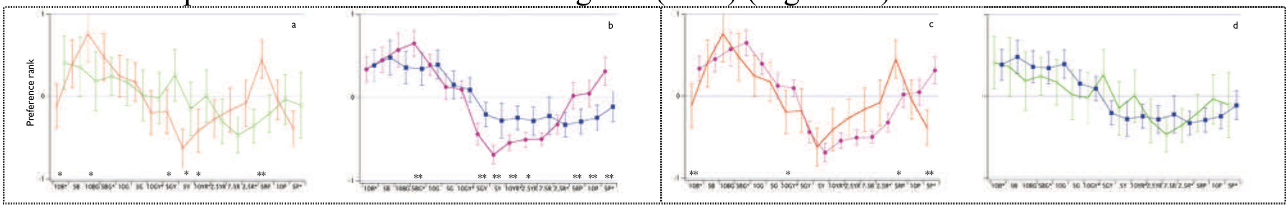

*Figure 1: Color Preference curves are plotted for females (circles) males (squares) Indian (empty symbols) and British (filled symbols) participants. Means are reported within a 95% Confidence Interval. Probalities associated to Mann-Whitney test are indicated by *p≤0.05 and **p≤0.01.*

Principal Component Analysis. Four Principal Component (PC) explaining 73.7% of the total variance were extracted. Variable loadings of absolute value greater than 0.4 plotted as polar plots provide a representation of the color samples carried by each PC (Figure 2). PC1 carries pinks-purple (2.5R*, 5RP & 10P) vs blue-turquoises (5B, 10BG & 5BG*). PC2 opposes pink (5RP), purple (10P) and lavender (5P*) to olive green (5GY) and brown (5Y). PC3 opposes greens (5G & 10G) to beige (10YR*) and lavender (5P*) and PC4 opposes tan (2.5YR), coral (7.5 R) and light pink (2.5R*) to lavender (5P*).

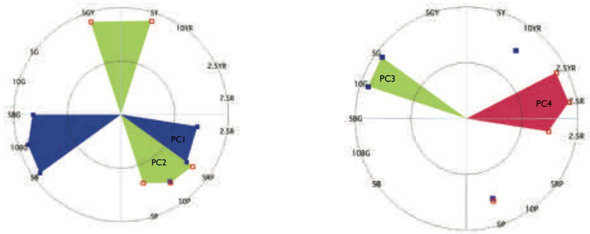

Figure 4:Polar representation of absolute values of factor loading on color samples. Each factor carries positive and negative loadings. Factor labels are located on segment corresponding to positive loading with the other segment corresponding to negative loading. Left: PC1 (filled symbols and dark shade) and PC2 (open symbols and clear shade). Right: PC3 (filled symbols and clear shade) and PC4 (open symbols and dark shade).

Mean participant PC scores were subjected to group comparison. Mean scores' signs can be straightforwardly explained with positive values being associated to color preference in accordance with the PC polarity and negative values associated to preference for the opposite color polarity.

No statistical difference was observed between Indian and British, but a gender difference was observed for PC2 (X_F= .399 (SE_F=0.094) vs. X_M= -.44 (SE_M = 0.554), $t(135) = 5.4$, $p<0.001$), with females on average preferring pink-purple-lavender to olive-green and brown, while males show a reverse pattern of preference. Considering each gender individually, a cultural difference was observed in female sub-sample for PC4 (X_{INDF}= .455 (SE_{INDF}=1.28) vs. X_{UKF}= -.386 (SE_{UKF} = 0.06), $t(32.3) = 3.41$, $p<0.002$), in average Indian females prefer tan-coral-light pink to lavender, whereas British females prefer the opposite color polarity. No difference reached statistical significance in cultural comparison between males. Gender difference in PC2 scores was confirmed within the British (X_{UKF} = .408 (SE_{UKF} =0.103) vs. X_{UKM}= -.3143 (SE_{UKM} = 0.139), $t(78) = 4.25$, $p<0.001$) and the Indian samples (X_{INDF} = .385 (SE_{INDF}=0.179) vs. X_{INDM}= -.611 (SE_{INDM} = 0.227), $t(55) = 3.44$, $p<0.001$). A second difference was obtained in the British sample for PC4 (X_F= -.386 (SE_F=0.06) vs. X_M= .211 (SE_M = 0.149), $t(49.5) = -3.66$, $p=0.001$); British males prefer tan-coral-light pink to lavender.

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4. DISCUSSION

Cultural differences. Color preferences do not differ greatly between Indian and British participants. Considering individual color samples, a higher ranking was noted for olive green and light green for the Indians and a higher ranking for lavender and light blue for the British, but the overall pattern of preference as described by the PCA is comparable in the two groups. In particular, Indian and British males behave in a remarkably similar way with a preference for cold (from light green to blue) as compared to warm (brown to lavender) colors. A cultural difference is obtained among females; British females show a marked preference for lavender and a relative disliking for orange colors compared to Indian females.

Gender difference. Gender difference in color preference is replicated in Indian sample and its expression bears similarities with those observed among British, in both cultures pink and purple divide gender. In the PCA, gender difference is revealed by the component that opposes pink-purple-lavender to olive green-brown. PCA performed within each cultural group reveals some distinctions between Bristish and Indians. In British sample, the gender-sensitive component opposes pink-purple-lavender to olive green-green-light green and could be described as a red-green color-opponent component. In Indian sample, the gender-sensitive component is limited to pink-purple in opposition to light green-brown and no is longer in conformity with the canonical r-g color opponent component. Moreover, in British sample, a second gender difference is observed in a males' preference for orangey as opposed to greenish-blue colors which is reversed in females. These observations tend to show a more prominent gender difference among British sample compared to the Indian sample. In conclusion, in a task where color choices are elicited in the absence of context, the present data bring additional support to previous experimental results (Bonnardel et al. 2006, Ling et al. 2006 & Bonnardel and Lanning, 2010) consistent with the influence of pan-cultural factors in color-preference gender differences in young adult population.

REFERENCES

Bimler, D. and J. Kirkland. 2009. Colour-space distortion in women who are heterozygous for colour deficiency. *Vision Research* 49: 536-543.

Bonnardel, V., L. Harper, F. Duffie, and D. Bimler. 2006. Gender differences in colour preferences: Men are more predictable than women. *Perception* 35:187a.

Bonnardel, V. and L. Lanning. 2010. Gender differences in colour preference: Personality and gender schemata factors. In *2nd CIE Expert Symposium on Appearance.8-10 September 2010*, Ghent: Belgium.

Eysenck, H. J. 1941. A critical and experimental study of color preferences. *American Journal of Psychology* 54: 385-391.

Ling, Y., A. Hurlbert and L. Robinson. 2006.Sex differences in colour preference. In *Progress in Colour Studies Volume II, Psychological Aspects* ,eds. N.J. Pitchford and C.P. Biggam, Amsterdam: John Benjamins, 173-188.

McManus, I. C., A. L. Jones and J. Cottrell. 1981. The aesthetics of colour.*Perception* 10: 651-666.

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Consumer Preference and Expectations for Coffee Colour Used in Advertisement

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ABSTRACT

This study investigated colour preference of espresso coffee in prints and relationships between colours and consumer expectations of tastes and quality. Forty printed samples of espresso coffee having different colours only in the coffee part with the same colours for the rest of the image were evaluated by 40 Thai observers, including 10 experts and 30 general coffee drinkers. The visual assessments were conducted under D65 lighting conditions. Each observer assessed all 40 images using a 1-9 scale, where 1 means the least and 9 means the most, for expectations of preference, quality, intention of purchase, flavour strength and 4 tastes: sweet, bitter, sour and astringent. It was found that the results from two observer groups were significantly different. The results from factor analysis showed that the experts related the scales of quality, intention of purchase, preference and sweetness with the levels of chroma and lightness. On the other hand, the general coffee drinkers associated chroma and lightness with the scales of flavour strength, bitterness, astringency and sourness. The experts preferred espresso images having high lightness and yellowish colour and associated them with quality of coffee. The general coffee drinkers preferred the images with low chroma and lightness, as they associated them with strong flavour.

1. INTRODUCTION

Colour is the first impression that can make consumers interested in products, especially in food and beverage products. Colour appearance signifies quality and character of the food. As well as the package design, colour used in advertisement has an impact on marketing communications. Wei et al. (2008) showed that colour harmony had effects on product quality and the expectations of consumers. Yonemaru et al. (2010) investigated suitable colours for a label of mineral water and found that bluish colours were suitable and gave positive impressions, while lower saturated colours were not suitable. Fernandez-Vazquez et al. (2012) studied colour preference of orange juice. They found significant differences in gender: male preferred redness, while female preferred yellowness. Differences in colours from different age ranges were also found. Wei et al. (2009) found in the study of relationships between orange juice colour and consumer expectations that higher chroma had relationships with sweetness. Lower lightness affected bitterness. These findings agreed with the results from Sueeprasan and Traisiwakul's study (2012), in which colours of green tea drinks were evaluated. This shows that consumers associate colours with quality and tastes of food products. Hence, an appropriate use of colour could stimulate consumers' purchase motivation.

Espresso is the main type of coffee consumed almost in all parts of Europe and also popular in many other countries throughout the world. It is the base for other drinks, such as a latte, cappuccino, macchiato, mocha, or americano. One of the quality indicators of espresso is its colour. The top layer of espresso, called crema, should be hazel colour for the best espresso. This study investigated the association between colour of espresso coffee in prints and expectations of consumers. The visual assessments were conducted to investigate association between colorimetric values and each of the expectation scales of preference, intention of purchase, quality, flavour strength and tastes, under D65 simulators.

2. EXPERIMENTS

To investigate the association between colour of espresso coffee used in advertisement and consumer expectations and preference, observer evaluated a series of printed image samples that were varied in colour of only the coffee part. The preparation of experimental samples and the method of visual assessments are described in the following sections.

2.1 Experimental samples

To generate the image samples, firstly, espresso was freshly prepared by a barista who ensured the perfect quality of expresso. The image of espresso in a white cup was taken against a white background in a photo studio. This image was digitally combined with a complex background similar to that used in advertisement. The colour of coffee in the original image was altered to generate a variety of colour samples. The only difference between different samples was the colour of coffee. The background and other part were kept constant.

The image samples were printed using an inkjet printer with high resolution on matte paper. The sample size was 21 cm x 29 cm (A4). Colours in coffee area in the printed samples were measured using a spectroradiometer under D65 lighting condition used in the visual assessments. The spectrophotometer was set to light source mode and 10 degree Observer.

In the selection of image samples, 50 advertising images of espresso coffee in print media were collected and measured using a spectrophotometer with D65/10 conditions. The experimental samples were then selected to give a good coverage of the espresso colours used in advertisement. Forty image samples were included in the visual assessments.

2.2 Visual assessments

Forty Thai observers participated in visual experiments. Amongst them were 10 experts (all females) and 30 general coffee drinkers (16 females and 14 males). The experts were those who work in a coffee company as a researcher, developer, or quality controller. The general coffee drinkers (referred to as the inexperts hereafter) were 14 students in Imaging and Printing Technology, 1 student in Biology, and 15 employees from Graphic Design Company. The experts ranged in age from 28 to 36 years old with the average age of 30, and the inexperts from 18 to 32 years old with the average of 26.

In the visual assessments, observers assessed the samples under D65 lighting. The experiments were conducted in a darkened room where observers sat approximately 60 cm away from the samples, which was the same position as when the measurements were done. Forty samples were presented to observers in a random order. Observers viewed the samples one by one and were instructed to evaluate each sample using a 1-9 rating scale, with the ends verbally anchored with “the least” and “the most”, the numbers in between corresponding to degree of expectations. For example in the preference scale, 1 rating represented “least preferred” and 9 rating represented “most preferred”. Eight expectations scales including preference, intention of purchase, quality, flavour strength and expectations of tastes--sweet, bitter, sour and astringent--were investigated.

3. RESULTS AND DISCUSSIONS

In this study, the visual scores (observers' expectations) for each image were averaged according to observer groups (the expert and inexpert). Significant differences between the results were analysed by means of the paired t-test. It was found that all expectation scales from the experts and inexperts were significantly different at 95% confidence. In other words, the experts had different expectations from the inexperts in all aspects when seeing the same coffee images. Thus, the analyses of the visual results will henceforth be carried out with respect to two observer groups.

The method of factor analysis was employed to extract underlying factors from 8 expectation scales by cluster of homogeneous variables in the components. Table 1 shows the results of factor loading, which represents the correlations between components and each of the expectation scales. It was found that, in the case of the expert group, three components accounting for the cumulative percentage of variance of 86.5 could explain the relationship between expectation scales. The first component (PC1) contained quality, intention of purchase, preference, sweetness and astringency (inverse relationship). The second component (PC2) included flavour strength and bitterness, and only sourness was in the third component (PC3). Two components accounting for 93.4% of variance were found for the inexpert group. The first component included preference, intention of purchase and quality. The second component comprised sweetness (inverse relationship), bitterness, astringency, flavour strength and sourness.

Table 1. Factor loading of component matrix for the expectations of observers.

	Expert				Inexpert	
	PC1	PC2	PC3		PC1	PC2
Quality	0.96			Preference	0.99	
Intention of Purchase	0.95			Intention of Purchase	0.98	
Preference	0.94			Quality	0.97	
Sweetness	0.77			Sweetness		-0.97
Astringency	-0.69			Bitterness		0.93
Flavour Strength		0.83		Astringency		0.87
Bitterness		0.82		Flavour Strength		0.84
Sourness			0.98	Sourness		0.64

From the results of factor analysis, the scales that were in the same component were highly correlated and could be explained by the same factor. To identify colorimetric values as an underlying factor of the expectation scales, factor scores for each image sample were calculated for each component and plotted against colorimetric values (C^*_{ab}, L^*_{ab}, a* and b*). Figures 1 and 2 illustrate the results that show the tendency of correlations between colorimetric values and expectation scales for the expert and inexpert groups, respectively.

In the case of the expert group, the results showed that PC1 (representing quality and preference) tended to correlate with lightness and chroma, as the factor scores increased with the values of lightness and chroma. This means that the expert preferred somewhat light and high chroma espresso image. The tendency of correlation between factor scores and b* values was also found, indicating that the experts preferred espresso images having yellowish colour.

The results from the inexpert group showed no correlation between PC1 and colorimetric values, but the correlations were found for PC2 (representing tastes). The results showed that the inexperts associated colorimetric values with tastes, in which coffee colour with low lightness and chroma were expected to be bitter and strong in flavour. It is possible that while the experts looked for the crema of espresso, which is supposed to be hazel colour, the inexperts considered espresso as black coffee (no sugar, milk, or cream added) and therefore looked for dark colour, resulting in different results between two observer groups.

Figure 1. The expert group's results: scatter plots between factor scores of PC1 (quality, intention of purchase, preference, sweetness and astringency) and colorimetric values.

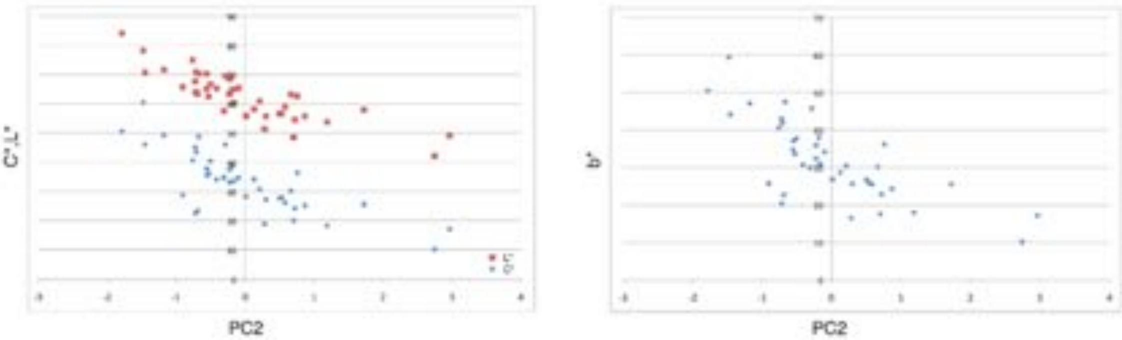

Figure 2. The inexpert group's results: scatter plots between factor scores of PC2 (sweetness, bitterness, astringency, flavour strength and sourness) and colorimetric values.

REFERENCES

Fernandez-Vazquez, R., C. Stinco, F. Melendez-Martinez, F. Heredia, and I. Vicario. 2010. Orange juice colour: Visual evaluation and consumer preference. In *AIC 2010 Color and Food, Proceedings*, Mar del Plata, Argentina, 357-359.

Sueeprasan, S., and C. Traisiwakul. 2012. Color evaluation in association with consumer expectations of green tea drinks in Thailand (Chapter 43). In *Color in food: Technological and psychophysical aspects*, ed. by J. Caivano and M. Buera. New York: CRC press.

Wei, S., L. Ou, and M.R. Luo. 2008. The association between package colour and consumer expectations: Taking juice package design as an example. In *AIC 2008 Colour – Effects & Affects, Proceedings*, Stockholm, Sweden, 15-18.

Wei, S., L. Ou, M.R. Luo, and J. Hutchings. 2009. Quantification of the relation between juice colour and consumer expectations. In *AIC 2009, Proceedings*, Sydney, Australia.

Yonemaru, Y., O. Panyarjun, S. Kitaguchi, Y. Kitani, and T. Sato. 2010. Influence of package colour for mineral water plastic bottle to consumer's purchase motivation. In *AIC 2010 Color and Food, Proceedings*, Mar del Plata, Argentina, 266-269.

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The comparative study of psychological cognition of black as fashion color in Japan, China &U.S.

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ABSTRACT

To measure the psychological cognition of black as fashion color in Japan, China and U.S., 93 subjects were asked to evaluate the impression of black, describe the association of black, choose the ratio ranges of possessing black clothes to all clothes in each season, and explain their own reasons of wearing black for both public and private occasions. It's concluded that ⑴The impression of black in China is somewhat different from that in Japan and U.S. ⑵The association of black also changes with the social trend. ⑶Black clothes are more preferred in fall/ winter season than spring/ summer season. ⑷People from the 3 countries all choose black as fashion color at a high percentage, but by different reasons.

1. INTRODUCTION

From culture to culture, black has always been regarded as a key color of fashion in various occasions, such as ceremonies, uniforms, etc. Ohmi (2009) summarized the investigation of the color change of women fashion in Japan and found out that the average frequency of occurrences of BLACK was the third highest; and the coefficient of change in BLACK was lowest. Not only in Japan, black fashion came into styles in western world for many time periods. Moreover, as a traditional basic color, black has always been much used in clothes from ancient China.

2. METHOD

2.1 Subjects

The total number of subjects was 93, who are students from undergraduate schools, graduate schools and employees. Among them 32 are living in Tokyo, Japan (17 male and 15 female) with the average age of 24.0; 31 are living in Shanghai, China (13 male and 18 female) with the average age of 26.1; 30 are living in New York City, U.S. (12 male and 18 female) with the average age of 26.5. The survey was carried out from January to February, 2012.

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2.2 Procedures

Online questionnaires with 3 versions (Japanese, Chinese and English) developed by Google Documents were made including the following parts. In survey 1, the subjects gave rankings to 20 pairs of adjectives as above according to the five-grade evaluation system with semantic differential method. Then the subjects wrote 3 words at the moment when they think of "Black" in survey 2. In survey 3, the subjects selected the percentage ranges of black clothes in all their clothes by seasons. In survey 4, the subjects explained why they wear black by choosing from the 17 options as above without number limit, or they could write their own answers if they select the option "Other".

Table 1. Contents of Questionnaire

Survey 1- Impression Evaluation of Black			
Loud - Quiet	Soft - Hard	Warm - Cold	Light - Heavy
Strong - Pale	Excited - Calm	Lively - Gloomy	Sharp - Blunt
Clean - Dirty	Clear - Vague	Manly - Feminine	Sophisticated - Naive
Elegant - Vulgar	Pure - Complex	Beautiful - Ugly	Intellectual - Sentimental
Natural - Artificial	Vivid - Static	Kind - Distant	Special - Ordinary
Survey 2 - Association of black			
Survey 3 – Possession of black clothes in every season			

Survey 4 - The reasons of wearing black					
Personal like	Looks slimmer	All- match	Looks formal	Color of uniform	Job demand
Cool	Mystic	Calm	Suitable	Get used to	Mature
Noble	Acceptable	Simple	Cheer up	Not easy to get dirty	Other ( )

3. RESULTS

3.1 Impression evaluation of black

Figure 1 presents the image profiles of black from Japan, China and U.S. and the results of factor analysis. To compare the 3 factor scores among areas and between genders, 2-way analysis of variance was conducted and the simple main effects of areas for factor 1 ($F(2,87)=18.965$, $p< .001$) and factor 3 ($F(2,87)=8.454$, $p< .001$) were confirmed. The perceptual evaluation of black of China is higher ($p< .001$) than that of both Japan and U.S. Besides, the evaluation of black in sociability of China is lower ($p< .001$) than that of Japan and lower ($p< .05$) than that of U.S. Moreover, the interaction effect was confirmed ($F(2,87)=5.162$, $p< .01$) for factor 2, it shows that among the male subjects, the emotional evaluation of black in U.S. is higher ($p< .005$) than that in China.

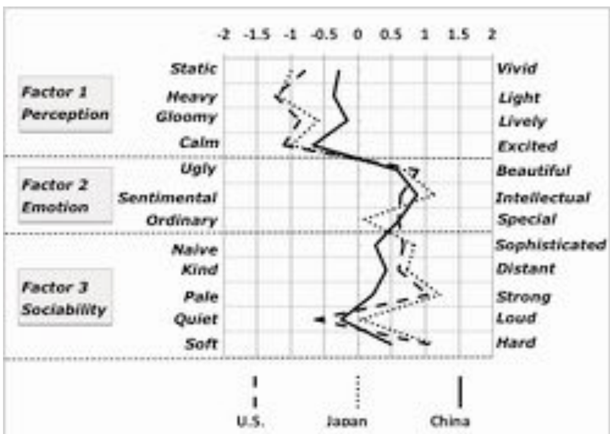


Figure 1. Impression evaluation of black

3.2 Observation of association of black

Table 2 shows the top 3 of rank orders of words associated from black in each area. Many abstractive adjectives about fashion were given in the Chinese' answers. Relatively, there are more concrete nouns about everyday life showed in the answers of Japanese and American subjects. Compared with the surveys on association of black before, which usually came out with "death", "funeral", etc., the results of this research tend to be more positive. Moreover, some happening words, such as "iPhone", "Steve Jobs", also turned up this time.

Table 2. Association of black

	NO.1	NO.2	NO.3
Japan	Dark	Night	Universe
China	Classy	Sexy	Low-profile
U.S.	Cool	Night	Earth

3.3 Percentage of black in all the clothes by seasons

2-way analysis of variance was conducted among 3 districts and 4 seasons to see if there is significant difference in the possession of black clothes, and the simple main effect (F (3,368)= 33.966, p< .001) was confirmed. The same as the surveys before, black clothes were preferred in fall/winter season than in spring/summer season, as illustrated in Figure 2.

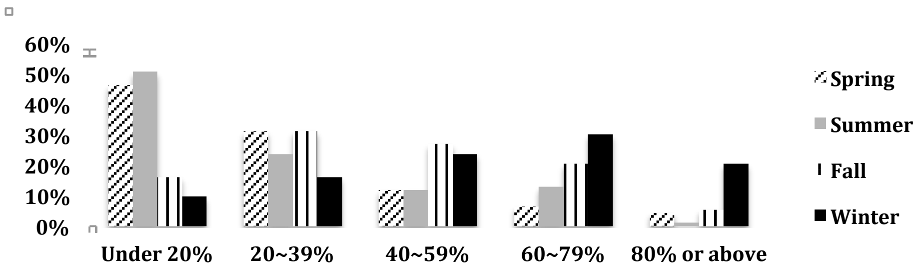
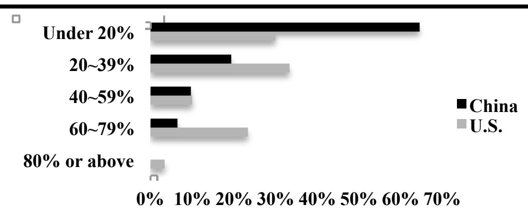
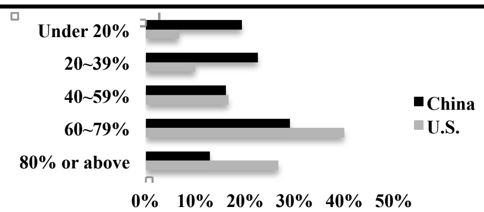


Figure 2. Percentage of black in all the clothes by seasons

Furthermore, 1-way analysis of variance of possessing black clothes was conducted among 3 districts in each season. Table 3 indicates that the Americans chose black more than the Chinese do in summer (F (2,90)=4.390, p< .05) and winter (F (2,90)=3.103, p< .05).

Table 3. Possession of black clothes between China and U.S.

Summer	Winter
	

3.4 The reasons of wearing black

Figure 3 displays the scatter diagram of reasons of wearing black in 3 countries, analyzed by correspondence analysis. As shown in the figure, the Japanese tend to wear black for the reasons of “Acceptable”, “Calm”, “Cool”, “Cheer up” because those reasons are located relatively close together. Likewise, “Looks slimmer”, “Personal like” and “Mature” are the main reasons for the Chinese to choose; and relatively, the Americans choose to wear black because it’s “simple”, “mystic” and “suitable”. In addition, the reason of “All-match” is the most option for both Japanese and Chinese subjects to explain why they love to wear black.

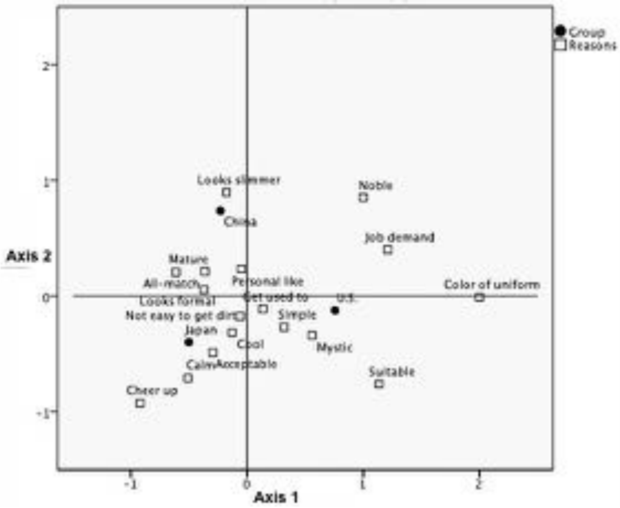


Figure 3. Results of correspondence analysis

4. CONCLUSION

The overall impression evaluation of black suggested that the Japanese and the Americans have relatively similar impression about black, but the Chinese give different evaluation to impression of black in perception and sociability, however, that the high emotional evaluation of black in the 3 areas was distinctive. The association of black revealed the correlations between psychological cognition of black and the social trends. Besides, it showed that black fashion is more preferred in U.S and cold seasons. Regarding why people wear black, the Chinese likely to wear black for their physical appearances and care about the impression they make on others. The Japanese consider the mental energy more, which explained that the traditional culture still influences the modern fashion styles in Japan. The Americans tend to choose black to express their inner selves and they pay more attention to their personalities.

REFERENCES

Ohmi, G. 2009. *Science of Good Color*. Tokyo: Japanese Standards Association

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Monte-Carlo Simulations for Paired-Comparison Experiments

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ABSTRACT

This study seeks to explore the effect of number of observers and the proportion of possible paired comparisons carried out on the accuracy of estimated scale values where each observer evaluates a different set of paired comparisons. The study also considers the effect of selection criteria in incomplete paired-comparison experiments on the accuracy of estimated scale values. The results indicate that with the same number of observers and stimuli, more accurate scale values can be obtained when each observer evaluates a different set of pairs rather than the same. In addition, the results show that when each observer evaluates a different set of pairs, selecting pairs in a certain pattern does not improve the accuracy of estimated scale values in incomplete paired-comparison experiments.

1. INTRODUCTION

The paired-comparison method is assumed to provide more accurate predicted scale values than some other indirect scaling methods (such as categorical judgment) when stimuli are closely spaced in perceptual space (Engeldrum 2000). However, the total number of pairs increases rapidly as more stimuli need to be evaluated. Thus, incomplete paired comparison is widely-used (Clark 1977; Morrissey 1955). However, some practical questions exist. For example, how many observers should be invited? What is the smallest proportion of paired comparisons which should be considered? In previous work, a framework was developed using Monte-Carlo simulation with an ideal observer model to address these questions surrounding the design of incomplete paired-comparison experiments where each observer evaluates the same set of paired comparisons (Cheung, et al. 2009). The results indicated that the estimated scale values were more sensitive to the proportion of paired comparisons p than the number of observers k and to obtain the accuracy of r^2 (between estimated and real scale values) = 0.95 about 30% of paired comparisons should be considered.

In this study, Monte-Carlo simulations with an ideal observer model assigned with a bias were again adopted to investigate the effect of number of observers k and the proportion of paired comparisons p on the accuracy of estimations in experiments where each observer evaluated the same or different set of pairs. More conditions of experimental design, varying in k, p and the number of stimuli n, were considered in this work. In the case where each observer evaluates a different set of pairs, the method of pair selection (randomly or in a certain pattern) on the accuracy of estimation was also investigated. Many analytical methods are available for determining the scale values from an incomplete pair comparison experiment, but Morrissey's (1955) least-square solution was adopted in this study.

2. METHOD

2.1 Ideal observer model

This work is based on computational simulation (no real observer or stimuli will be involved). Thus, an ideal observer model has been constructed to simulate the response in a paired-comparison experiment using MATLAB. According to Thursone's assumption for the judgement scaling model, the responses to a given stimulus will follow a normal distribution; thus the perceptual response P to a stimulus S is modelled by a normal distribution with mean S and standard deviation σ where σ is internal noise in the perceptual system determining the degree of dispersion of perceptual responses. In the ideal observer model, σ was defined to guarantee that the difference between the adjacent stimuli is close to just noticeable difference. The ideal observer model will be used many times for each pair of stimuli to generate responses. The number of observers will influence the times that the ideal observer is presented with each pair of stimuli. However, in practice, not every observer is identical because of internal noise in each observer's perceptual system, so each ideal observer was assigned with a bias which is also defined.

2.1 Monte-Carlo simulation

A Monte-Carlo simulation IR was conducted for each observer evaluating the same set of stimuli.

1. Randomly select n scale values from the uniform distribution $[-n/2, n/2]$.
2. Generate totally c ($c = p \times n(n-1)/2$) paired comparisons randomly according to a given proportion p. The proportion of paired comparisons used in this simulation ranges from 10% to 100%. For each of the selected paired comparisons, present the two stimuli to the ideal observer model and obtain the observer preference. Repeat for k observers.
3. Construct the preference ratio matrix.
4. Estimate scale values using Morrissey's method.
5. Compare the evaluated scale values obtained from the simulation with the actual scale values selected in step 1.

Another two Monte-Carlo simulations were conducted for each observer evaluating a different set of stimuli. In simulation IIR with bias, all the pairs presented to observers were randomly selected but in simulation IIP with bias, the pairs were selected in a certain pattern. The procedure of these two simulations is similar to the simulation IR except in step 2.

3. RESULTS

Figures 1 and 2 show the effects of proportion p and number of observers k on the accuracy of estimated scale values for various numbers of stimuli for the cases where each observer evaluates the same set of pairs (in simulation IR) and a different set of pairs (in simulation IIR with bias) respectively.

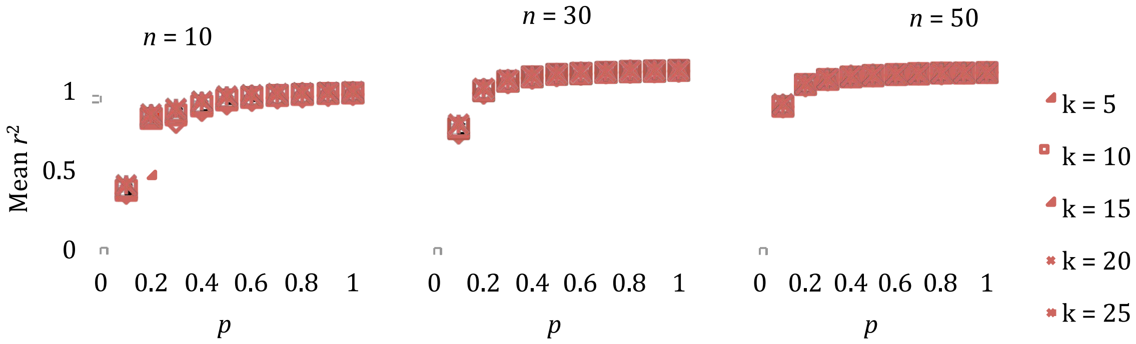

Figure 1: The performance (mean r^2) obtained from simulation IR is plotted against the proportion of the paired comparisons p for each condition defined by n (n = 10, 20 & 30) and k (k = 5, 10, 15, 20 & 25).

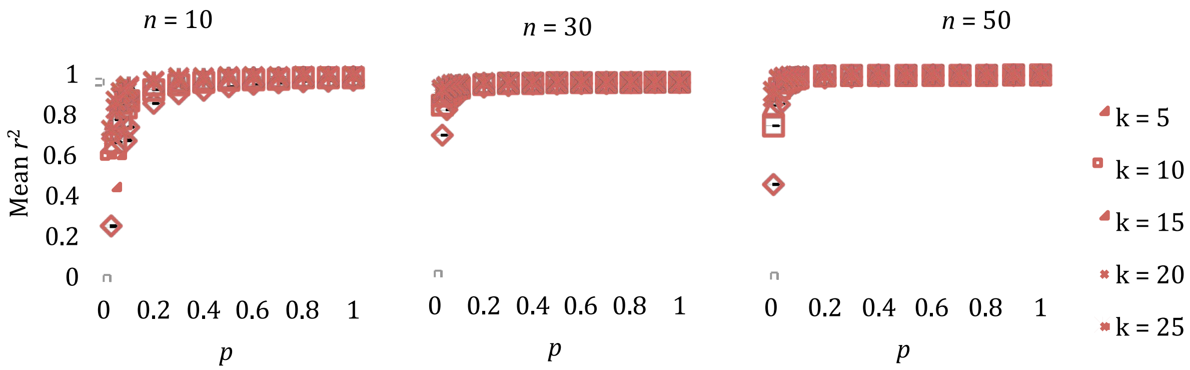

Figure 2: The performance (mean r^2) obtained from simulation IIR is plotted against the proportion of the paired comparisons p for each condition defined by n (n = 10, 20 & 30) and k (k = 5, 10, 15, 20 & 25).

Figure 3 shows the proportion of comparisons required to achieve given performance of mean r^2 = 0.95 for each case defined by n and k. The red and green symbols in the left figure are drawn from simulation IR & simulation IR with bias respectively. The blue & orange symbols in the right figure are drawn from simulation IIR with bias & simulation IIP with bias respectively. Table 1 the proportion required to achieve a given performance of mean r^2 = 0.95 for both experimental designs with observer bias.

Table 1: The proportion required to achieve a given performance of mean r^2 = 0.95 for each case defined by n and k for both experimental designs with observer bias.

	***n* = 10**		***n* = 20**		***n* = 30**		***n* = 40**		***n* = 50**	
	same	different	same	different	same	different	same	different	same	different
k = 5	78%	79%	59%	28%	46%	19%	37%	11%	29%	9%
k = 10	68%	41%	51%	16%	40%	8%	32%	6%	25%	5%
k = 15	62%	28%	47%	9%	37%	6%	29%	4%	24%	3%
k = 20	58%	23%	44%	7%	36%	5%	30%	3%	23%	3%
k = 25	55%	17%	42%	6%	34%	3%	28%	3%	23%	3%

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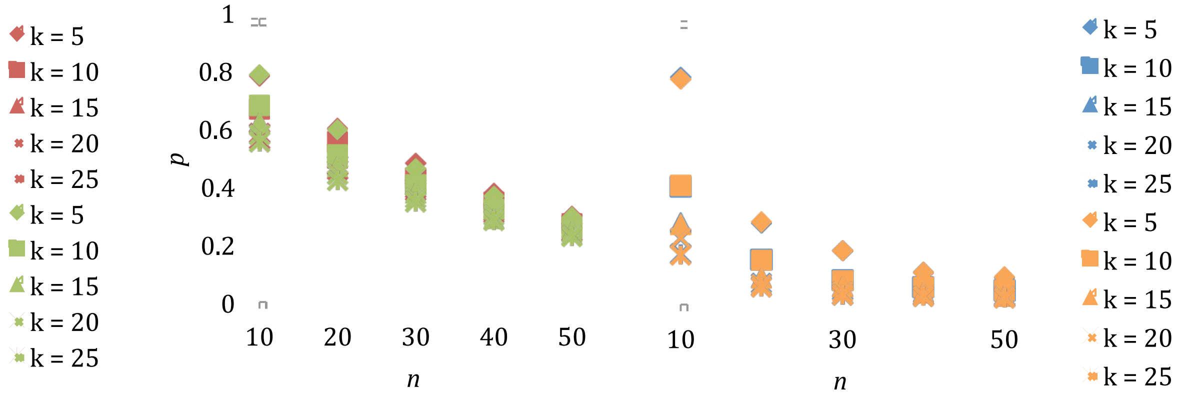

Figure 3: The proportion of comparisons required to achieve given performance of mean r^2 = 0.95 for each case defined by n and k. The red & green symbols in the left figure are from simulation IR & simulation IR with bias respectively. The blue & orange symbols in the right figure are from simulation IIR with bias & simulation IIP with bias respectively.

4. CONCLUSION

This work addressed some practical questions on the design of incomplete paired-comparison experiments. The findings suggest that when each observer evaluates the same set of pairs the proportion considered is more critical than the number of observers but when each observer evaluates a different set of pairs with lower proportions considered in experiments the number of observers becomes more important. This could due to that when each observer evaluates a different set of pairs more invited observers can increase the considered proportion of all possible pairs. Moreover, when each observer evaluates a different set of pairs, the accuracy of estimation could be increased and also selecting pairs in a certain pattern cannot improve the accuracy. All the simulations were conducted based on Morrissey's least-square solution, so other analytical methods are worth to evaluate the models.

REFERENCES

Cheung, V., S. Westland, and Y. LI. 2009. Experimental Design in Incomplete Paired-Comparison Experiments. In *Seventeenth Color Imaging Conference: Color Science and Engineering Systems, Technologies, and Applications*, Albuquerque, New Mexico, 107-110.

Clark, J. A. 1977. A Method of Scaling with Incomplete Pair-Comparison Data. *Educational and Psychological Measurement,* 37: 603-611.

Engeldrum, P. G. 2000. *Psychometric scaling a toolkit imaging systems development*. Winchester: Imcotek Press.

Morrissey, J. H. 1955. New method for the assignment of psychometric scale values from incomplete paired comparisons. *Journal of the optical society of America,* 45: 373-378.

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The impression of tones and hues in gradations of practical color co-ordinate system(PCCS)

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ABSTRACT

This study investigated the influence of colors, particularly tones and hues of the Practical Color Coordinate System (PCCS). The stimuli used were eleven PCCS tones, grayscale, and twelve PCCS hue gradations. These stimuli were evaluated using 20 pairs of words. One hundred and fifty participants joined this experiment. The following results of factor analysis were obtained for four factors. The image map of factors 1 and 2 showed similar mapping of tone on lightness and saturation. Each hue was plotted near the origin of the coordinate axes. The result of ANOVA for tones and hues of each pair of words and F tests for variance of tones and hues showed that tones in an image could be more widely caught by the observers than hues could be. This result clarified the difference in the impression of each tone and hue.

1. INTRODUCTION

The Practical Color Co-ordinate System (PCCS) was developed by the Japan Color Research Institute in 1964, based on psychological elements. The psychological intervals of individual attributions (hue, lightness, and saturation) are constant. The feature of the PCCS is "Hue–Tone system." Tone consists of lightness (value) and saturation (chroma). Color is usually represented by three attributes—hue, value, and chroma—but the PCCS can represent a color by two attributes, hue and tone, hence the name "hue–tone system." Each tone has an individual image, that is, "dark" tone colors (low lightness and middle saturation) have a heavy and dim image; "vivid" tone colors (middle lightness and high saturation) have a bright and clear image. These images are common even with different hues. Thus, the PCCS offers the advantage of treating the color as an image by using tone.

Previous studies of color order systems focused on hue, value, and chroma, and investigated each attribute individually. Typically, the Munsell value has been investigated in detail. In the PCCS, lightness is of the same scale as the Munsell value. There has been little investigation of tone, and most of the studies of PCCS are written in Japanese and were performed in the 1960–1970s. Therefore, the PCCS is not currently as well-known globally as the NCS, another psychological color order system.

Investigating tone is important because it is an original concept and few studies of tone have been conducted in the past few decades. Thus, the purpose of this study is to investigate the influence of color, particularly tone, of the PCCS.

2. METHOD

2.1.Stimuli

Hue circle of tones; eleven tones (vivid, bright, deep, light, soft, dull, dark, pale, light grayish, grayish, dark grayish) were used for tone stimuli. Tone stimuli (twelve hues; 1.5 cm × 1.5 cm) were pasted in a circle on a neutral gray mount (10 cm × 10.5 cm) (Figure1).

Gray scale; chromatic color stimuli (nine color chips; 1.5 cm × 0.7 cm) were pasted in a row on a neutral gray mount (10 cm × 10.5 cm) (Figure2).

Hue belt; typical twelve colors (2:R, 4:rO, 6:yO, 8:Y, 10:YG, 12:G, 14:BG, 16gB, 18B, 20:V, 22:P, 24:RP) were used as hue stimuli, and each stimulus (eleven tone color chips, 3 cm × 1.5 cm) was pasted in a row by gradation (order in which value and chroma change) on a neutral gray mount (5 cm × 21 cm) (Figure3).

Figure 1. Sample of hue circle of tones

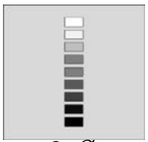

Figure 2. Sample of Gray scale

Figure 3. Sample of Hue belt

2.2.Procedure

In this experiment, the number of participants was 129(70 male and 59 female, average age 20.7 ± 1.4 years). The seven-point scale semantic differential method (SD method) was used with a questionnaire consisting of twenty pair words (warm–cool, sweet–not sweet, soft–hard, feminine–masculine, loosen–strained, cheerful–gloomy, bright–dark, dynamic–static, light–heavy, distinctly–blurred, dull–sharp, clear–muddy, gaudy–subdued, composured–fidgety, preferable–hateful, stable–unstable, beautiful–ugly, plain–rich, modern–classic, and loud–quiet).

Subjects were divided in five groups. Each group was presented with a different order of colors and a different order of the twenty pair words. The subjects looked at each color and answered the questionnaire.

3. RESULT and DISCUSSION

3.1.Factor Analysis

Factor analysis was used for evaluation of the SD results. The result of the factor analysis (maximum likelihood method, promax rotation) revealed four significant factors (Table1). This result differs from those of previous studies of color impression. Many studies of color impression revealed the structure of color images and nearly all were based on Osgood's three factors: *evaluation*, *activity*, and *potency*. The first factor seemed to combine Osgood's *activity* and *potency*. The second factor was similar to Oyama's *sharpness* factor (Oyama; 2001). Oyama (2001) proposed that Osgood's *potency* was split into *sharpness* and *lightness*. The third factor was similar to Osgood's *evaluation*. The fourth factor was plain–rich, which suggests an independent image in this study's stimuli. The lightness and saturation of each tone stimuli were changed incrementally, which corresponded to the image of plain–rich.

The average value of the factor score for each stimulus was calculated. They were plotted on factor2 (x axis) and factor1 (y axis) as shown in Figure 4. Correlations were seen between factor2 and saturation (r = 0.653), and between factor1 and lightness (r = 0.767). Implicitly, factor2 corresponds to saturation and factor1 corresponds to lightness. Each hue was plotted near the origin of the coordinate axes.

Table 1. Pattern matrix(Factor analysis)

	FAC1	FAC2	FAC3	FAC4
warm – cool	.860	–.148	.055	–.305
sweet – not sweet	.783	–.063	.061	–.003
soft – hard	.755	–.358	.053	.182
feminine – masculine	.747	–.133	–.034	.046
loosen – strained	.687	–.448	.144	.075
cheerful – gloomy	.600	.373	–.026	.005
bright – dark	.600	.346	–.046	.096
dynamic – static	.504	.368	–.259	–.272
light – heavy	.466	.148	–.142	.456
distinctly – blurred	–.322	.801	.118	–.182
dull – sharp	.272	–.758	.069	–.096
clear – muddy	–.023	.600	.176	.315
gaudy – subdued	.396	.581	–.125	–.062
composured – fidgety	–.080	–.208	.646	–.007
preferable – hateful	.220	.229	.632	–.075
stable – unstable	.007	.022	.598	–.237
beautiful – ugly	.203	.368	.495	.056
plain – rich	–.041	–.028	–.179	.780

※FAC1:Factor1, FAC2:Factor2, FAC3:Factor3, FAC4:factor4

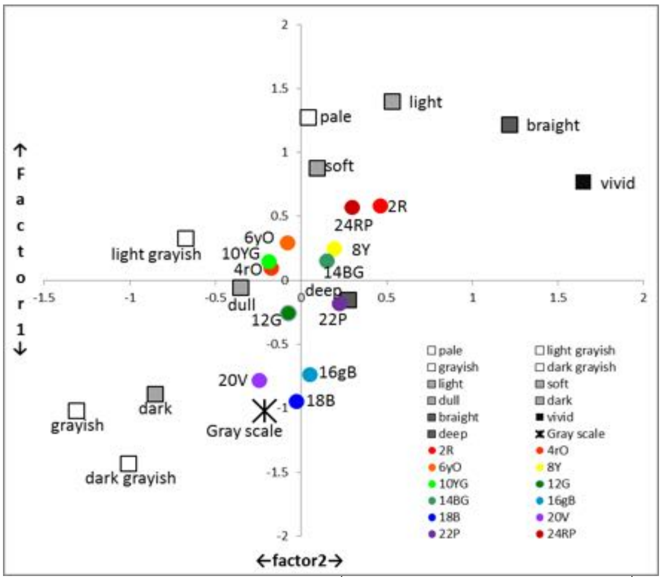

Figure 4. Image map(average of factor score)
x axis: fantor2, y axis: factor1

3.2. Image profile and Analysis of Variance

One-way analysis of variance was conducted for the hue stimuli for each pair of words, a total of twenty times. As a result, a significant difference was seen in all pair words ($p < 0.001$). For example, warm–cool ($F(8.9, 1124.8) = 145.893$, $p < 0.001$) and feminine–masculine ($F(7.6, 952.1) = 98.164$, $p < 0.001$). These results suggest that these words correspond to "warm color" and "cool color." Warm colors were evaluated as "warm," and "feminine," and cool color were evaluated as "cool" and "masculine." This tendency was also seen in other words (sweet–not sweet, loud–quiet, cheerful–gloomy, bright–dark, dynamic–static, and composed–fidgety). In addition to this tendency, factor1 was included in nearly all these words. In contrast, dull–sharp, preferable–hateful, stable–unstable, beautiful–ugly, and so on were considered not to be related to "warm color" and "cool color."

One-way analysis of variance was conducted for the hue stimuli for each pair of words, a total of twenty times. As a result, a significant difference was seen in all pair words ($p < 0.001$). For example, distinctly–blurred ($F(6.6, 844.6) = 107.613$, $p < 0.001$), and plain–rich

(F(7.3, 929.36) = 116.165, $p < 0.001$). Distinct–blurred, dynamic–static, and loud–quiet were considered to correspond to saturation. Plain–rich, bright–dark, light–heavy, and so on were considered to correspond to lightness.

F tests were conducted for hue and tone stimuli for each pair words to compare variance between hue and tone (Figure5). As a result, a significant difference was observed for preferable–hateful (F(11) = 9.209, $p < 0.001$). Modern–classic, distinctly–blurred, clear–muddy, light–heavy, gaudy–subdued and beautiful–ugly were also observed with a significant difference ($p < 0.001$). Soft–hard, cheerful–gloomy, plain–rich, dull–sharp and bright–dark were observed with a significant difference ($p < 0.01$). Sweet–not sweet and loosen–strained were also observed with a significant difference ($p < 0.05$). The distribution of the tone was larger than that of the hue in all cases, which suggests that tone characterizes the image in more detail than does hue.

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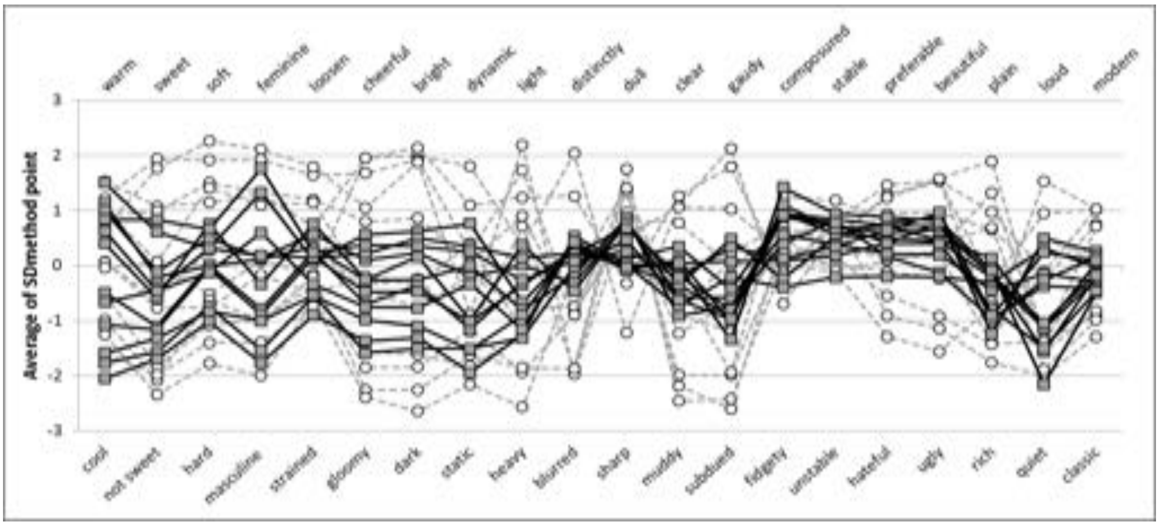

Figure 5. Image profile(Average of SD method score)

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REFERENCE

Oyama, T. 2001. Color Harmony or Color-Combination Effects : From a Psychological Point of View. *Journal of the color science association of japan* 25(4): 283-287.

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Individual differences in macular pigment optical density and color perception

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ABSTRACT

We studied to examine whether individual differences in the macular pigment influence color vision. We conducted two experiments: one to measure macular pigment optical density(MPOD) and one to measure color matching functions(CMFs), in order to examine correlation between these two factors. In the first experiment, we measured MPOD of 50 subjects (46 males, and 4 females), using heterochromatic flicker photometry. The mean MPOD was 0.387 (±0.119) in right eye. Then, we conducted the color matching experiments for 11 subjects who participated in Experiment 1. We found individual differences in both MPOD and CMFs, but we could not find clean correlation between MPOD and CMFs.

1. INTRODUCTION

It is well known that there are individual differences in color perception, but the factors that determine the individual differences have not been fully clarified. Macular pigment is considered as one of these factors. It lies in front of the fovea, and absorbs some portion of the visible light (about 380-520 nm). It is reported that the MPOD differ among people. Therefore, there is a possibility that individual differences in color vision are mediated by individual differences in MPOD. The purpose of this study is to clarify whether the individual differences in MPOD correlated with individual differences in color perception.

2. EXPERIMENTS

2.1 Experiment 1

MPOD was measured with heterochromatic flicker photometry [Yamauchi and Hayasaka (2011)]. Subjects observed flickering stimulus: the reference LED light of 570nm, and the test LED light of 470 nm. The alternation frequency was 20 Hz. The luminance of the reference light was 4.8 cd / m^2. The task of the subject is to adjust the luminance (brightness) of the test light so that the flicker disappeared or minimized. Measurement was conducted in two conditions: foveal viewing and peripheral viewing. As the flicker null point may have some range, we used two starting luminance level: high and low. We obtained null point mean value of all the sessions. Thus, for each single measurement, the subject by 4 times settings. MPOD was obtained from the intensity ratio of two conditions (foveal and peripheral). Basically the subjects performed 9 set each in the right eye and the left eye.

The LEDs were used to present the stimuli, which were placed in an integral sphere. The subject viewed the stimulus through an aperture of 1.6 degree visual angle which was located at the center of a hemisphere dome. Inside the wall of the dome was illuminated with a D_{65} fluorescent light. Its intensity was 47 cd / m^2. The subject used a chin-rest to observe the stimulus with 300 mm distance. 50 subjects participated in the experiment.

2.2 Experiment 2

Subjects conducted color matching experiments to measure their CMFs using a LED system which was reported previously [Suzuki et al. (2011)]. The subject changed the color of the test stimulus by controlling the intensities of three primaries (R:629nm, G:523nm, B:471nm) until it matched the color of the reference stimulus. CMFs were obtained for 20 different wavelengths (401, 414, 431, 447, 464, 500, 538, 560, 571, 579, 593, 611, 633, 642, 647, 655, 680nm, and three primaries). Luminance of all the reference stimulus was 2 cd / m^2. The experiment was conducted for 11 subjects who participated in Experiment 1 (range of MPOD: 0.289～0.522). Each subject ran 3 sessions.

3. RESULT

3.1 Experiment 1

The measured mean MPOD was 0.387 (±0.119, 0.157～0.671) and 0.380 (±0.127, 0.071～0.657) in the right eye and in the left eye, respectively. There was observed no significant differences in the right eye and the left eyes. Figure 1 shows the histogram of the MPOD obtained from the right eye. MPOD measured in this study, did not differ show a significant difference from previous studies [Churk-Yan Tang et al.(2004), and Shiao Hui Melissa Liew et al.(2005)].

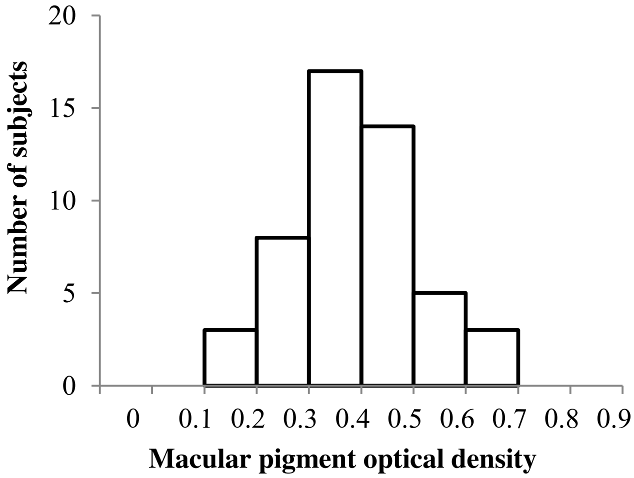


Fig.1 Distribution of MPOD(right eye)

3.2 Experiment 2

Figure 2 shows the results of all the subjects. The results were normalized at a wavelength of the three primaries (R:629nm, G:523nm, B471nm).

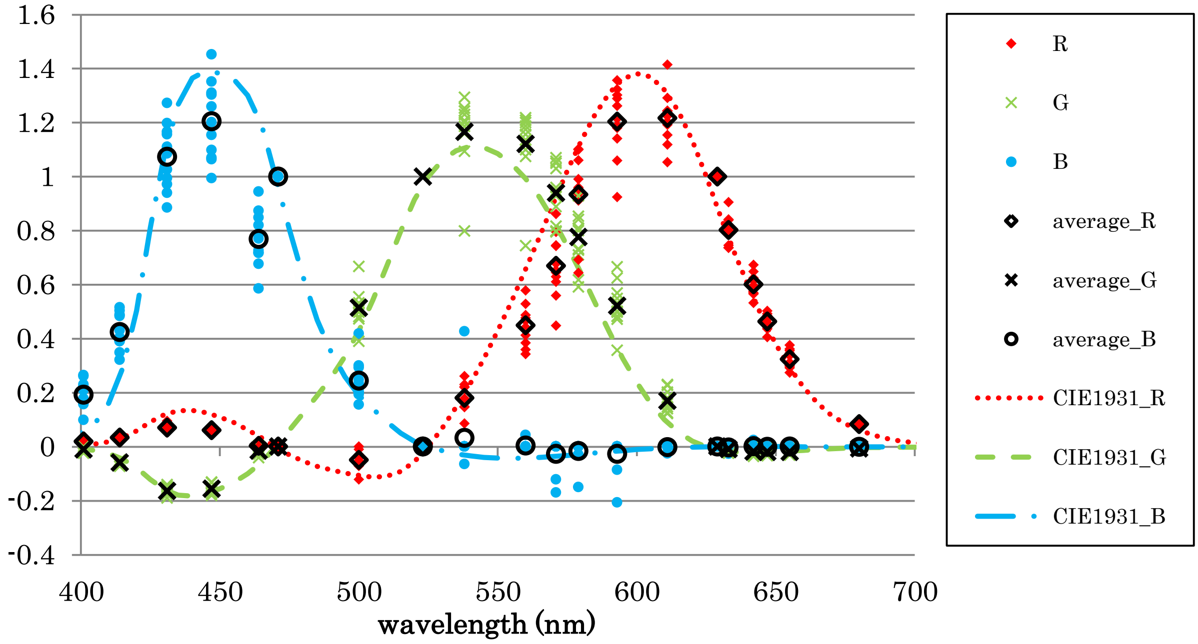
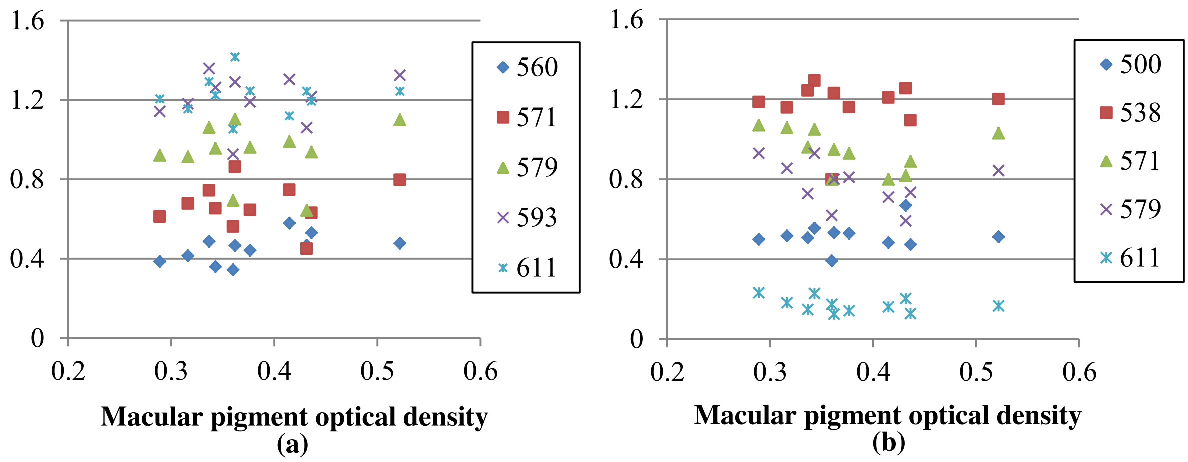
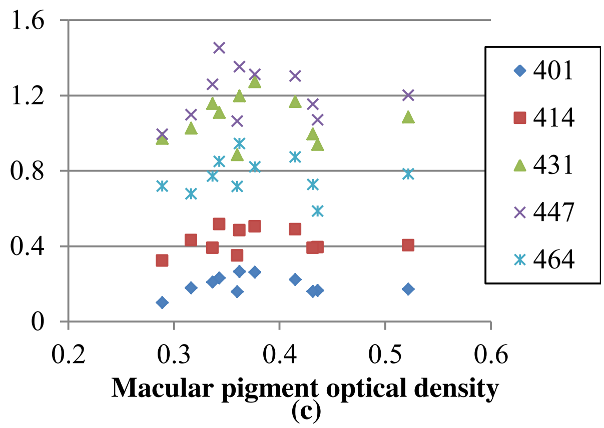


Fig.2 Color Matching Functions

3.3 Correlation between MPOD and CMFs

We examined the correlation of data obtained from Experiment 1 and 2. Figure 3 shows the result, a cross axle as MPOD (result of Experiment 1), a vertical axis as RGB (result of Experiment 2). (a) is that vertical axis is R, (b) is G, (c) is B. There was not the correlation between MPOD and CMFs (coefficient of correlation: -0.53～0.54).





(c)

Fig.3 Correlation between MPOD and CMFs

4. CONCLUSION

In this study, the two experiments were conducted in order to measuring MPOD and CMFs. Although both results showed individual differences, the significant correlation between these results was not clearly found, even in the CMFs of range shorter wavelength, where the absorption of the macular pigment may affect.

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REFERENCES

Yamauchi, Y., and Hayasaka, H. 2011. Macular Pigment Density of Japanese Subjects. *Japanese Journal of Visual Science* 32(4): 95-101.

Suzuki, T., Suzuki, M., Yamauchi, Y., and Okajima, K. 2011. Development of simple color bipartite apparatus using single light source with LEDs and measurement of individual color matching functions. In *AIC Color 2011, Proceedings*, ed. by V. M Schindler and S. Cuber. Switzerland, 763-766.

Churk-Yan, T. H. Y., Ming-yeung, P. W. Y., and Maurice, K. H. Y. 2004. Macular pigment optical density in young Chinese adults. *Ophthal. Physiol. Opt.* 24: 586-593.

Shiao, H. M. L, Clare, E. G., Tim, D. S., John, M., John, M., Fredericus, J. V. K., Stephen B., Fred, F., and Christopher, J. H. 2005. Heritability of Macular Pigment: A Twin Study. *Ophthalmol. Vis. Sci.* 46(12): 4430-4436.

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Effect of Different Sample Types on Color Harmony

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ABSTRACT

The effect of different types of sample modules in multiple-color combinations on color harmony was investigated using 45 samples of fashion apparel images having various color combinations accumulated in this study as an original set of experimental samples. And, three another sets of experimental samples were also emerged from the original one in apparel-image without human form, arranged color block and traditional color block respectively. All the four sets of experimental samples described above were used in different sections of color harmony-assessment experiments separately. The experimental results indicate that the two sets of arranged color-block and traditional color block samples have higher agreement with each other in the visual color harmony than that between one of them against one of another two sets of original apparel images and these images having their own patterns without human form respectively. On the other hand, both the set of original apparel images and the set of those without human form have good consistent relationship in visual color harmony. This new finding may imply that the color-harmony assessment on multiple-color combinations of fashion apparel is regardless of human form to the apparel image. And, different types of specimens have significant influence on visual results of color harmony.

Keywords: color, color harmony, multiple-color combination, performance, agreement

1. INTRODUCTION

Color colorimetry has long had the purpose of measuring color or estimating or predicting color difference for more than eight decades since 1931. And, it is also able to be employed in specifying a color by color coordinate or color appearance, but not in indicating one by harmony or color imagery. The latter had been further studied since 1956 at the Budapest Technical University (Nemcsics 2007: 477), and there were advanced theories of color harmony also subsequently proposed, for example, Szabo et al. (2009: 34) and Kuo (2011:187). Furthermore, following those theories, several researches were carried out and published during the past five years, such as Ou et al. (2011: 355). But, there exists a difference among those researches in which various types of samples were used respectively, and it may influence the experimental results of their studies. Therefore, in this study, different types of experimental samples were used to investigate the effect of these ones on color harmony.

2. EXPERIMENTAL

Most previous studies on color harmony were typically concerned with whether the color harmony scale can be expressed with a small number of categories, or factors, by using the psychological method of category judgement proposed by Torgerson (1958: 205). In this study, the psychophysical method of magnitude estimation was used instead of the psychological method of category judgement (Kuo 2007: 463).

In the visual assessment experiments of scaling color harmony, 45 color specimens of apparel images having a large size of 3×3 square inch that subtends 10^0 at the observer's eye, and various color combinations accumulated in this study as an original set of experimental samples. And, three another sets of experimental samples were also emerged from the original one in apparel-image without human form, arranged color block and traditional color block respectively. All the four sets of experimental samples described above were used in different sections of color harmony-assessment experiments separately. Each color-image sample shown on a flat display was assessed twice by a panel of fifteen observers in a dark room, including seven female and eight male ones, and all of them being within the ages of 20 and 35 using the psychophysical method combining both magnitude estimation method and semantic differential method (Kuo and Kuo 2000: 137).

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3. RESULTS AND DISCUSSIONS

3.1 Stability of visual assessment

In this study, a series of color-harmony assessing experiments under a dark room were carried out respectively by a panel of fifteen observers using the magnitude estimation method. The coefficient of variation (CV%) proposed by Coates et al. (1981: 179) was used to indicate the observer variation, and can be calculated used the following equation:

$$CV(\%) = 100[\Sigma(x_i - y_i)^2 / n]^{1/2} / \tilde{y},$$

where n is the number of samples in x_i and y_i sets of data, and $\tilde{y}$ is the mean value of the y_i set data. The larger the value of CV is, the worse the agreement between the two sets of data compared. For a perfect agreement, the value of CV should be zero. The results show that a general stability can be found for the visual results, i.e. the total mean value of 78 in CV unit. And, the result of assessing stability for the observers in this study is less or equal to that for those experiments of color appearance or color difference assessment (Luo et al. 1996: 412; Kuo and Luo 1996: 312).

3.2 Effect of different sample types on color harmony

The experimental results for the four sets of color-image samples described above and used in different sections of color harmony-assessment experiments separately were further employed to estimate the effect of different sample types on color harmony. The results indicate that as shown on Figure 1, both the set of original apparel images and the set of those without human form have good consistent relationship in visual color harmony. On the other hand, the two sets of arranged color-block and traditional color block samples have higher agreement with each other in the visual color harmony than that between one of them against one of another two sets of original apparel images and these images having their own patterns without human form respectively, as shown on Figures 2 to 6.

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4. CONCLUSIONS

In this study, 45 color specimens of apparel images having a large size of 3×3 square inch that subtends 10^0 at the observer's eye, and various color combinations were accumulated and used as an original set of experimental samples. And, three another sets of experimental samples were also created from the original one in apparel-image without human form, arranged color block and traditional color block respectively. Subsequently, a series of color psychophysical experiments were carried out using those four sets of experimental specimens. The results show that the two sets of original apparel images and those ones without human form have the best relationship in visual color harmony among the four sets of image samples employed. Meanwhile, there exists a finding that the color-harmony assessment on multiple-color combinations of fashion apparel is regardless of human form to the apparel image. And, different types of specimens have significant influence on visual results of color harmony.

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REFERENCES

Nemcsics, A., 2007, Experimental determination of laws of color harmony. Part 1: harmony content of different scales with similar hue, *Color Research and Application* 32 (6): 477~488.

Szabo, F., Bodrogi, P. and Schanda, J., 2009, Experimental modeling of color harmony, *Color Research and Application* 35 (1): 34~49.

Kuo, W. G., Lee, C. K., Wei, Y. C. and Huang, Y. Y., 2011, Effect of different sample patterns on color harmony, *Proceedings of 12th International Conference on Color Design, Application and Science in 2011*: 187~194.

Ou, L. C., Chong, P. and Luo, M. R., 2011, Additivity of color harmony, *Color Research and Application* 36 (5): 355~372.

Torgerson, W. S., 1958, *Theory and Methods of Scaling,* John Wiley & Sons, New York, USA: 205~246.

Kuo, W. G., 2007, The Feasibility of Establishing New Colour Image Scales Using the Magnitude Estimation Method, *Color Research and Application* 32 (6): 463~468.

Kuo, W. G. and Kuo Y. C., 2000, The Investigation on the Relationship between DRP Color Image Scale and CIEL*a*b* Color Space, *Proceedings of the Conference on the Color Application and Color Science in 2000*: 137~144.

Coates, E., Fong, K. Y. and Rigg, B., 1981, '*Uniform Lightness Scales,*' J.S.D.C. 97: 179-183

Luo, M. R., Lo, M. C. and Kuo, W. G., 1996, The LLAB(l:c) Colour model, *Color Res. Appl.* 21: 412-429.

Kuo, W. G. and Luo, M. R., 1996, Methods for quantifying metamerism. Part I – visual assessment, *J. Soc. Dyers Colour.* 112: 312-320

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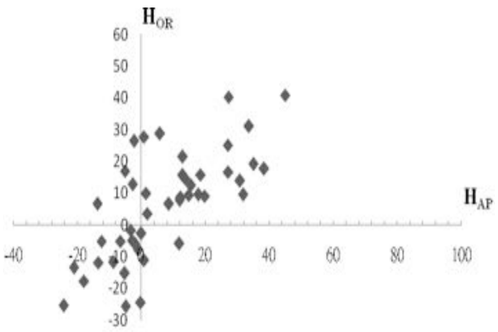

Figure 1. The experimental results of color harmony for original images (H_{OR}) are ploted against those for apparal images without human form (H_{AP}).

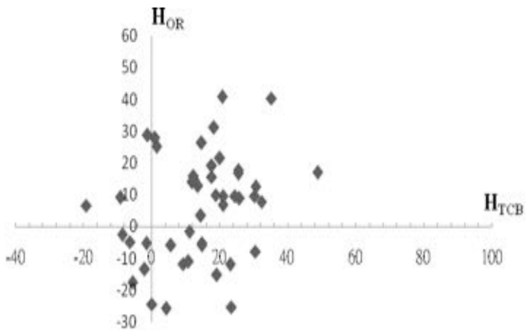

Figure 2. The same as Figure 1 but for original images (H_{OR}) against those for traditional color blocks (H_{TCB}).

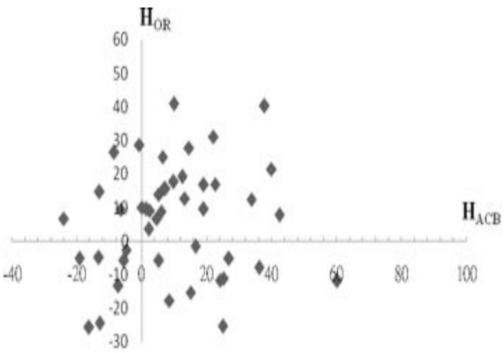

Figure 3. The same as Figure 1 but for original images (H_{OR}) against those for arranged color blocks (H_{ACB}).

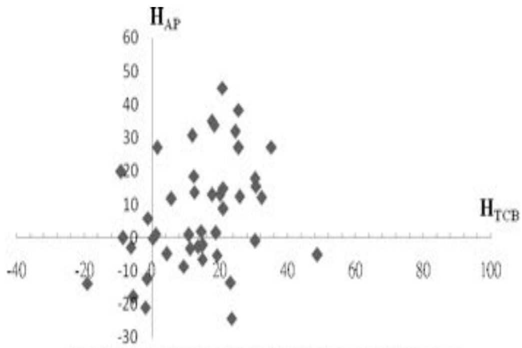

Figure 4. The same as Figure 1 but for apparal images without human form (H_{AP}) against those for traditional color blocks (H_{TCB}).

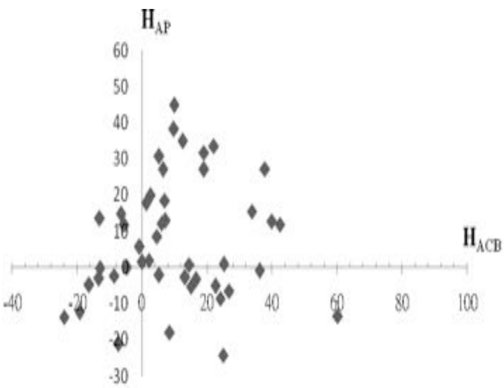

Figure 5. The same as Figure 1 but for apparal images without human form (H_{AP}) against those for arranged color blocks (H_{ACB}).

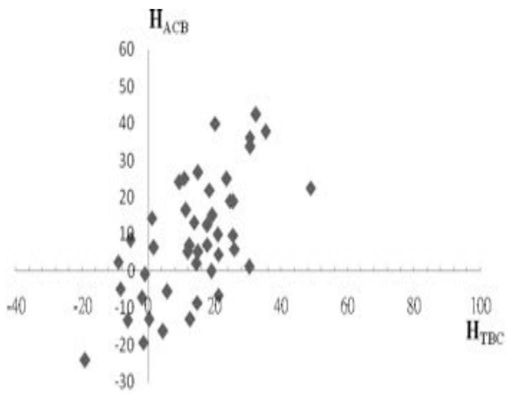

Figure 6. The same as Figure 1 but for arranged color blocks (H_{ACB}) against those for traditional color block (H_{TCB}).

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Effect of image category on acceptability and perceptibility of color difference in natural images

Takanori KATSUMATA, Hirohisa YAGUCHI, Yoko MIZOKAMI

ABSTRACT

Although perceptibility is a useful indicator on image color difference, the acceptability of image difference is also important especially for practical use. Both criterions could be influenced by image categories. We investigated the effect of image category on both acceptability and perceptibility in natural images. Ten images including three landscape, three still life, and four portrait images were used in experiments. Each image was manipulated by a contrast modulation in L^* a^* b^* component independently. Judgments of perceptibility and acceptability of image difference were made for each image. As a result, the acceptability was lower if perceptibility was higher in general, suggesting that acceptability would link with perceptibility. However, it is also suggested that acceptability was more influenced by image categories than perceptibility.

Keywords: color-difference, acceptability, perceptibility, natural images

1. INTRODUCTION

Recently, devices handling variety of color information on images has come to be used. It is important to match color reproductions between devices dealing with color information. However, conventional color-difference formula (ΔE^*_{ab}) does not sufficiently reflect color differences perceived in images. A New color difference formula has been proposed (Luo et al. 2001). However, further investigation taking into account image-dependent factors is still needed. Researches on the perceptibility of image color difference have been conducted in order to establish a method to describe color differences between natural images. It has been shown that the perceptibility is largely different depending on images, suggesting that image category is an important factor for the perception of image color difference. Furthermore, while perceptibility is a useful indicator on color difference, the acceptability of image difference is an important indicator as well, especially for practical use. Here, the acceptability can be defined as image difference that maintains the overall impression of the original image. The purpose of this study is to investigate the effect of image category on both, acceptability and perceptibility in image color difference.

2. EXPERIMENT

2.1 Image categories

Ten natural images were used in experiments. They were chosen from the SHIPP (Standard High Precision Picture data), the ISO/JIS-SCID, and the McGill Calibrated Color Image Database. They were divided into three categories; three images for landscape, three images for still life, and four images for portrait (Figure.1).

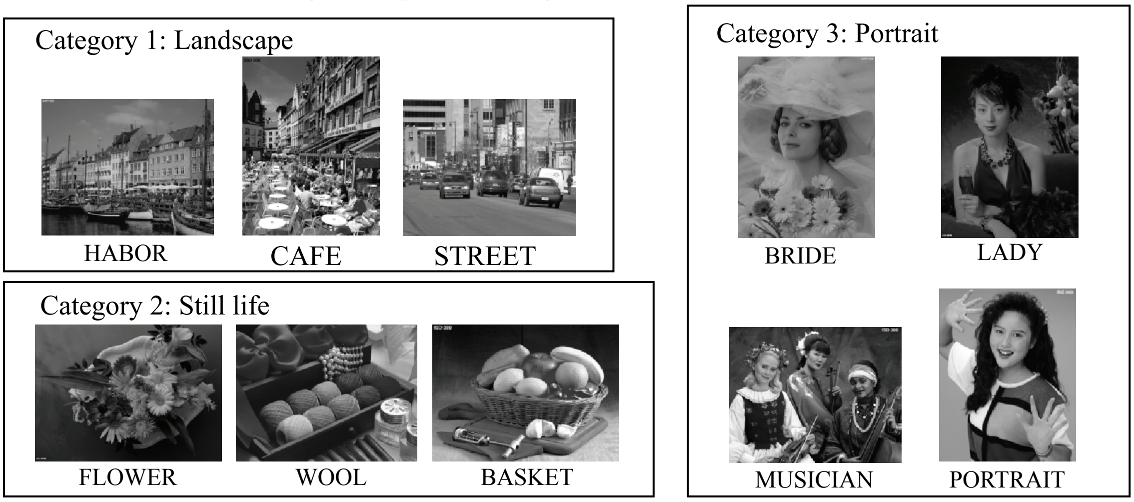

Figure 1 Three categories of natural images

2.2 Experiment

Each image was manipulated by a contrast modulation in each $L^* a^* b^*$ channel (see Equation (1) (2) (3)). k is a modulation coefficient; $k > 1$ and $k < 1$ represent the incremental and decremental direction of contrast modulation, respectively.

$$L^* = k\,(L^*_{original} - L^*_{average}) + L^*_{average} \quad (1)$$

$$a^* = k\, a^*_{original} \quad (2)$$

$$b^* = k\, b^*_{original} \quad (3)$$

An original and a test image were shown side by side on a display in a dark room. Referring to the original image an observer changed the degree of contrast modulation of a test image until the limitation of acceptable difference from the original by the method of adjustment. In the case of perceptibility, the degree of contrast modulation was changed until a perceptible difference from the original. For each image, acceptability and perceptibility were measured in incremental and decremental direction of contrast in each channel L^*, a^*, b^* respectively. There was no time limit for the judgment. Nine judgments total were obtained for each condition. Three color-normal observers participated.

3. RESULTS AND DISCUSSION

3.1 Acceptability

Figure 2 shows the results of acceptability from three observers. Ordinate indicates acceptable color difference shown by ΔE^*_{ab}. Color difference above zero is the result of incremental direction of k, and below is the decremental direction. Error bars represent standard deviation of nine judgments. The acceptability of color difference varies between the images. However, there is a similar tendency in each category. For landscape images, the acceptable color difference of L^* is larger than that of a^*, b^*. This is probably because we are used to landscapes with a variety of brightness on a daily basis, and might have higher tolerance to lightness variation. For portrait, acceptability is smaller compared with other image categories, except for the *MUSICIAN*, suggesting that we are sensitive to changes in skin color. For still life, the result was more varied in each image than other categories. One possible reason would be because the criteria differed with the observers depending on the objects of interest. In all categories, the acceptability of b^* is larger or equal to a^*.

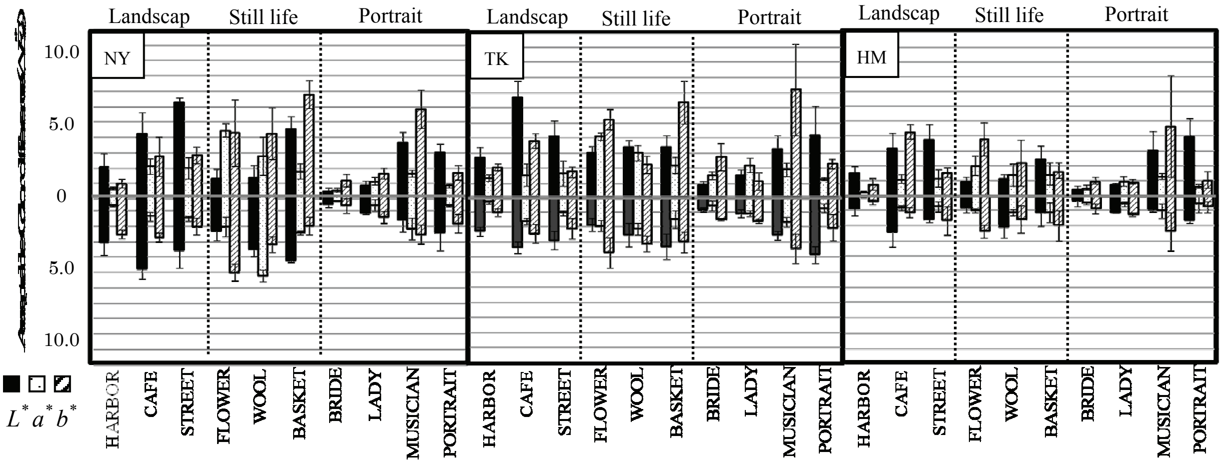

Figure 2 Acceptable color difference

3.2 Perceptibility

Figure 3 shows the results of perceptibility. Perceptibility varies depending on images as same as acceptability. The tendencies that large perceptible color difference for L^* in landscape and smaller perceptible color difference in portrait, are also similar to the result of acceptability. In all categories, the perceptibility of a^* is generally smaller.

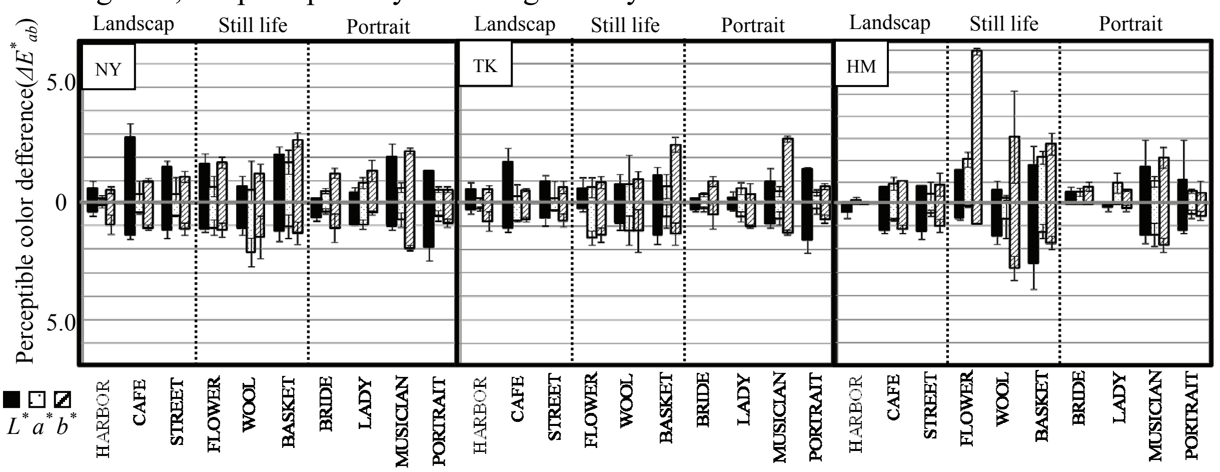

Figure 3 Perceptible color defference

3.3 Comparison between acceptability and perceptibility

To examine the relationship between acceptability and perceptibility, we show acceptable color difference as a function of perceptible color difference for all images in Figure 4. Acceptable color difference is larger than perceptible color difference in general. There is a trend that the amount of acceptable color difference changes according to that of perceptible color difference, suggesting that acceptability would link with perceptibility. The coefficients of determination (r^2) of three observers are 0.45 (NY), 0.63 (TK) and 0.17(HM). The slopes of correlation are different in each observer.

Figure 5 shows the correlation of acceptability and perceptibility in each image category separately. Portrait and landscape show high correlation, but still life shows low correlation. This suggests that acceptability can be predicted from perceptibility for portrait and landscape, but acceptability for still life is highly image dependent.

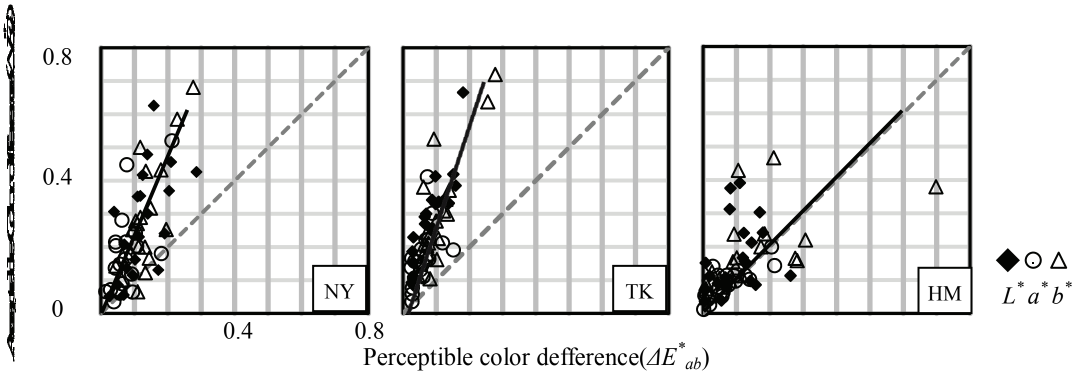

Figure 4 Acceptable color difference as a function of perceptible color difference

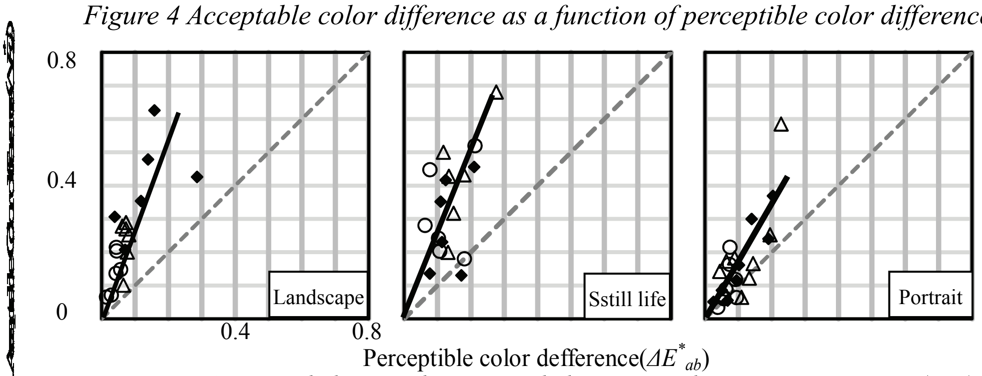

Figure 5 Acceptability and perceptibility in each image category (NY)

To summarize, it was suggested that acceptability links with perceptibility, whereas difference in image category has more influence to acceptability than perceptibility.

REFERENCE

Luo.M.R, Cui.G, Rigg.B, 2001, The development of the CIE 2000 color difference fomula:CIEDE2000, Col Res Appl 2001; 26: 340 - 350

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poster

A Novel Method to Measure Color-Matching Functions

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ABSTRACT

Although an adjustment method, which has been widely adopted in measuring color matching functions (CMFs), gives much flexibilities to subjects, its degree of freedom is too large for a naïve subject. As a result, this method sometimes causes a great stress for non-experts. Considering the possibilities to collect CMF data from non-experts, it is desirable that we reduce the load of the experiment without losing the accuracy of the measurement. Here we propose a novel method to measure CMFs: 6 alternative-forced-choice (AFC) method. In this method, a subject does not need to change the color of the reference stimulus. Instead, the subject is asked to compare the color of the multiple stimuli and simply pick up one of the six reference stimuli that appeared to be the best match to the test stimulus. Using this method, we measured CMFs for 19 different wavelengths using 5 subjects. We could obtain almost the same results as those obtained with the adjustment method. Some observers reported that our method was less stressful and more comfortable. This result indicates that our method may work as an effective method to measure CMFs for naïve subjects.

1. INTRODUCTION

Color Matching Functions (CMFs) have been widely used to calculate the tristimulus values. CMFs are the intensities of three primary lights required to match the equi-energy monochromatic lights. There are, however, individual differences in the CMFs even among people with normal color vision [Stiles and Burch (1959)]. In order to quantitatively evaluate the degree of color mismatch between observers, it is necessary to know CMFs of those observers. However, it is not easy to obtain individual CMFs. The difficulties come not only from the complexities of the optics system which is used to measure CMFs but also from the stress of the subjects. As for the complexity of the system, we have succeeded in building a simple and compact apparatus with LEDs, which was reported previously [Suzuki, T. et al. (2011)].

In most of the researches which tried to measure CMFs, an adjustment method was adopted. In this method, a subject adjusted the intensities of three primary lights independently, or freely, until the appearance of the reference light matches that of the test light. However, this large degree of freedom often gave a naïve, or un-experienced, subject a great stress for the experiment. In this study, we propose a novel method which enables to reduce the load of the setting. We adopted an alternative forced choice (AFC) method. There are several advantages in this method. The task of the subject is not to change or modify the reference color, but merely to look at the stimulus and judges whether it meets a given criteria or not. Thus, it is expected that this method is not so stressful for subjects.

2. METHOD

2.1 AFC Method

A subject was asked to evaluate the similarity between the test and the reference stimulus. Several reference stimuli were prepared in advance. In the preliminary experiment, six reference stimuli were chosen from the data obtained with an adjustment method which were collected previously. During the experiment, the subject could select which of six stimuli to appear right next to the test stimulus with a button on a controller. A subject chose the most similar one among those stimuli. Then the next trial started. Experimental procedure is shown in Fig.1. When the judgment completed, the reference stimulus was turned off for 300 ms so as to inform a subject that the stimulus was changing to a new one.

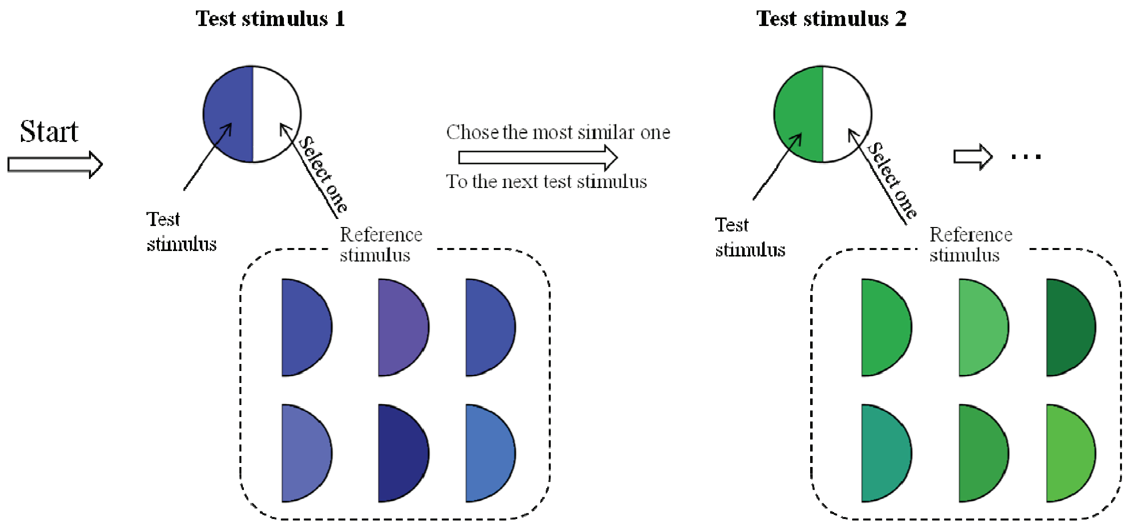

Fig.1 experimental procedure.

2.2 Experimental Condition

Experimental apparatus used in this study is shown in Fig.2. This apparatus used a single light source, in which plural LEDs inserted to a small integral sphere (6” diameter). All the optical parts were placed on a small breadboard (450mm (17.5”) x 300mm (11.7”)).

The experiment was conducted for 19 different monochromatic lights. As the reference stimuli, the mixture of R, G, B primaries were presented. Their peak wavelengths were 630, 523, 470nm, respectively. The spectral peaks and distributions of the LEDs used in the experiment are shown in Fig.3. As described in 2.1, one of the six reference stimuli were presented as the reference stimuli to be compared with the test stimulus whose luminance was set to 2 cd/m^2. A surrounding annular stimulus was presented to the subject to prevent from dark adaptation. The head of the subject was fixed with a chin-rest. Five color normal subjects participated in the experiment.

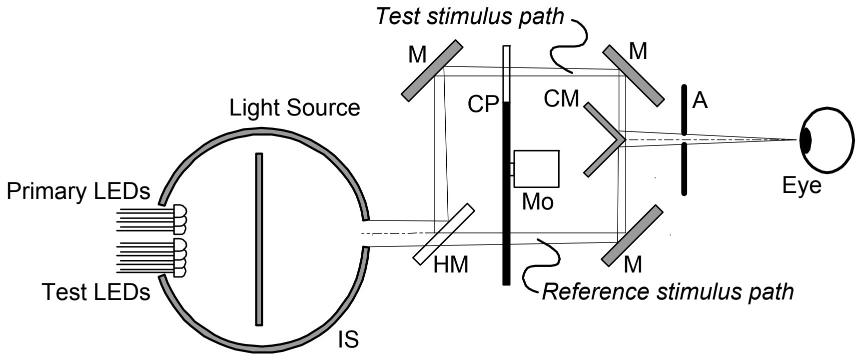

Fig.2 Experimental apparatus (IS: Integrating Sphere, M: Mirror, HM; Half Mirror, CP: Chopper, CM: Corner Mirror, Mo: Motor, A: Aperture)

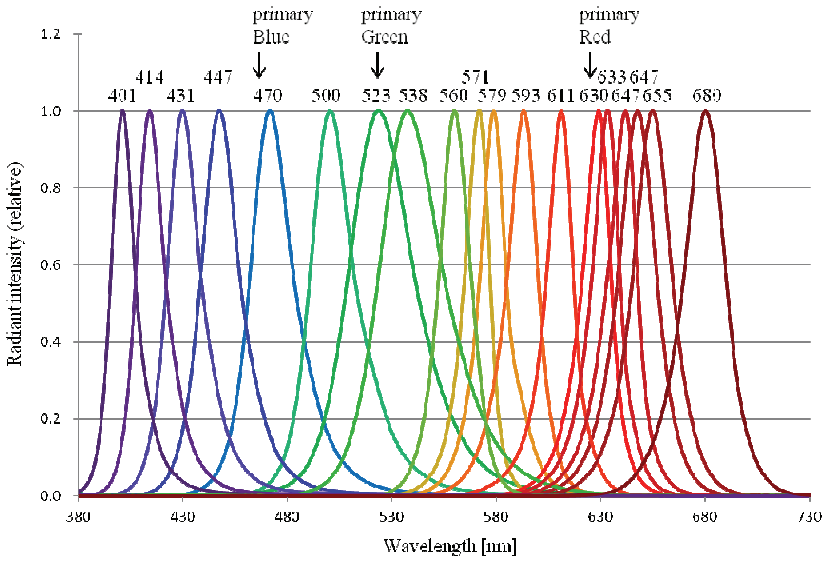

Fig.3 Spectral radiant intensity of the test stimuli used in the experiments

3. RESULTS

The CMFs obtained from five subjects are shown in Fig.4. Symbols ○, ◇ and, △ denote the mean value of R, G, B primaries, respectively, obtained from each subject's choice. Symbols + and, × represent the mean values of the 6-AFC method across 5 subjects and those obtained with the adjustment method across the same 5 subjects, respectively. The individual differences of CMFs can be seen in symbols ○, ◇ and, △. The similarities of the results obtained with two different experimental methods can be observed in, the symbols + and, ×. The total time required to complete a session was approximately 90 minutes, which were about three-fifths compared with the traditional adjustment method. Some observers reported that our novel method was less stressful and more comfortable than the previously used adjustment method. Although the color of the stimulus changed discretely in color space, nobody complained for it. This result indicates that our method has several advantages in measuring CMFs, especially those for a naïve subject.

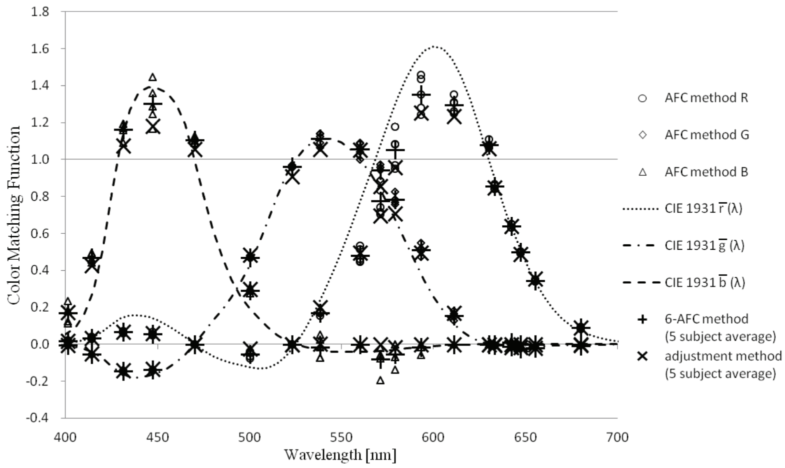

Fig.4 Measured individual CMFs. Symbol (○, ◊, Δ) represent R, G, B results of five subjects, and symbol (+, ×) represent mean value of AFC method (5 subjects) and the adjustment method (5 subjects), respectively. Dotted lines represent CMFs of the CIE1931 standard observer for primaries of 630nm, 523nm, and 470 nm.

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4. CONCLUSIONS

We proposed a novel method that adopted an alternative forced choice to measure color matching functions. We could obtain almost the same results with our methods as those obtained with the traditional adjustment method. Moreover, we confirmed that we can easily measure the CMFs and evaluate their individual differences. With this method, we need to collect data from many naïve subjects to quantitatively evaluate the individual differences of CMFs. In addition, we need to optimize the selection of reference stimuli that are used in the experiment more efficiently and accurately. We are also interested in collecting data from elderly observers to evaluate the individual differences among them. In order to reduce the load of the experiment, we should establish a new experimental method for them. Our method may work as an effective method to measure CMFs for naïve subjects.

Acknowledgment

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References

Wyszecki, G., and W. S. Stiles. 1967. Color science, concepts and methods, quantitative data and formulas. New York: John Wiley and Sons.

Suzuki, T., Suzuki, M., Yamauchi, Y. and Okajima K. 2011. Development of simple color bipartite apparatus using single light source with LEDs and measurement of individual color matching functions. *In AIC 2011 Proceedings*, ed. by V. M Schindler and S. Cuber. Zurich, Switzerland. 763-766.

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Subjective evaluation of metal like appearance for estimating the determinants of material perception

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ABSTRACT

It is not known which features of objects contribute to a material perception. It is helpful for create computer graphics if we know the relevance. This paper presents the results of subjective evaluation of metal like appearance for estimating the determinants of material perception. Images of a ball which have various parameters are generated using computer graphics software. The parameters are five steps on four types: reflectance, diffuse reflectance, first gloss, and second gloss. Subjects experiment is conducted with the 36 images and using five step rating scale method. A degree of metal likes is decided on mean of the results. Then, we do Thurstone's paired comparison test with 20 images that are generated on selected parameters. As the result, we can determine the order of the degree of metal. The degree of metal is high when its parameters are high reflectance, low diffuse reflectance, and gloss.

1. INTRODUCTION

Surfaces, such as those of metal, glass, wood and food, elicit unique material perceptions of each depending on the materials. And humans can distinguish between these various materials from visual information. Recently research on the material perception has been carried out actively. Motoyoshi have investigated image features that are diagnostic of the perceived translucency and transparency, focusing on the fact that variations in the opacity of a surface affect largely the non-specular component (shading pattern) of an image and little the specular component (highlights)(Motoyoshi 2010). Pellacini have discovered that a light reflection model where the dimensions of the model are perceptually meaningful, and variations along the dimensions are perceptually uniform (Pellacini 2000).

It is not known which features of objects contribute to a material perception. It is helpful for create computer graphics if we know the relevance. This paper presents the results of subjective evaluation of metal like appearance for estimating the determinants of material perception.

2. A RATING SCALE EXPERIMENT

2.1 Experimental settings

We experiment to measure subjective evaluation of metal like appearance based on rating scale method for estimating the determinants of material perception. First, we create test sample images using computer graphics software (Shade12 by e frontier, inc.). The images describe a ball which have various parameters are generated. The parameters are five steps on four types (reflectance, diffuse reflectance, first gloss, and second gloss).

Subjects experiment is conducted with the 36 images and using five step rating scale method. 56 observers (males and females, ages 20-24) took part in the experiment. The viewing distance is 40 cm, and, and the display is 21 inch LCD monitor (RTD201S by Mitsubishi Electric Corp.).

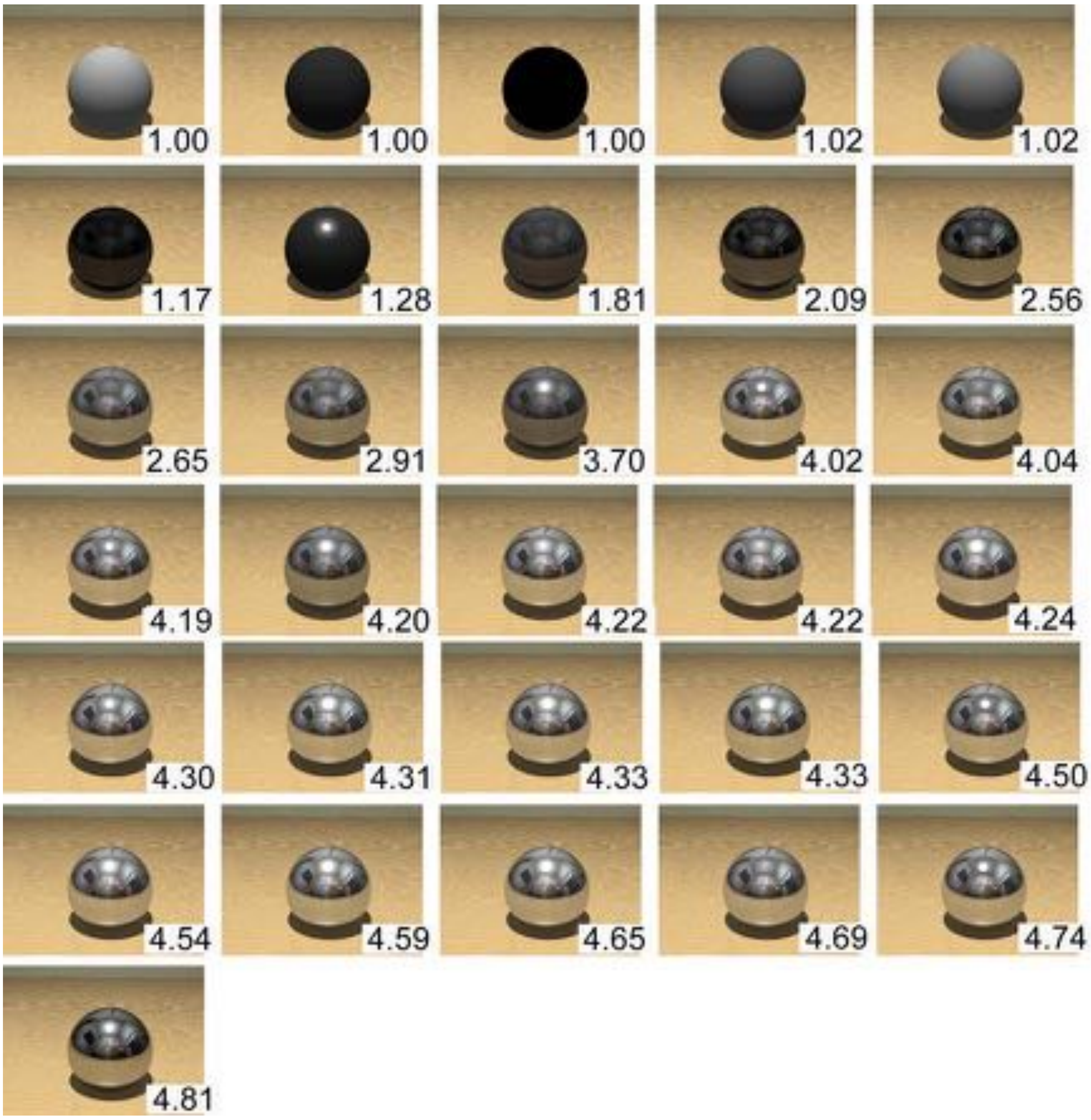

Figure1. The results of experiment based on rating scale method.

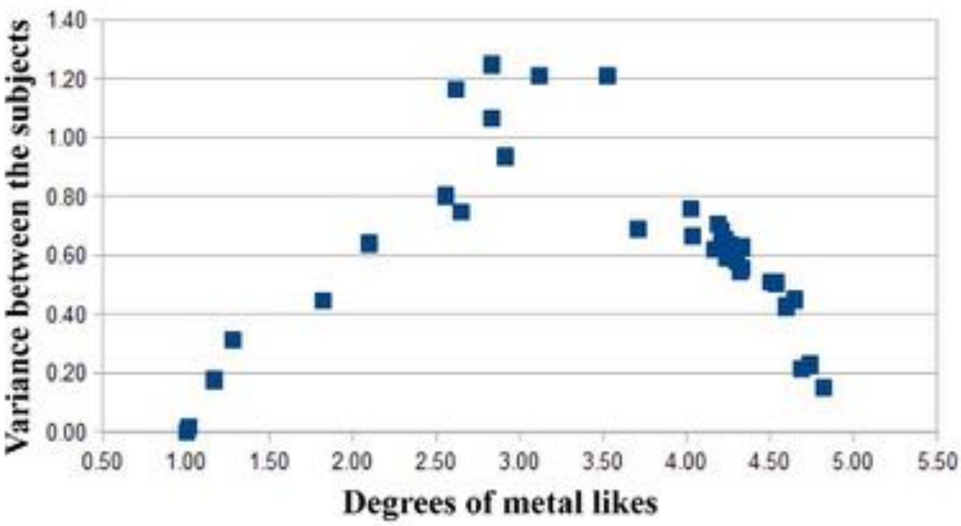

Figure2: The variance of the degrees of metal likes between the subjects.

2.2 Experimental results

Degrees of metal likes are decided on mean of the results of experiment based on rating scale method. Figure 1 shows the degrees of metal likes for some test samples. The Degrees and appearances of the images seem to match. The variances of the degrees of metal likes between the subjects are shown in Figure 2. It seems from the figure 2 that the variances are high value near the intermediate evaluation value, and low value near the maximum or the minimum evaluation value. In fact it would appear that evaluation of intermediate degrees of metal likes depends on the observer perceptions.

3. FORMULATION OF DEGREES OF METAL LIKES

We use multiple regression analysis to quantify the degree of metal likes. An objective variable is the degree of metal like, and explaining variables are parameters of computer graphics. We have selected parameters which are high relevance from the preliminary analysis results. The adopted parameters are a diffuse reflectance, a reflectance, and a specular gloss.

The regression function M is described as follows:

$$M = -1.53d + 0.91s + 2.28r + 1.32 \qquad (1)$$

Where d is the diffuse reflectance, s is specular gloss, and r is reflectance the ball. The range of d and r is [0.0, 1.0]. The value of s is 0 (matt) or 1 (gloss).A higher numerical value indicates more metal like. The adjusted coefficient of determination is a high value ”0.87".

Values of M are calculable from computer graphics images which not used in the experiments by this regression function. Figure 3 shows example of M and parameters of computer graphics.

4. A PAIRED COMPARISON TEST

4.1 Experimental settings

The degrees which based on rating scale method may dependent on subjectivity of observers. Therefore, we do Thurstone's paired comparison test with 20 test sample images that are generated on selected parameters (five step of reflectance, two step of diffuse reflectance, and matt or gloss). 16 observers (males and females, ages 20-24) took part in the test. The viewing distance and the display device are same as the rating scale experiment.

4.2 Experimental results

We can determine the order of the degree of metal from the result of the paired comparison test. Figure 4 shows the order of the test sample images on the number line of -1.0 to 1.0. The degree of metal is high when its parameters are high reflectance, low diffuse reflectance, and gloss. In contrast, it is low when its parameters are low reflectance, high diffuse reflectance, and matt. However, image parameters near the middle degrees show ambiguous tendency.

5. CONCLUSIONS

The degrees of metal likes were determined according to the results of experiment with images of a metal ball based on rating scale method. The variances between the subjects were high value near the intermediate evaluation value. The degrees of metal likes were formulated by a multiple regression analysis. Then we confirmed the order of the subjective evaluation

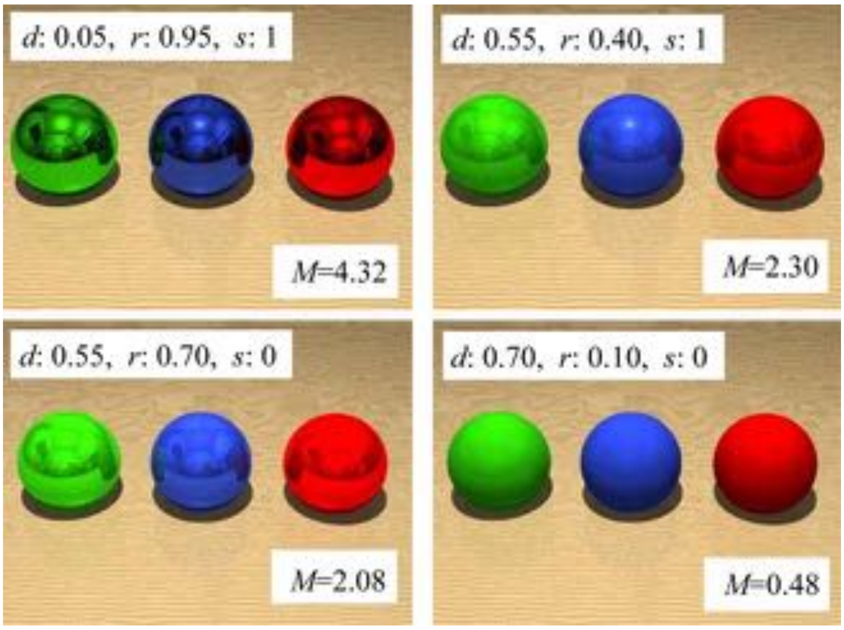

Figure3. Degrees of metal likes from the other images.

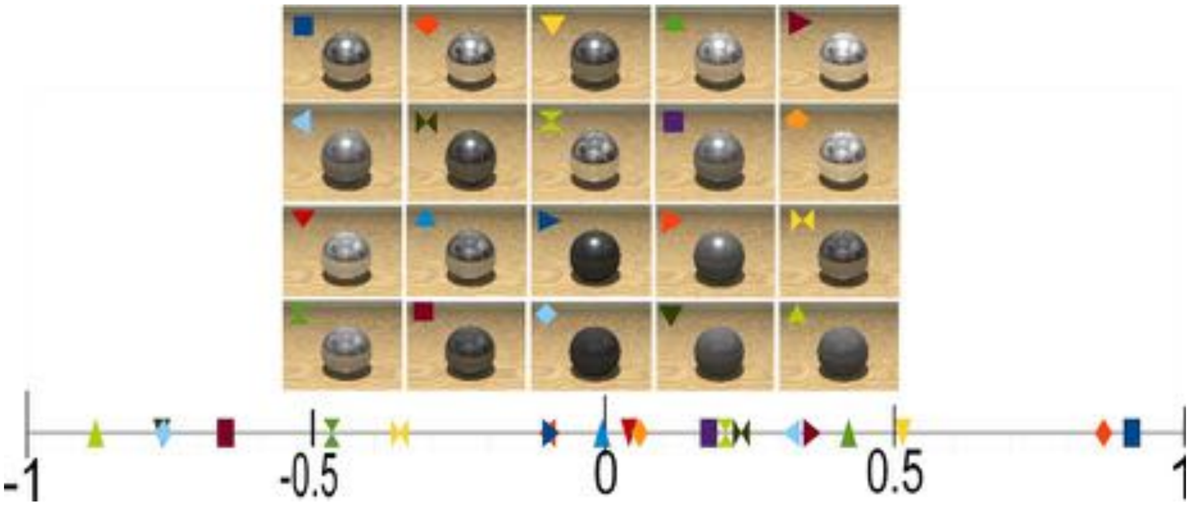

Figure4. The results of the paired comparison test.

for metal images by a pair comparison method. The degrees of metal were high when its parameters were high reflectance, low diffuse reflectance, and gloss. However, we were not able to quantify the results of the pair comparison experiment. It is necessary to consider the images used for subjective evaluation.

REFERENCES

Motoyoshi, I. 2010. Highlight-shading relationship as a cue for the perception of translucent and transparent materials. *Journal of vision* 10(9)6: 1-11.

Pellacini, F., J.A. Ferwerda, and D. P. 2000. Greenberg, Toward a psychophysically based light reflection model for image synthesis. In *SIGGRAPH 2000 Conference Proceedings*, ed. By J. S. Brown and K. Akeley. New Orleans: Ernest N. Morial Convention Center, 55-64

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Proper-sized thai letters suitable for elderlies and improvement of their visual performance.

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ABSTRACT

This research aims to investigate the visual acuity of printed small-sized Thai letters under various illumination conditions by using cataract experiencing goggles to simulate elderly eyes with cataract. The experiment composed of two environment illumination systems; one-room and two-room. In the one-room system four illumination levels, 20, 80, 280 and 800 lx were assigned to resemble supermarket and household lighting condition. Three Thai fonts were examined. In the two-room system the subject room and the test stimulus room were divided with a wall on which a window was opened for observation. Seven illumination levels, 0, 5, 20, 80, 280, 800, and 1500 lx were employed for subject's room while the test room was fixed at 280 lx. In both cases subjects determined the minimum readable letter size. For the one-room system the visual acuity improved with increasing illumination level, and it was lower with goggled eyes by about 0.4 at the illuminance 20 lx. Negative contrast fonts showed slightly better visual acuity than positive contrast fonts in all conditions. The 3 Thai fonts gave similar result in all conditions. For the two-room system the visual acuity stayed more or less constant for all the illumination levels in both cases of the normal eyes and the goggled eyes. The visual acuity did not decrease with the goggled eyes compared to the normal eyes to show the advantage of using two rooms for elderly people.

1. INTRODUCTION

The ratio of population of elderlies to young people in Thailand is increasing rapidly and the country becomes elderlies society. Since most of the outside information is collected to us through the visual system, the proper infrastructure of the visual environment for elderlies is one of the important tasks of the country. The printed labels represent visual environment as they are the targets for getting information of the products. They have been found to be expressed by so small letters and are too difficult for elderlies to read.

A serious problem of the visual performance of the elderly comes from the cloudy crystalline lens of the cataract that scatters the incoming light all over the retina. It is considered that the scattered light makes the legibility of letters worse as the scattered foggy light lays over the retinal image of letters. The deterioration of the visual acuity investigated in the forgoing experiments should be because of the scattered light and cannot be avoided as far as the reading condition stays normal, that is the subjects read labels under illumination provided by ceiling light.

To control scattered light from the environment, Ikeda et al. introduced the 2 room concept[1]. A test stimulus is placed in one room and a subject stays in the connecting room with window on the separating wall. If the illumination of the subject room is lowered, while the luminance of the test stimulus is kept the same, the scattered light should be decreased and the visual performance should be improved. This research aims to investigate the visual acuity of printed small-sized letters under various illumination conditions by using cataract experiencing goggles.

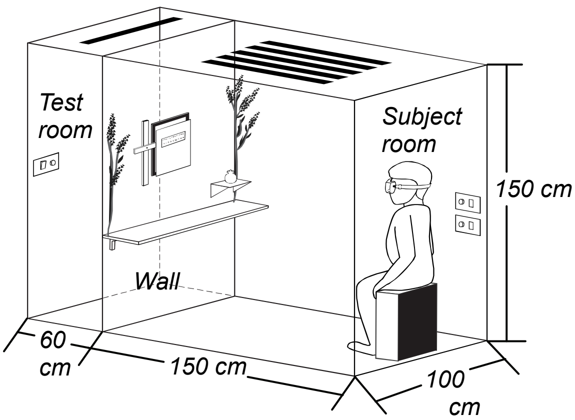
2. EXPERIMENT

The experimental apparatus was composed of cataract experiencing goggles, experimental rooms, and letter charts test stimulus.

The cataract experiencing goggles is the goggles made of filters that simulate the properties of cataract eyes[2]. They are composed of color filter, brightness filter and haze filter that together simulate the elderly vision with cataract especially in the state that started to cause the inconvenience in their daily life. Young subjects wear this goggles to simulate the vision of elderly to compare with the vision from their young naked eyes.

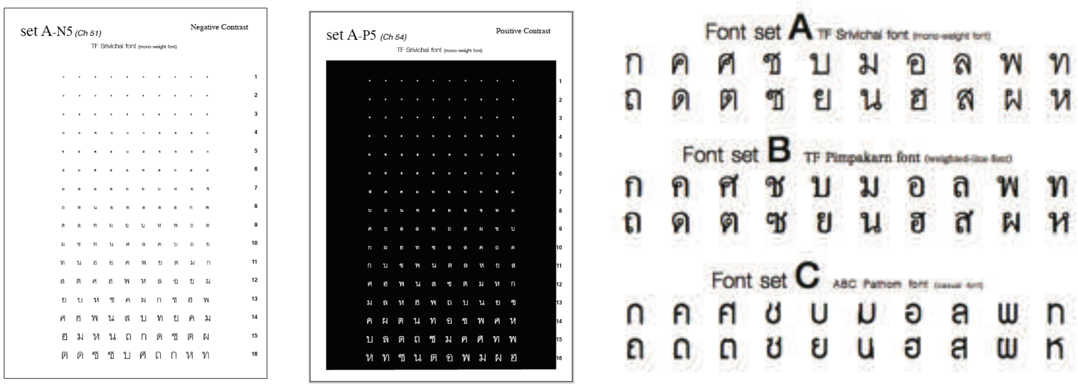
Experimental rooms utilized two environmental illumination systems; the one-room and the two-room as shown in Fig. 1. In the one-room system, the ceiling fluorescent lamps provided four illuminance levels (20, 80, 280 and 800 lx) on the chart placed on the wall in the subject room to resemble supermarket and household lighting condition. In the two-room system the subject room and the test stimulus room were divided with a wall on which a window was opened for observation, and were illuminated separately. Seven illuminance levels (0, 5, 20, 80, 280, 800, and 1500 lx) were employed for subject room while the test room was fixed at 280 lx of the vertical plane illuminance on the chart.

Fig. 1 The experimental room for one-room and two-room illumination system.



The letter chart was composed of 16 lines of Thai letters as shown in Fig. 2 (a) and (b). Each line composed 10 randomized letters of the same size. The 16 lines are varying in letter height ranging from 0.93 to 5.47 mm with 0.05 steps in logarithmic unit. Only achromatic letters and background were investigated in this study. The polarity contrast of charts implemented with negative contrast (black letters on white background) and positive contrast (white letters on black background). Three Thai fonts selected for the experiment are TF Srivichai (represent mono-weighted stroke text font), TF Pimpakarn (represent variable-weighted stroke text font), and ABCPathom (represent display font) as shown in fig 2 (c). The three Thai fonts were examined in the one-room system with observing distance of 120 cm, and only font TF Srivichai was examined in the two-room system with observing distance of 150 cm.

Fig. 2 The test chart in negative contrast (a) and positive contrast (b) and the three Thai fonts examined in the experiment (c)



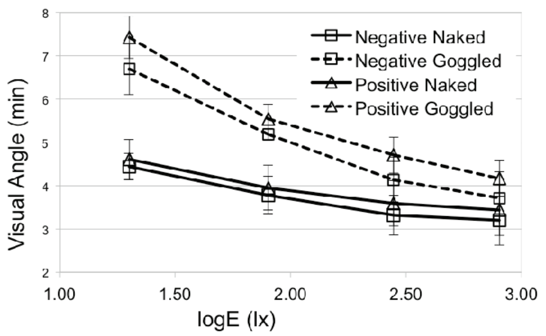
(a) (b) (c)

In both cases subjects determined the minimum legible letter size. Each line of 10 letters were presented to subjects at a time through open window of gray facet. Test charts were presented to subjects for determining the 50% seeing threshold of correct reading. Five young subjects aged between 25 to 35 years old performed the experiment binocularly.

3. RESULT AND DISCUSSION

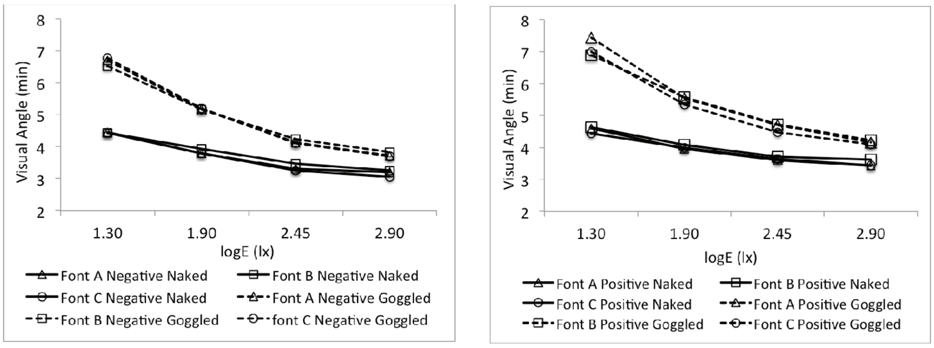
Results from the Average data from 5 subjects of the one-room system are shown in Fig. 3. The abscissa gives the room illuminance and the ordinate the visual angle of letters. The graph shows visual angle of 50% seeing under various illuminance levels, polarity contrast, and goggles wearing conditions of font TF Srivichai. Letter size decreased with increasing illuminance levels indicating the improvement of the visual acuity. At 20 lx the letter size with goggled eyes was larger than naked eyes by amount of 2.5 min. At bright light of 800 lx the goggled eyes can increase visual acuity to almost that of naked eyes.

Fig. 3 Visual angle of 50% seeing under various illuminance levels, polarity contrast, and goggles conditions of font TF Srivichai experimented with one-room illumination system.



Negative contrast fonts showed slightly better visual acuity than positive contrast fonts in all conditions. The 3 Thai fonts gave similar result in all conditions to show the insignificant font design factor on visual acuity compared to font size and illumination factors as shown in fig. 4.

fig. 4 Visual angle of 50% seeing, comparing the 3 fonts in negative contrast (a) and positive contrast (b).



(a) (b)

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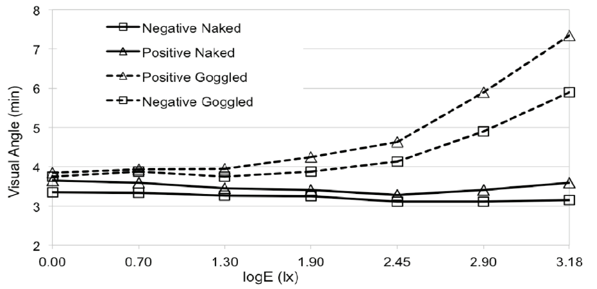
Results from the two-room system are shown in Fig. 5. The visual angle of letters stayed more or less constant for subject room illuminance that not higher than test room illuminance of 280 lx or 2.45 in log unit, in both cases of the normal eyes and the goggled eyes. The visual acuity did not decrease with the goggled eyes compared to the normal eyes to show the advantage of using two rooms for elderly people. The visual acuity decreased when subject room illuminance was higher than test room illuminance, by the amount of 2.5 min in letter height at 1500 lx.

Fig. 5 Visual Angle of 50% seeing under various illuminance levels, polarity contrast, and goggles conditions, experimented with two-room illumination system.



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REFERENCES

1) Ikeda, M., Pungrassamee, P., and Obama, T. Color Research & Application 34 (2009): 351-358

2) Obama, T., Uozsto, H.,Terauchi, H., and Matsuoka, M. Journal of the Color Science Association of Japan 28 (2004): 245-252

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Physiological and psychological responses to color lights under environmental temperature change: Focused on the comparison between normal subjects and subjects complaining of unusual coldness

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ABSTRACT

The purpose of this study was to investigate the physiological and psychological responses to color lights under environmental temperature change, focused on the comparison between normal subjects and subjects complaining of unusual coldness. Sixteen female subjects divided into "normal group" and "unusual coldness group" were exposed to normal condition and cold condition under white and yellow color light respectively. Skin temperature, skin blood flow, rectal temperature, blood pressure and pulse rate were continuously measured. At the meantime, impression towards the color lights, mood, thermesthesia, and cold discomfort were evaluated. The results indicated that in cold condition, skin temperature, skin blood flow rate, and rectal temperature of unusual coldness group was lower than normal group under both color lights. But these indicators maintained at higher level under yellow color light than that under white color light. In addition, subjects felt nervous, depressed and discomfortable in cold condition. And the rating scores of these were even greater in unusual coldness group. However, yellow color light deemed as warm color was considered decreasing the discomforts of cold. This study suggested yellow color light may help people, especially who complained of unusual coldness to reduce discomforts due to cold physiologically and psychologically.

1. INTRODUCTION

So far, researches of physiological and psychological effects of color have been conducted in various aspects. Warm and cold sense of color as emotional effect is well known. Kaku et al. (2009) reported that in cold water stimulation experiments, color light can affect self-regulatory body temperature adjustment reaction, and affect the thermesthesia and mood. Guo et al. (2012) reported that color light can significantly affect mood, thermesthesia, and thermal discomfort. In particularly, yellow color light may help reduce discomforts caused by cold physiologically and psychologically.

To further explore the effects of yellow color light, this study investigated the physiological and psychological responses to color lights under environmental temperature change, particularly focused on the comparison between normal subjects and subjects complaining of unusual coldness.

2. METHODS

Sixteen female subjects aged between 20 to 30 years old were divided into two groups as "normal group" and "unusual coldness group" by a 10-question interview referenced the report of Nagashima et al. (2002). Subject entered the environmental chamber 1 hour before the experiment. During the experiment, subject wore gray color (N6.5) short sleeves T-shirt and short pants, maintaining a sitting position. We respectively projected white (x: 0.358, y: 0.407, luminance: 23.3cd/m^2) and yellow (x: 0.461, y: 0.453, luminance: 21.9cd/m^2) color light produced from a projector and a computer to a rear projection screen placed 70cm in front of the subject. The subject was fully covered by color light. From the beginning of the experiment, there was a 20 minutes' exposure process in normal condition (28.5°C, 30%RH). Then, the temperature was reduced to 23.5°C for a cold exposure process (23.5°C, 30%RH) of 60 minutes. After that, the temperature was raised to 33.5°C till the end of the experiment. Figure 1 shows the experimental procedure. White and yellow color light were divided into 2 days and placed in a random day for each subject.

Through the experiment, skin temperature, skin blood flow, rectal temperature, blood pressure, pulse rate were continuously measured as physiological indicators. Subject's impression towards the 2 color lights were measured before the start of the experiment (SD method, 9 adjective pairs, 5-point scale). In addition, mood (POMS, 15 words, 4-point scale), thermesthesia (7-point scale) and cold discomfort (7-point scale) of hands, feet, and body were evaluated 12 times (①-⑫ on Figure 1) as psychological indicators.

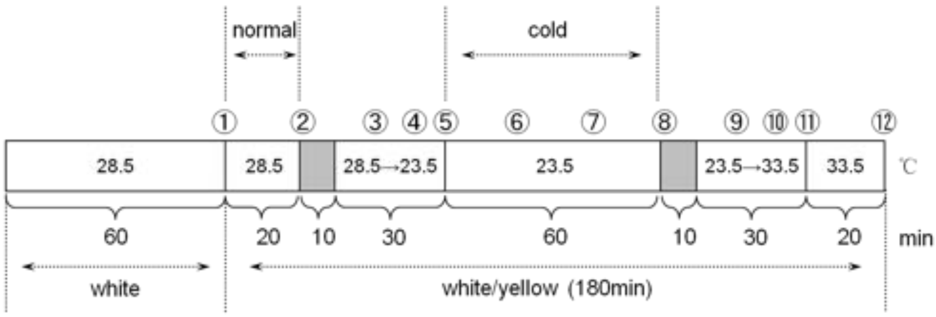

Figure 1. Experimental procedure

3. RESULTS

Physiological responses

Figure 2, 3, 4 shows the variation of finger skin temperature, finger skin blood flow and rectal temperature during the experiment. (N: normal group, C: unusual coldness group, Ta: Temperature Ambient) Under both color lights, during cold exposure process, finger skin temperature, skin blood flow of normal group maintained at higher level than unusual coldness group. However, under yellow color light, the finger skin temperature, skin blood flow of both groups maintained at higher level comparing to that under white color light. In addition, core temperature (rectal temperature) of unusual coldness group was significantly higher under yellow color light than that under white color light.

Psychological responses

Referring to subjects' impression of color light, white color light is thought to have neither cold nor warm feeling, while yellow light gives impression of warmth.

Evaluate the subjects' mood during the experiment under the 2 color lights, using factor analysis (major factor method, varimax rotation), select 4 factors: RELAX, ACTIVE, GLOOMY, TIRED. Using RELAX and GLOOMY as axes, produced a scatter plot of factor scores. (Figure 5)

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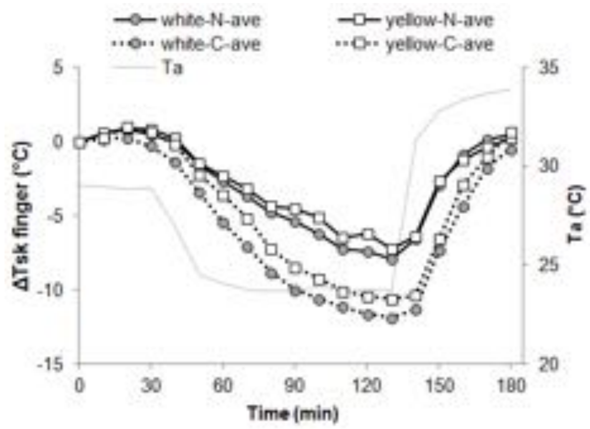


Figure 2. Variation of finger skin temperature

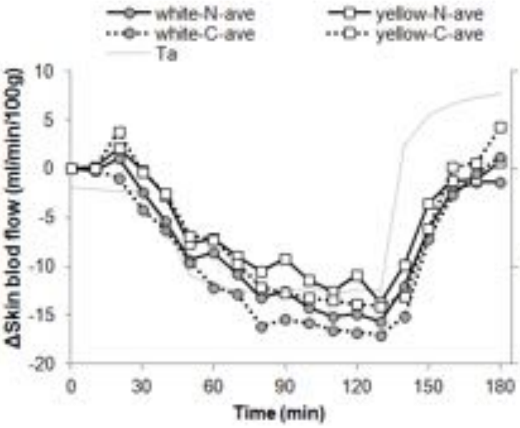


Figure 3. Variation of finger skin blood flow

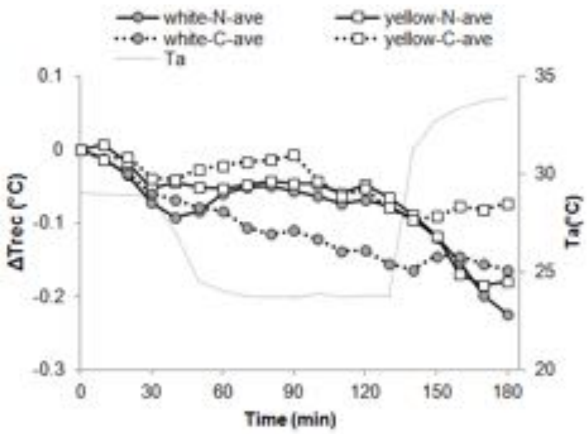
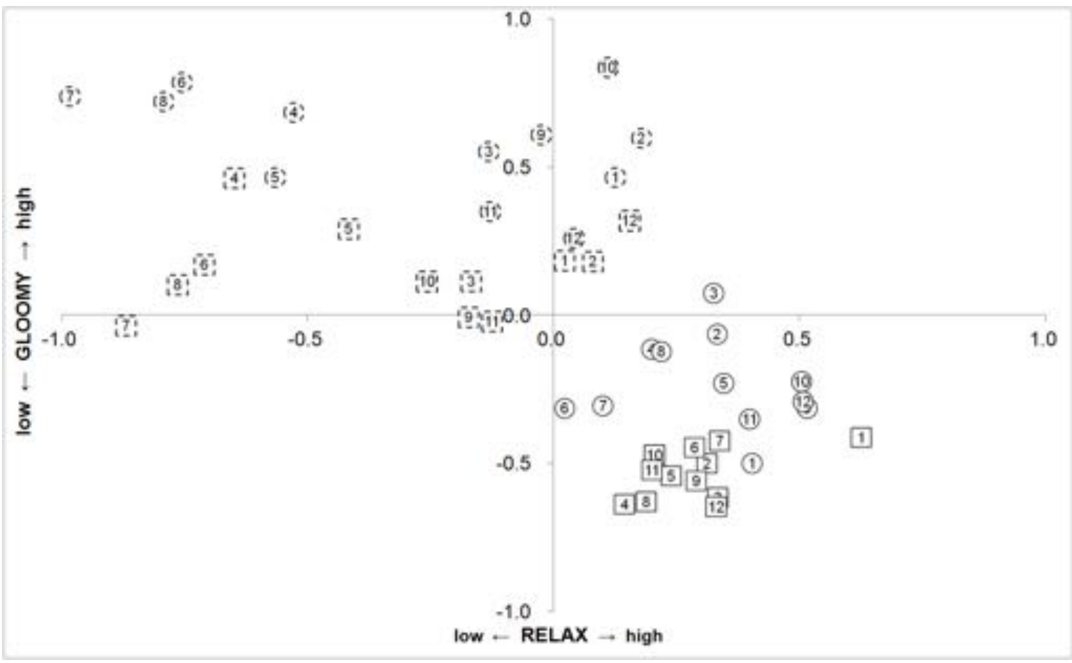


Figure 4. Variation of rectal temperature



Normal group:

①-⑫ : 1st -12th mood evaluations under white color light 1-12 : 1st -12th mood evaluations under yellow color light

Unusual coldness group:

①-⑫ : 1st -12th mood evaluations under white color light 1-12 : 1st -12th mood evaluations under yellow color light

Figure 5. Scatter plot of factor scores（RELAX×GLOOMY）

Figure 5 shows that, plots of normal group are relatively concentrated, but plots of unusual coldness group are scattered. These results suggest that subjects' mood in unusual coldness group is relatively more affected by the temperature change comparing to normal group. GLOOMY scores of unusual coldness group are higher than normal group under both color lights. RELAX scores of unusual coldness group are lower than normal group. Especially, during cold exposure process (5th-8th mood evaluations), RELAX scores of unusual coldness group are significant low. These results show that, in cold condition, the subjects of unusual coldness group felt more nervous and depressed than normal group. However, under yellow color light, GLOOMY scores of both groups are lower than under white color light. It could be understood as that, to a certain extent yellow color light may ease the sense of nervous and depressed caused by cold.

Evaluations of thermesthesia and cold discomfort during cold exposure process show that, comparing to normal group, subjects of unusual coldness group felt relatively cold and discomfortable. And they felt relatively warm and comfortable with their hands under yellow color light comparing to white color light.

4. DISCUSSION & CONCLUSION

Nagashima et al. (2002) reported that peripheral skin temperature and skin blood flow decreased in cold condition, at the mean time, psychological discomforts caused by cold emerged. These physiological and psychological discomforts were greater in unusual coldness group than normal group. Guo et al. (2012) reported that yellow color light may help reduce discomfort caused by cold physiologically and psychologically.

This study indicates that, in cold condition, the physiological and psychological discomforts of unusual coldness group are more significant comparing to normal group. Under yellow color light, which gives impression of warmth, the physiological and psychological discomforts of both groups could be reduced. Compared to normal group, yellow light's effects to unusual coldness group may be more significant.

The results of this study, which are consistent with previous studies, further indicate that color lights have certain physiological and psychological effects. In particularly, this study shows yellow color light may help people, especially who complained of unusual coldness to reduce discomforts caused by cold physiologically and psychologically.

REFERENCES

Kaku, Y., M. Saito, K. Oza, K. Tokizawa, and K. Nagashima. 2009. The effects of color light on the human thermoregulation and mood under the condition of cold water load. *Journal of the color science association of Japan* 33 (supplement): 46-47.

Guo, Y., M. Saito, M. Nakamura, and K. Nagashima. 2012. Physiological and psychological responses to color lights under cold environmental condition. *Journal of the color science association of Japan* 36 (supplement): 226-227.

Nagashima, K., T. Yoda, T. Yagishita, A. Taniguchi, T. Hosono, and K. Kanosue. 2002. Thermal regulation and comfort during a mild-cold exposure in young Japanese women complaining of unusual coldness. *Journal of Applied Physiology* 92: 1029-1035.

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Color Choice: Product Type, Personal Preferences and Social Norm

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1. INTRODUCTION AND OBJECTIVES

Due to the advancement of communication technology, the consumer market has been transformed rapidly over the last 20 years. Today's young consumers are relatively more technological savvy, sophisticated, assertive and even more demanding than the prior generations. According to some researchers, this young consumer group can be described as "me-generation" (Wilska, 2002) and "consumer tribes" (Cova et al., 2007). They are not only fragmented in terms of lifestyle but also constantly searching for new products. They move from one idea/concept or culture to another in a much faster pace. It becomes a challenge for many fashion manufacturers and practitioners to understand what constitute their mind when they shop for clothing products. In many cases, people do not look for a single benefit or a monolithic feature of a product. They often seek for multi-dimensional values and benefits from a product such as functions and performance, psychological benefits, symbolic meanings, emotion values, and experiential pleasure (Rahman et al., 2010). Thus, product design, especially colour, could play a pivotal role on product acceptance, differentiation, integration and overall success. It directly affects the consumer's aesthetic responses and visual stimulations of a product.

In order to gain a better and deeper understanding of today's young consumers' needs and aspirations, and what role the colour cue play in the process of evaluation and consumption of clothing, a qualitative research method and visual stimuli (hoodie) were used as a vehicle to explore and examine this particular topic. The objectives of this study are three-fold: (1) to study the link between the colour attribute of hoodie and consumer perceptions, (2) to uncover the salient impact of both visual cues or physical characteristics of hoodie, and how colour may affect a consumer's purchasing decision, and finally (3) to understand the underlying symbolic meanings of hoodie in general and colour cue in particular – e.g., How does hoodie shape, define or redefine an individual's self? The overarching goal of the present study is to generate practical and theoretical interest, identify research opportunities for the future, and offer insightful recommendations for fashion designers, marketers and manufacturers.

2. RELEVANT LITERATURE

2.1 Colour

According to many studies (Chu et al., 2011; Whitfield and Wiltshire, 1983), the desirability of colors is closely related to the product type (e.g., a car, a toaster or a table) and product style (e.g., modern or classic). Another study conducted by Holmes and Buchanan (1984) confirms that consumer's color choice often based on the product categories rather than personal colour preferences. People often purchase their wedding dress in white or ivory colour, and the electrical appliances in white or stainless steel. Colour preference for certain products is based on associations consumers have learned and formulated through their past experience and observation. Apart from the product type association, colour trend, and personal taste may also play a role in the process of product choice. In some cases, consumers may choose certain colour for a specific product according to the colour trend rather than the social acceptable norm. Indeed, choosing colors for a specific object/product could be a complex process consists of many tangible and intangible factors. For example, consumers may not necessarily buy their favourite color (e.g., pink) if it looks "childish", "girlie" or "inappropriate" in particular life stage and/or social context (Creusen and Schoormans, 2005). On the contrary, some consumers may want to buy unusual colour to make a fashion statement or draw other people's attention. In other words, colour desirability and preferences may change over the course of life as well as depend on an individual's wants.

2.2 Hoodie

"Hoodie" is a slang for a hooded garment or people who wear this particular garment. This word had officially accepted and entered the Oxford English Dictionary and the Collins English Dictionary in 2005 and 2007 respectively. It has been widely used in different media over the last two decades. However, this word often links to or perceives as negative/bad connotations such as gangster, crimes, violence and vandalism. For example, the North London riot in 2011 – many youngsters who threw beer cans and stones to the police officers and set the cars on fire were hoodies. Why this clothing style often associates with crimes? Is the negative connotation more associated with its style rather than the colour? Is this a gender issue instead of a norm? With this perspective, we deliberately chose hoodie as a vehicle to uncover and illuminate consumer's underlying motives of color/product choice during the selection and decision-making processes – including various areas such as the congruency of self-image and product image; personal preferences and social norm; and color appropriateness and product type.

2. RESEARCH METHOD

The qualitative research method was employed to collect demographic information, to measure the importance of evaluative criteria such as style, design features and colour. Laddering" interview technique was used to understand how consumers translate product attributes into meaningful associations. This interviewing method has been widely used in many "means-end effect" research studies. As Reynolds and Gutman pointed out in their seminal (2001; pp. 26), "laddering involves a tailored interviewing format using primarily a series of directed probes, … to determine sets of linkage between the key perceptual elements across the range of attributes (A), consequences (C), and values (V)". In total, 18 female informants ranged from 20 to 26 years old were recruited for this study. As McCracken (1988 17) suggested in *The Long Interview: Qualitative Research Methods*, "The first principle is that 'less is more.' It is more important to work longer, and with greater care, with a few people than more superficially with many of them. For many research projects, eight respondents will be perfectly sufficient." Therefore, the total number of participants (n=18) is deemed to be sufficient for this type of research study.

In total, fourteen colours were chosen for this study for elicitation (as shown in Figure 1). 16 colours were selected from the Pantone Colour palette and four basic colours (charcoal, black, navy and grey) were determined by the authors.

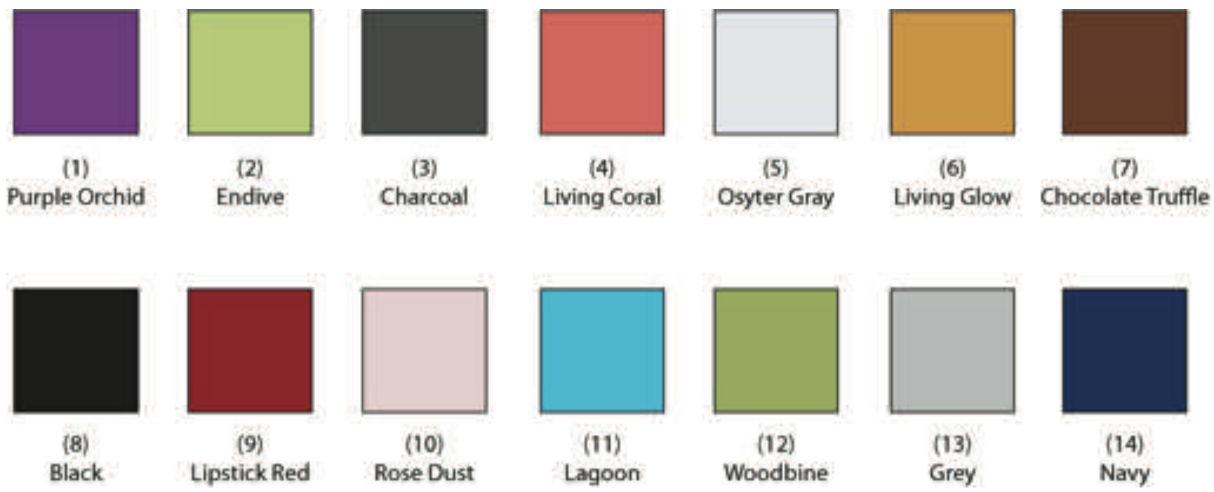

Figure 1. Colour Palette

4. FINDINGS AND DISCUSSION

According to the results of this study, it is evident that the colors of a product carry various learned and associative meanings within a specific consumption context. In many cases, colors do not only provide the psychological comfort to the users but also use as a signifier to manifest/express an individual's self.

It is evident that majority of the informants preferred dark colours over bright or pastel colours. For example, five informants ranked Charcoal and four chose black as their first choice (see Table 1).

Colour	First Choice	Second Choice	Third Choice	Total Number of Counts
Charcoal	5	1	2	8
Black	4	2	1	7
Living Coral	2	3	2	7
Navy	1	4	2	7
Grey	-	4	2	6
Purple Orchid	2	-	3	5
Lagoon	1	-	3	4
Oyster Grey	2	1	-	3
Endive	1	-	1	2
Lipstick Red	-	2	-	2
Living Glow	1	-	-	1
Woodbine	-	1	-	1
Rose Dust	-	-	1	1

Table 1. Colour Choice for Hoodie

The reasons why they preferred dark colour over other colours are closely related to its usage and functions. To many informants, dark colours were perceived as "more versatile, get less dirty/don't have to wash them as much, slim their body, more flattering, more serious and mature" whereas bright colours were perceived as "more fun, make me happy, refreshing." The following excerpts present and illustrate informants' underlying motives of their colour preference and choice.

4.1 Body enhancement

"Definitely darks. I like any dark grey, navy, dark green. I don't really wear patterns. Dark colour is more flattering. … I like to complement my body. It's how I would choose my outfits." [P7]

4.2 Versatility

"Usually neutral colors. I like black and grays Because they go with everything and they're easy to match up and you can wear something colorful underneath." [P15]

"Well it was very hard to make this choice but Grey [first choice] because it's my thing, and then Navy because it's just that comforting, soothing color, and I don't know if it's actually a neutral in terms of fashion but it's like that blue jean, everyday kind of thing." [P3]

4.3 Practicality and ease of care

"Because I like wearing dark colors rather than bright colors. … They get less dirty. … you don't have to wash them as much. And I think I look better in darker colors personally." [P9]

4.4 Maturity

"Dark colours go with everything. They look more mature as a hoodie. They're not so kid-ish. I always think of hoodies as something a younger person would wear and if I were to wear it in purple or bright pink I might be taken as a little immature. And when you're tinier to wear a lot of brights you look childish. So I think black and navy and grey are more serious or mature colors." [P12]

According to our study, many informants perceived hoodie as casual, relax, and immature. Regardless of individual's perceptions and preferences, all the informants liked hoodie because of its comfort factor. The vast majority of the informants (n=13) wore hoodie all year round in various social settings including home, workplace, gym and school. It is evident that people selected dark colour to meet their functional, practical and psychological needs. In addition, many informants found bright colours such as Living Coral and Purple Orchid were fun, youthful and fresh. Without a doubt, colour can generate different emotional and psychological meanings and benefits to both consumers and viewers.

REFERENCES

Chu, A., Rahman, O. and Mandal, S. 2011. A cross-cultural study of the relationships between colours and products. *International Colour Association (AIC) Conference*, Zurich, Switzerland, 342-347.

Cova, B., Kozinets, R.V. and Shankar, A. 2007. *Consumer Tribes*. Oxford: Elsevier.

Creusen, M.E.H. and Schoormans, J.P.L. 2005. The different roles of product appearance in consumer choice. *The Journal of Product Innovation Management* 22(1): 63-81.

Holmes, C.B. and Buchanan, J. 1984. Color preference as a function of the object described. *Bulletin of the Psychonomic Society* 22: 423-425.

McCracken, G. 1988. *The Long Interview: Qualitative Research Methods*. Thousand Oaks, London: Sage Publications.

Rahman, O., Yan, J. and Liu, W.-S. 2010. Evaluative criteria of denim jeans: A cross-national study of functional and aesthetic aspects. *The Design Journal*, 13(3): 291-311.

Whitfield, A. and Wiltshire, T. 1983. Color. In: *Industrial Design in Engineering*, Charles H. Flurscheim (ed.). Worcester, UK: The Design Council, 133-157.

Wilska, Terhi-Anna 2002. Me - a consumer? Consumption, identities and lifestyles in today's Finland, *ACTA Sociologia*.

poster

Analysis on the emotional reaction differences considering visual characteristics of normal sighted persons and weak-sighted persons

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ABSTRACT

Our eyes not only deliver original forms of objects, but they help us perceive social relations between me and objects from designs. in this study, following experiment was executed in order to identify differences in environment perception by normal-sighted persons and weak-sighted persons(color vision of color blind and old person). As the result of the experiment, compare to normal person sight who naturally recognize the environments the most, it was shown that red green blindness recognize those simply. Especially for the case of old person, general feeling of sensitivity differences are quite big. Through such studies, indiscriminative designs that allow same impressions and communications regardless of physical handicaps and that bring reasonable bond of sympathy with understanding and amalgamation will be created.

1. INTRODUCTION

In 20th century, design was normal one which didn't comply with users demands because of simple uniform design from mass production. But , in the 21st century, universal design which is value structure for multiple people emerged as a new design for realization of well being society has been spread out.

To comply with this trend, many studies are increasingly being regard universal design principle and application guide lines. But, it is still necessary to continue to work to set up plans that consider the weak positioned people who have disadvantages because things are being done by the intention of the planners. For this purpose, standing in the weak positioned people and understand the feelings of theirs, have to understand the distinction from normal people. Our eyes not only transfer the images of shapes themselves but also help to understand the relationship between objects social relations. Thus, ‘cannot see clearly’ can be an obstacle for normal living.

Therefore, this study is to understand the differences in sensitivities of awareness of objects between normal people and people with weak optical sight.

2. EXPERIMENT METHOD

In this study, to understand the differences of environmental recognition of optical abnormality and to compare normal-sighted persons, the real images between color blindness people(red-green color blindness and yellow-blue blindness) and old people has been simulated then evaluate the images. To making evaluation images used 'Vischeck simulation program' for color blindness people and 'Cambridge Vision Impairment Simulator' for old people.

The target of evaluation was limited in environments composed of nature, artificial elements and Korea as for space wise. 8 images were selected according to the purpose of the study and 32 target of evaluation were made by using simulation programs.

The evaluation method was that subject describes each evaluation adjectives by looking at evaluation images. 21 subjects participated in the experiments. They were accepted as color normal due to their previous record and experience in color evaluation. Such evaluation adjectives included words that allow evaluation of potency and activity. The rating scale presented 7-steps SD method with 12-pairs of adjectives.

3. RESULT

To get the accuracy and precision of the evaluation adjectives, the results of the reliability analysis using the coefficient of Crombach's alpha was 0.829 for all items. And the overall evaluation was acceptable as every variable coefficient was over the range of 0.79~0.86.

Table 1. The result of reliability analysis

The coefficient of Crombach's Alpha			**.829**
Evaluation Item	**Cronbach's Alpha if Item Deleted**	**Evaluation Item**	**Cronbach's Alpha if Item Deleted**
Bright - Dark	.809	Diversified - Monotonous	.802
Warm - Cool	.841	Fancy - Plain	.807
Clear - Blur	.808	Opened - Closed	.801
Natural - Awkward	.822	Vigorous - Calm	.797
Active - Steady	.800	Arrange - Scattered	.863
Complex - Simple	.816	Strong - Subdued	.812

When 'warm-cool' and 'arrange-scattered' were removed from evaluation adjectives, since the coefficient was analyzed higher. So the analysis process was advance with removal of those.

After removing two pairs through reliability analysis, factor analysis was conducted to understand the sensitivity evaluation structure of the evaluation target.

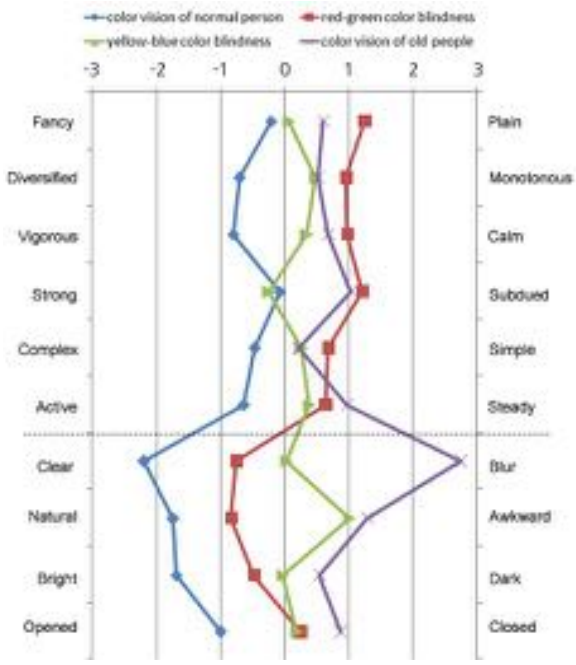
Divided into two main factors, overall explanation number was analyzed as 72.39%. The first factor was named as “ Activity’ with contribution rate f 45.594 . The second factor was names as “Potency” with contribution of 26.796.

Table 2. The result of Factor analysis

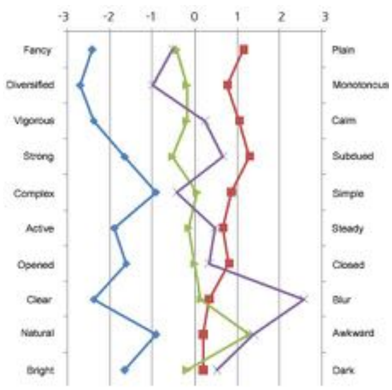
Factor	**Evaluation adjectives**	**Component**		**Extraction**	**Factor Interpretation**
		I	II		
I	Fancy - Plain	.918	.029	.843	Activity
	Diversified - Monotonous	.862	.150	.765	
	Vigorous - Calm	.846	.276	.791	
	Strong - Subdued	.819	.067	.676	
	Complex - Simple	.809	.067	.655	
	Active - Steady	.779	.010	.700	
II	Opened - Closed	.503	.600	.613	Potency
	Clear - Blur	.143	.866	.771	

Natural - Awkward	-.099	.863	.755
Bright - Dark	.209	.792	.671
Eigenvalue	4.559	2.680	
Proportion(%)	45.594	26.796	
Cumulative(%)	45.594	72.390	

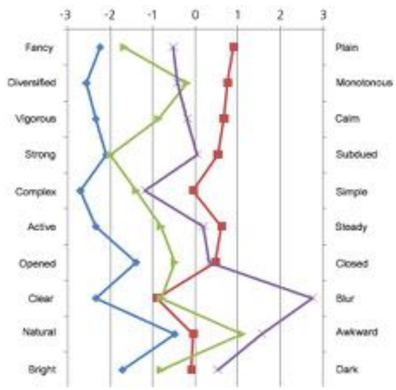
The profile analysis from technical statistics regarding evaluation items of images is followed: Show not much of difference in evaluation words of first cause in cause, it was analyzed that the average value is centered. As for the general tendency, Normal person > Yellow-blue color blindness > old people > Red Green Color blindness, generally evaluated leaning towards right. But in the case of types A, D, G, the big differences of average values were observed per each optical characteristics. Showed quite a difference in evaluation words of second cause. Optical evaluation of the normal person is positioned the right most and that of the old person the left most. And, Red Green color blindness and Yellow blue color blindness are centered.



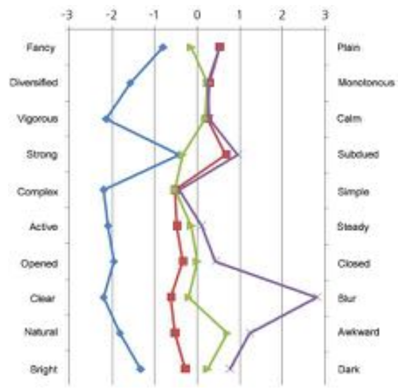
- profile graph of the whole



- profile graph of type A



- profile graph of type D



- profile graph of type G

Figure 2. The result of profile analysis

Based on the factor analysis selected as representative 'diversified– monotonous' word pair in first factor and 'natural – awkward' word pair in second factor. Then the graph plotted by factor scores.

On the plotted graph, diversity image was highly evaluated for normal person sight in types A, D, G. Monotonous image was highly evaluated for red green color blindness in types B, E, F. For normal person sight, types F and H were evaluated as the most natural and all evaluation subject were awkward images for old person.

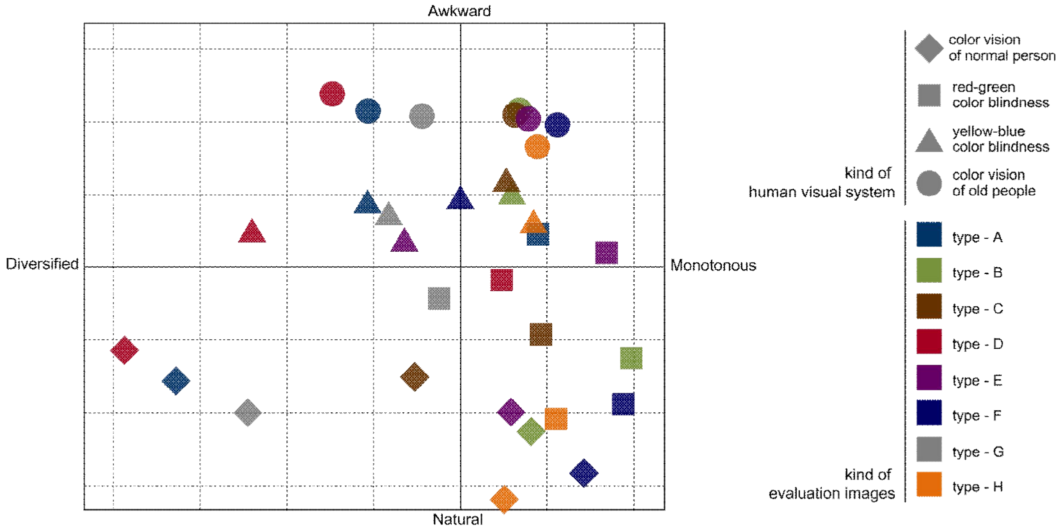


Figure 2. The plotted graph by factor scores

4. DISCUSSIONS

As for the result of the experiment, compare to normal person sight who naturally recognize the environments the most, it was shown that red green blindness recognize those simply. Also, because there more sensitivity difference of optic changes in environments where many colors are used rather than in environment of simple color structure. Especially for the case of old person, general feeling of sensitivity differences are quite big, consideration should be done for old person.

It is necessary to have continuous studies from various aspects are required to accomplish the design with which there will be no difficulties in communication among either handicapped or not and which provides no differences, discrimination and understanding and consolidation are possible.

REFERENCES

Mark D. Fairchild, 2005, Color Appearence Models (Second Edition), England:John Wiley & Sons, Ltd
Roy S. Berns(translator; Cho, Maeng-Sub), 2003, *Principles of color technology*, Korea:Sigma Press

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Depth Control Algorithm using Object Color and Depth Characteristics

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ABSTRACT

In this study, a 3D image processing method of improving the visual sense of depth in line with the human visual perception characteristics was developed. Some of the visual processes that occur in human visual perception were reproduced to estimate the interest area that would correspond to the visual selective attention through the visual attention factor, the depth was translated on the basis of the interest area, and the image quality was enhanced in tune with the 3D image characteristics. In this way, the perceptive sense of depth can be improved and fatigue can be decreased when watching a 3D display. The method developed in this study differs from other proposed methods in that the depth associated with visual selective attention was compromised while the relative sense of depth was maintained by focusing on the fact that the visual sense of depth is relative, rather than absolute. Thus, the method proposed in this study is more satisfactory in terms of human visual perception and more effectively reduces visual fatigue and enhances the sense of three dimensions.

1. INTRODUCTION

Visual fatigue is a major issue with 3D displays, is closely related to the sense of depth. The greater the sense of depth is, the more visual fatigue occurs. Although many methods of addressing visual fatigue in 3D displays and improving satisfaction with the sense of depth have been proposed, no methods of simultaneously reducing visual fatigue and improving satisfaction with the sense of depth have been proposed. One solution to the visual fatigue problem is to readjust the sense of depth of 3D images for lower visual fatigue; but although this method can decrease visual fatigue, the sense of depth via the human vision declines as the sense of depth cannot be adaptively controlled in tune with the characteristics of the inputted 3D images.

In this study, based on the theories of Livingstone and Hubel, the colors, shapes, motions, and depth that are used in the visual process in the brain were assumed as the basis for theoretical modeling that corresponds to selective visual attention. (Livingstone 1987). Among them, color information, which has great influence on human visual perception in static images (Theeuwes 1992), and sense of depth information, which is a differentiator of 3D displays, were selected as stimulants. Based on these two selected stimulants, color and the sense of depth, the effects of visual attention according to the perception factors of visual fatigue in a 3D image environment and the improvement of the sense of three dimensions were examined. Furthermore, an algorithm for improving the perceptive sense of depth and reducing visual fatigue based on selective visual attention was developed to reproduce images that give a sense of depth and a sense of three dimensions while reducing visual fatigue.

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2. ALGORITHM STRUCTURE

Based on the theories of visual attention, the designed technical algorithm for the reduction of visual fatigue and the enhancement of the sense of three dimensions is described as follows. A visual attention map that is adaptive to inputted 3D images was created on a 3D display on the basis of visual attention to certain human visual perception characteristics. The depth was readjusted on the basis of the interest area that was predicted with the visual attention map to improve or maintain the sense of three dimensions while reducing visual fatigue.

Figure 1. Flowchart of the algorithm

The technology for reducing visual fatigue and enhancing the sense of three dimensions that was developed in this study largely consists of the construction of a visual attention map, disparity readjustment, and the creation of a 3D image with the application of the optimum depth. Among these components, the construction of a visual attention map divides the area into 1 to N using the depth information that represents the sense of depth when the disparity information, which represents the color information and depth of the 3D images, is inputted. The weight value of the pixel depth is applied differently to each area that has been divided by depth, and is used to complete the visual attention map that corresponds to the selection visual attention. For color information, R, G, and B are converted, based on the pixel value of the input image, into the J (lightness), C (chroma), and h (hue quadrature) of CIECAM02, which is most similar to the human visual perception or to other color spaces such as L, C, and H. The J, C, and h of CIECAM02 that have been converted from the R, G, and B of the input image refer to the lightness, chroma, and hue values, respectively. The aforementioned color spaces for the input image are the RGB digital signals that are not associated with the human visual system. Thus, human perception characteristics such as lightness, chroma, and hue can be used as the final outputs of the human visual system. The pixels that have the specified color property values are given a weight because they are regarded as having selective visual attention. For example, it is determined if the value that corresponds to J is equal to or higher than the perceivable value, and a weight is applied to the value that is found to be perceivable. As with J, different weights are applied to the C and h values that corresponds to the specified thresholds to which selective visual attention is applied. Through this method, the pixels that correspond to each characteristic that is given selective visual attention have greater weights than other pixels, and the values calculated for each pixel are summed up in the Visual Attention Map Unit, after which the visual attention map is constructed.

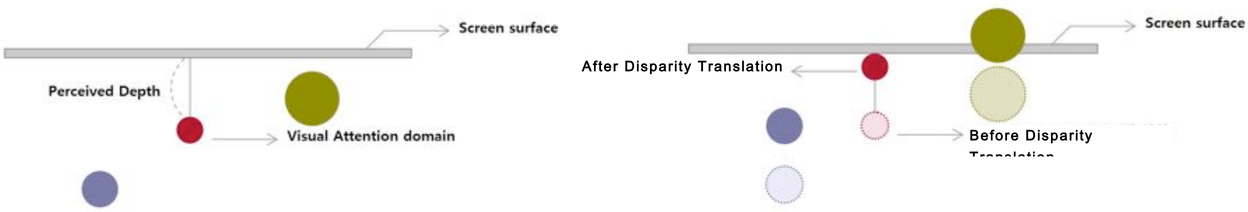

Figure 2. Before the disparity adjustment (Left) and after the disparity adjustment (Right) in the 3D Image Creation Unit

The Disparity Readjustment Unit plays the role of deciding on the representative value so that disparity can be readjusted using the disparity of the completed visual attention map. There are many methods of setting the representative value for readjustment, but in this study, the disparity was divided into sections and the value of the disparity section to which the greatest number of pixels that correspond to the visual attention map belongs and the representative value were set. That is, the representative disparity value was determined on the basis of the disparity area to which the greatest number of pixels that corresponded to the visual attention map belonged. The disparity representative value α is used to move the depth of all the inputted 3D images. The final disparity value is applied to each pixel, the pixels that correspond to the interest area are positioned on the display, and the other pixels are moved on the basis of the representative disparity value α in the interest area. The 3D Image Creation Unit plays the role of rendering again the 3D images with disparity values that differ from those of the input images through the changed disparity values after the disparity readjustment.

3. PHYCHOPHYSICAL EXPERIMENT

The changes in the visual fatigue and satisfaction of the sense of three dimensions from those with the original images via the application of the algorithm that controls the sense of depth in 3D displays were investigated using the aforementioned color and depth information that corresponded to the visual attention in the human visual information processing process. Besides the color and depth information, another core element of visual attention is motion; but in this study, color which is a controllable limited condition, and disparity, which is the sense of depth needed to determine the tendency, were used.

To evaluate the results of this study, 11 Middlebury stereo data set images were used. The static 3D images were toggled to compare the original images and the algorithm-applied images, after which relative evaluations were conducted. The algorithm-applied images and the original images were mixed randomly, and the subjects were asked to evaluate each image with respect to visual fatigue and satisfaction of the sense of three dimensions on a scale of 1-5 points. For the display, a glass-type 40-inch dual LCD stereo display (3D resolution: full HD) was used, and 10 subjects were asked to evaluate the images at the visual distance of 1 m.

The results of the experiment are as follows. The visual fatigue of the images to which the algorithm for the reduction of visual fatigue and the enhancement of the sense of three dimensions was applied decreased by about 20%, and the satisfaction of the sense of three dimensions improved by about 4% from that with the original images. The visual fatigue results of the experiment with adaptive adjustment of the sense of depth of the interest objects according to the visual attention were significant because the original images and the algorithm-applied images in most of the error bar graphs did not overlap. Furthermore, the satisfaction of the sense of three dimensions increased as the visual fatigue decreased. The following graph shows the improved sense of three dimensions according to the reduced visual fatigue in the images to which the algorithm for the reduction of visual fatigue and the enhancement of the sense of three dimensions was applied, in comparison to the original images.

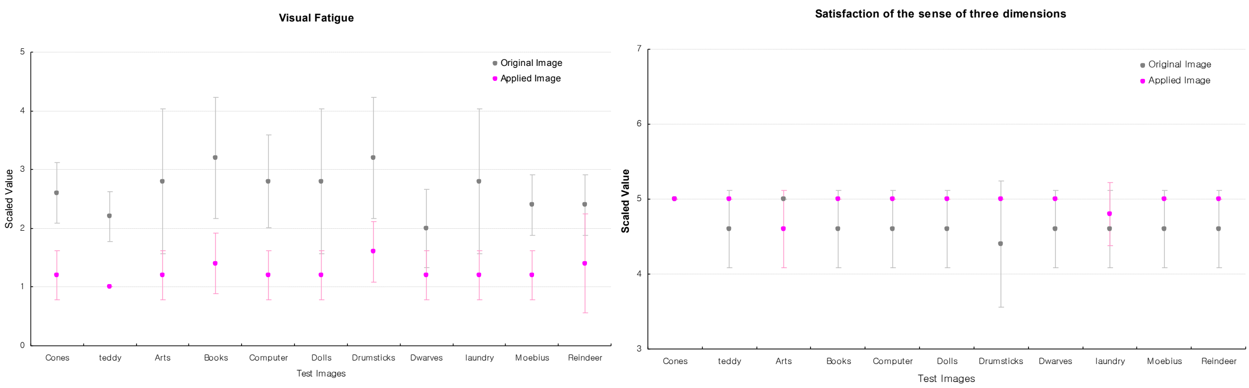

Figure 3. Graph of the visual fatigue experiment results (Left) and the experiment results for the sense of three dimensions (Right)

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4. CONCLUSION

Some of the visual processes that occur in human visual perception were reproduced to estimate the interest area that corresponded to the selective visual attention through the visual attention factor, and the sense of depth was readjusted by considering the characteristics of the interest area of the input images and the characteristics of human visual perception. In this way, the perceptive sense of depth can be improved and fatigue can be decreased when watching a 3D display. The method developed in this study differs from other proposed methods in that the depth associated with selective visual attention was compromised while the relative sense of depth was maintained by focusing on the fact that the visual sense of depth is relative, rather than absolute. Thus, the method developed in this study is more satisfactory in terms of human visual perception and more effectively reduces visual fatigue and enhances the sense of three dimensions.

ACKNOWLEDGMENTS

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REFERENCES

Livingstone, M. S., Hubel, D. H. 1987. Psychophysical Evidence for Separate Channels for the Perception of Form, Color, Movement, and Depth. Journal of Neuroscience. 3416-3468.

Theeuwes, J. 1992. Perceptual selectivity for color and form. Perception & Psychophysics, 51,599-606.

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Study of an acceptable color-difference formula for printed documents on white paper

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ABSTRACT

CIE recommends the CIEDE2000 formula for industrial color difference evaluation. This formula was developed based on the evaluations using samples with small to medium color differences on the background of Munsell N5 gray. However, in the case of evaluations of printed documents on white paper, we can not use this formula as it is, since the evaluation conditions differ from each other. In this paper, we report that we conducted the evaluations of accepatable color difference using printed documents on the background of plain white paper and developed a color-difference formula for printed documents based on CIEDE2000. We also report the comparison results of performance between CIEDE2000 and our developed formula.

1. INTRODUCTION

The values of color difference ΔE^*_{ab} in the uniform color space CIELAB (CIE1976)(Robertson 1977) are known not to correspond to the visual color difference in some cases. In order to improve the agreement with the visual differences, several color-difference formulas have been developed by modifying ΔE^*_{ab}. In 2001, the CIE recommended the CIEDE2000 formula (Luo et al. 2001) because of the good agreement between the calculation results and the visual differences. However, we cannot apply it for the evaluations of the acceptable color difference with white paper background, because it was developed based on the color difference evaluations using Munsell N5 gray background. Therefore, we tried developing an acceptable color-difference formula of printed documents on white paper correlating with visual impressions and we conducted the visual experiments on acceptable color-difference using color difference sets which have color differences for each of three color components of lightness, chroma, and hue. We found that the acceptable color difference of each component has different tendencies. Then, we propose a formula for acceptable color difference based on the CIEDE2000 formula, which can predict the results for each of the three components.

2. EXPERIMENTS

The experiments were conducted under fluorescent lamps (illuminant D_{50}, color rendering AAA) resulting 500lx at the color samples and PPC - Plain Paper Copier - paper (Fuji Xerox C^2, ISO brightness:84%) was used as a background. The size of each color patch was 20 x 20 mm. We made each color patch by changing colors at regular intervals towards one of the directions of each of the three components and showed the sample sets which were placed in line and spaced 5 mm apart to observers. Twenty observers were male and female, ranging in age from 20 to 50 years with normal color vision. The hue of color samples adopted for each of the component evaluations were from ISO 12641 (IT8.7/1), which are twelve hue angles (h^*:16, 41, 67, 92, 119, 161, 190, 229, 274, 299, 325, 350). The details of our color samples are listed in Table 1. Also, we showed the examples of color samples of lightness difference evaluations in Figure 1. We asked observers to select the acceptable color patch number. When number 0 was the standard for example, we asked them to choose which color can be accepted even if they feel the color difference. If their acceptable color was between the patches, we allowed them to answer in 0.5 increments.

Table 1. Experiment Sample Detail

	Chroma	Lightness	Hue
Hue (h^*)	12 hue	12 hue	12 hue
Lightness (L^*)	High (75-55), Middle (45-35)	High (75-55), Middle (45-35)	57.5, 40
Chroma (C^*)	Neutral - Max	Middle	10, 20, 40
Interval of Color difference	ΔC^*:3	ΔL^*:3	ΔE^*_{ab}:2

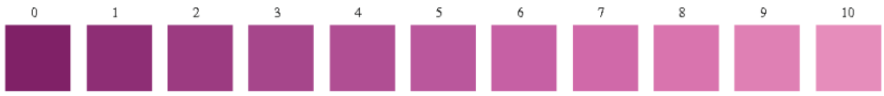

Figure 1. Experiment Sample Example

3. RESULTS

3.1 Chroma difference evaluation

In the chroma difference evaluation, we prepared sample sets whose the first patch (number 0) was the maximum chroma of the hue and the lightness in the KYOCERA printer gamut and the last patch was C^*=0. Then we conducted the acceptable evaluations towards both increasing and decreasing chroma. We evaluated acceptable difference towards low chroma as a standard of the first patch and towards high chroma as a standard of the last patch and towards high and low chroma as a standard of the middle patch. We show the results in Figure 2(a) in which the horizontal axis indicates C^* of the standard patch and the vertical axis indicates acceptable color difference $|\Delta C^*|$ and the solid line indicates the average and the dashed line indicates the standard deviation $\pm\sigma$. From these results, we found that the allowance is wider as the standard chroma is higher and $|\Delta C^*|$ is about a sixth part of C^*. Also in the figure, marks ◆ and ■ indicate acceptability towards low and high chroma respectively, and we found that color difference toward high chroma tended to be accepted a little more as the same standard chroma.

3.2 Lightness difference evaluation

In the lightness difference evaluation, chroma for sample sets were middle chroma between maximum and minimum at each hue and lightness. The range of lightness used for sets was within the gamut of our printer. We evaluated the acceptability toward decreased lightness from maximum lightness and toward increased lightness from minimum lightness. Figure 2(b) shows the results. The horizontal axis indicates L^* of the standard patch and the vertical axis indicates the acceptable color difference $|\Delta L^*|$, the solid line indicates the average and the dashed line indicates the standard deviation $\pm\sigma$. As shown in this Figure, the acceptability was smaller as L^* of the standard patch was higher. This is thought to be related to the

Crispening effect (Takasaki 1977) due to the white paper background. There was no difference in acceptability between increased and decreased lightness in lightness variation.

3.3 Hue difference evaluation

In the hue evaluation, we surveyed the acceptability of the hue difference when the hue was rotated both clockwise and counterclockwise. We show the results in Figure 2(c) at L^*:57.5, C^*:20. The figure shows independency on the standard hue angle and almost constant acceptable hue difference. We also cannot see much difference in the clockwise and counterclockwise rotation. The error bar of Figure 2(c) shows the standard deviation $\pm\sigma$ and the variation among individuals was bigger than other color components in the hue difference evaluation.

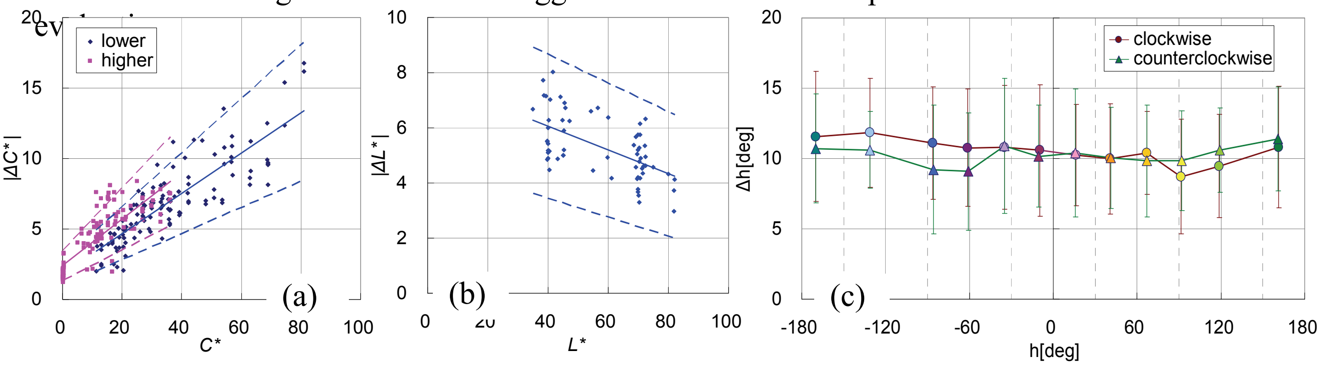

Figure 2. Acceptable differences

4. DEVELOPMENT OF A COLOR DIFFERENCE FORMULA OF PRINTED PAPER

We derived the new color-difference formula based on the CIEDE2000 formula, which can predict the results in Figure 2. The CIEDE2000 formula is shown below.

$$< CIEDE\ 2000 > \quad \Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{k_C S_C}\right)\left(\frac{\Delta H'}{k_H S_H}\right)}$$

$$L' = L^*, \quad a' = (1+G)a^*, \quad b' = b^*, \qquad G = 0.5\left(1 - \sqrt{\frac{\overline{C^*_{ab}}^7}{\overline{C^*_{ab}}^7 + 25^7}}\right)$$

$$S_L = 1 + \frac{0.015\left(\overline{L'} - 50\right)^2}{\sqrt{20 + \left(\overline{L'} - 50\right)^2}}, \quad S_C = 1 + 0.045\overline{C'}, \quad S_H = 1 + 0.015\overline{C'}T, \quad R_T = -\sin(2\Delta\theta)R_C$$

$$T = 1 - 0.17\cos(\overline{h'} - 30°) + 0.24\cos(2\overline{h'}) + 0.32\cos(3\overline{h'} + 6°) - 0.20\cos(4\overline{h'} - 63°)$$

$$\Delta\theta = 30\exp\left\{-\left[\left(\overline{h'} - 275\right)/25\right]^2\right\}, \quad R_C = 2\sqrt{\frac{\overline{C'}^7}{\overline{C'}^7 + 25^7}}$$

$$< new\ formula > \quad \Delta E'_{00} = \sqrt{\left(\frac{\Delta L'}{S_L}\right)^2 + \left(\frac{\Delta C'}{S_C}\right)^2 + \left(\frac{\Delta H'}{S_H}\right)^2}$$

$$S_L = 1 + \frac{0.015\left(\overline{L'} - 94.5\right)^2}{\sqrt{20 + \left(\overline{L'} - 94.5\right)^2}}, \quad S_C = 1 + 0.045\overline{C'}, \quad S_H = 1 + 0.015\overline{C'}$$

In the new formula $\Delta E'_{00}$, we modified the S_L coefficient 50 in the ΔE_{00} to white paper lightness 94.5 in consideration of the Crispening effect of the white paper background. We also

modified R_T=0, T=1, G=0, because we cannot see the dependence on hue angle in hue evaluations.
We show the prediction in $\Delta E'_{00}$ (solid line) and ΔE_{00} (dashed line) in Figure 3 : (a) Chroma, (b) Lightness, (c) Hue difference evaluation. From these results, we can summarize that the acceptability limit of color difference in each of the components is about 3 in this new formula and $\Delta E'_{00}$ over 3 can not be accepted. On the other hand, the acceptability limit of color difference in each component is not equal in the ΔE_{00}. Therefore, we find that our formula outperformed the ΔE_{00} in the evaluations of printed documents on the white background in terms of the agreement between predictions and visual impressions.

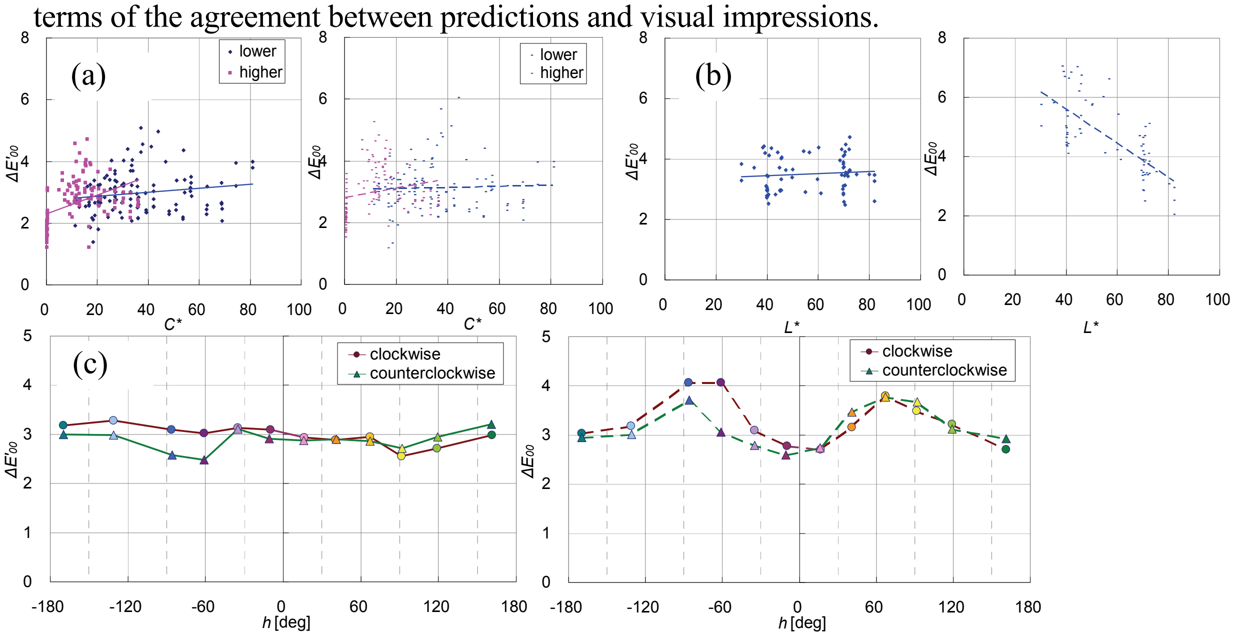

Figure 3. Comparison with CIEDE2000 and our formula

5. CONCLUSION

We developed the acceptable color-difference formula suited for evaluations of printed documents on the white background. We could attain good results by excluding the terms related to dependency on hue angle and modifying the lightness function coefficient to the white paper lightness value in the CIEDE2000 formula.

REFERENCES

Luo, M.R., G. Cui and B. Rigg. 2001. The development of the CIE 2000 colour-difference formula : CIEDE2000. *Color Research & Application* 26: 340-350

Robertson, A.R. 1977. The CIE 1976 Color-Difference Formulae. *Color Research & Application* 2: 7-11

Takasaki, H. 1966. Lightness Change of Grays Induced by Change in Reflectance of Gray Background.
Journal of the Optical Society of America 56: 504-509

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An Augmented Method of Skin Color on Multi-primary Display

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ABSTRACT

Recent years, with the development of multi-primary displays, skin colors also play an important role in color reproduction. This study investigates an augmented method of skin color on multi-primary display based on a psychophysical experiment. We examined six skin colors of different ethnicities. Modified skin colors with different expanding ratio were evaluated by comparison with original skin color. Our results showed that an expanding ratio suit for Asian was lower compared with that for Caucasian and Negroid. Corrected expanding ratio appropriate for skin color types would be necessary for a better display.

1. INTRODUCTION

Recent years, with popularity and advances in the development of multi-primary technology, the reproduction of colors in multi-primary display becomes more and more important.

Cheng et al. (2010) have developed two five-primary methods. The one uses the same (CCFL) backlight without losing any brightness, and it reached its best gamut more than 90% NTSC and increased 26% in luminance. Other attempts are to adjust the color orders and ratio of backlight, it provided excellent color reproduction when the color gamut reached to 140% NTSC and increased 13% in luminance.

We developed a six-primary method to improve the color reproduction, and realized a wider color gamut (Sun et al., 2008). However, we found a problem that skin was represented too reddish. Besides, it was reported that the color tolerance of skin was smaller than the others. (Katsumata et al. 2011). The main propose of this study is to propose an augmented method of skin color on six-primary display based on a psychophysical experiment.

2. SIX-PRIMARY METHODS

Here, we explain our six-primary display method. We provided a six-primary LCD transformation, which realized the wide gamut in xvYCC (709) color space. (Sun et al., 2008) This six-primary display was regarded as a combination of a RGB display and a CMY display. The chromaticity coordinates of the white point of both RGB and CMY corresponded to that of D65, but the luminance ratio of the RGB and the CMY white points were 1:1.5. The expanding ratios in CMY were 1.4, 1.2 and 1.1, respectively. Then we derived an adjustable regression-based method to generate six-primary color signals on 5 different brightness levels, and reached its best display gamut. The mean and maximum CIEDE2000 color differences between target xvYCC (709) color space and the proposed method were about 0.8 and 5.9, respectively.

In order to transform the sRGB signals to six-primary signals smoothly, we also set up another algorithm to improve the whole efficiency (Sun, P.L, 2009).

We further expanded the whole gamut by changing the backlight into RGB LEDs (Chang, 2011), and the chromaticity coordinates of each primary color were R (0.700, 0.300), G (0.204, 0.728), B (0.152, 0.030), respectively. The white point we used was (0.313, 0.300) as same as AdobeRGB (1998).

Then we derived a sophisticated method, which divided L-C plane into four areas, where the lightness level of 50% and the chroma level of 50% was regarded as a center. As a result the luminance and chroma increased, but there was an over-enhancement in hue, especially in skin colors.

3. SKIN COLOR

It is known that image quality usually depends on skin colors when people are looking at a portrait or a picture with skin colors. This means that human eye has lower color tolerance to skin. Therefore, we try to derive a modified method to reduce the over-enhancement phenomenon of skin color when transferring into a multi-primary environment. A psychophysical experiment was performed to find expanding ratios maintaining natural skin color appearance.

We used the SOCS database to divide skin colors. It is a database of spectral reflectance, including six groups of skin color data from different ethnicities: Northern Asian (bare skin and make-up skin), Southern Asian (bared skin and make-up skin), Caucasian and Negroid. Based on the reflectance of each group, we calculated corresponding x and y chromaticity coordinates, as shown in Figure 1. The average of each group is shown by large symbols. We regarded those six average chromaticity coordinates as references representing skin colors of each ethnicity. Then we calculated corresponding RGB values, and made color chips for evaluation. We transferred those six values into a six-primary circumstance. Here, we prepared the range of expanding ratios from 1.1 to maximum 1.5, and performed a psychophysical experiment. Short lines in Figure 1 shows the shifts of skin colors with expanding ratios from 1.1 to 1.5.

A color patch with one of the original skin color and two test patches with modified skin colors were presented on an Eizo ColorEdge monitor. We tested two conditions. One was that color patches were presented on gray background of monitor size. The size of each patch was 10 x 8 cm (17 x 15 degrees in visual angle). The other was that each color patch was on a colorful mosaic background. In this condition, the size of each color patch was 6 x 6 cm (10 x 10 deg.) and it was surrounded by 1.5 cm color squares. It was simulated the skin colors under a natural scene with various colors. The color of the mosaic background for the original original was shown by triangle symbols, and that for test patch was set to the maximum expanding ratio as shown by square symbols in Figure 2. Observers judged which modified color was closer to the original color. Three observers participated.

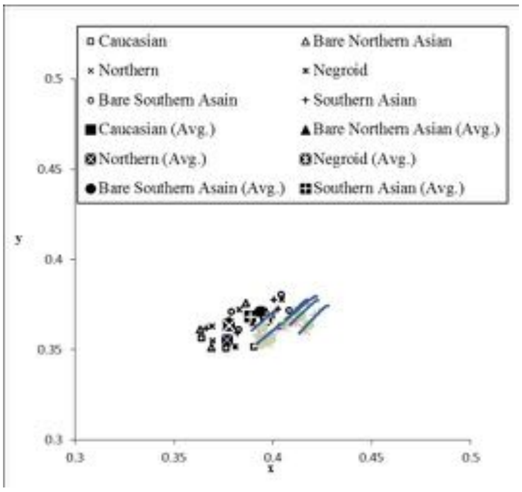

Figure 1 The distribution of skin colors

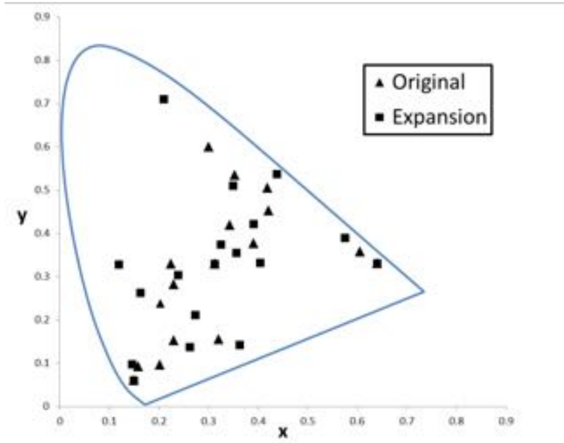

Figure 2 The distribution of square color chips in mosaic condition

4. Result

The results of psychophysical experiment are shown in Figure 3. The Z-score on ordinates indicates the degree of approaching to the original color. The higher Z-score means that the appearance of test skin color is closer to the original skin color. In the case of neutral background (blue bar), the expanding ratios showing the highest Z-score are around 1.2 for the bare and, make-up Northern Asian skin colors, around 1.3 for the bare and make-up Southern Asian, 1.5 for bare Caucasian, and 1.5 for bare Negroid. The results of mosaic background (red bar) have a similar tendency in Z-score distribution to those of neutral background. The results of mosaic shows the highest score in lower expanding ratio than those of normal, suggesting that appearance of skin color is affected by environmental color. Both Caucasian and the Southern Asian show lower Z-score, meaning smaller differences in appearance among expanding ratios. The results of bare and make-up skin in Northern Asian showed very different trends. All observers were Northern Asian people, thus it might have some influence of preferences of colors and memory colors on this result.

Our results showed that appropriate expanding ratio was different for skin color of different ethnicities. The expanding ratio suit for Asian was lower compared with Caucasian and Negroid. However, we tested the limited number of skin colors to, the limited number of Northern Asian observers. Therefore, further investigation is needed to determine parameters for an augmented method of skin color on six-primary display.

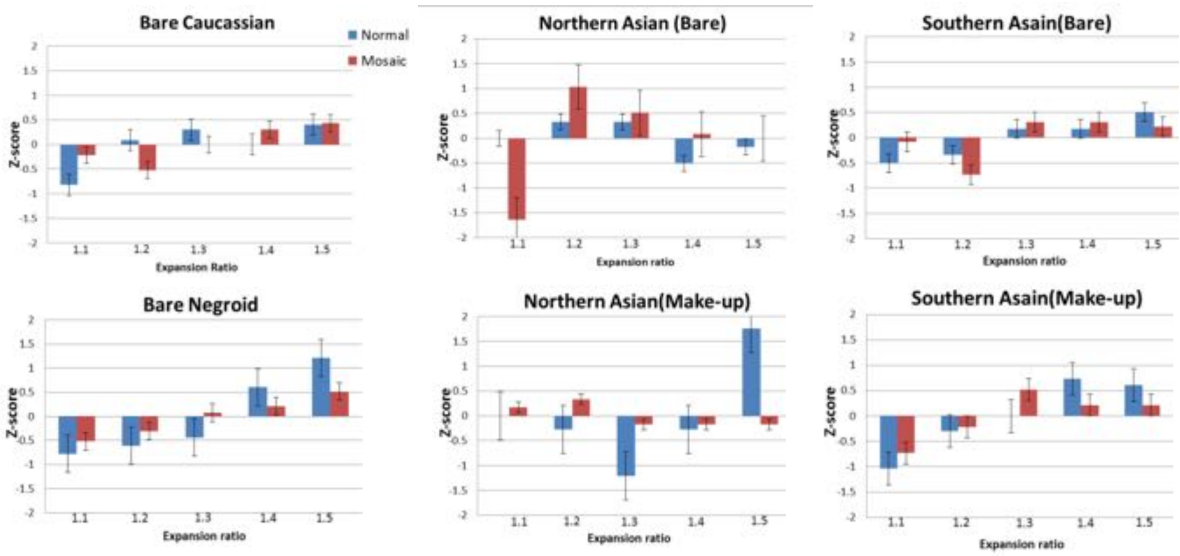

Figure 3 Result of psychophysical experiment

REFERENCE

Cheng, H. C., L. H. Rao., and S. T. Wu. 2010. Color Breakup Suppression in Field-Sequential Five-Primary-Color LCDs. *JOURNAL OF DISPLAY TECHNOLOGY* 6 (6): 229-234.

Cheng, H. C., I. B. David., and S. T. Wu. 2010. Five-Primary-Color LCDs. *JOURNAL OF DISPLAY TECHNOLOGY 6* (1): 3-7.

C. K, Chang. 2011. Enhancement methods in sRGB to six-primary LCD color space. *SPIE The 18th International Display Workshops*: 1307-1311

IEC, Multimedia systems and equipment - Colour measurement and management - Part 2-4: Colour management – Extended-gamut YCC colour space for video applications – xvYCC, 61966-2-4.

Katsumata, T., H. Yaguchi, Y. Mizokami. 2011. The color tolerance range of natural color image in L*a*b* color space, *Journal of the Color Science Association of Japan* 35: 8-9.

Luo, M. R., G. Cui., and B. Rigg. 2001. The development of the CIE 2000 colour-difference formula: CIEDE2000", *Color Research and Application*, 26(5): 340-350.

Sun, P. L., H. S. Chen., C. K. Chang. 2008. Six-primary LCD color separation for wide-gamut xvYCC images. *The 15th International Display Workshops*: 1425-1428

Tsai, C. C., C. C. Lai., and S. M. Hsieh. 2009. Wide color-gamut improvement of LCM using multi-phosphor white LED and modified rich color method. *IEEE Transactions on Consumer Electronics* 55(3): 1566-1571.

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Adaptive Estimation Method based on Colorimetry for Spectral Recovery

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ABSTRACT

Extensive work has been carried out on spectral information estimation methods for spectral-based colour reproduction systems. This paper proposes modifications to the Wiener estimation and Pseudo-inverse methods. The modification involved selecting the localised training samples and introducing a weighting factor. The weighting factor and the localised set were determined by four measures (ΔL^*, ΔC^*_{ab}, ΔH^*_{ab} or ΔE^*_{ab}) . The proposed methods were compared with the conventional Wiener estimation and pseudo-inverse methods. The results showed the two conventional methods were improved by using the weighting factor and the localised training samples.

1. INTRODUCTION

Spectral reflectance is an important property of a surface which enables device- and illuminate-independent colour information. Extensive work has been carried out on spectral information estimation methods for spectral-based colour reproduction systems. Most of these methods are learning-based algorithms. Their performance are highly dependent on the training samples which are used to derive the algorithms. For example, Shen e*t al.* (2007) adaptively select training samples for the autocorrelation matrix calculation in Wiener estimation (WE). In their study, the reflectance spectra of the training samples have similar profiles to that of the testing samples. Babaei, Amirshahi and Agahian (2009, 2011) adopted a weighting factor determined by the ΔE^*_{ab} between training and testing sample sets for the Wiener estimation and pseudo-inverse (PI) method. This paper proposes a new method using a weighting factor and an adaptive training sample set in which the training samples were determined by ΔL^*, ΔC^*_{ab}, ΔH^*_{ab} or $\Delta E^*_{ab.}$

2. METHOD

The relationship between tristimulus values and spectral reflectance of most of the surfaces can be represented by

$$\boldsymbol{O} = \boldsymbol{MP} \tag{1}$$

where $\boldsymbol{O}$ is an $3 \times k$ matrix with each column vector relates to XYZ tristimulus values of each samples; $\boldsymbol{P}$ is an $31 \times k$ matrix of k reflectance functions ranged from 400 to 700nm at 10 nm intervals; $\boldsymbol{M}$ is a 3×31 matrix with each column contains the wavelength by wavelength product of the spectral power distribution of the illuminant and colour matching function of the CIE standard observer. In reflectance recovery *RGB* camera systems are commonly employed and, therefore, reflectance functions $\boldsymbol{P}$ are desired to estimate from $\boldsymbol{O}$ and a matrix $\boldsymbol{W}$ applied to transfer the camera response to reflectance functions should be determined. Once, the matrix $\boldsymbol{W}$ is obtained, the reflectance can be reconstructed by

$$\boldsymbol{P} = \boldsymbol{WO} \tag{2}$$

where $\boldsymbol{W}$ is an 31 × 3 matrix which maps the tristimulus values to spectral reflectance. The linear system in Equation 2 is met by adopting a learning-based procedure in which a training set is used for building a relationship $\boldsymbol{W}$ between the sensor responses matrix $\boldsymbol{O}$ and the reflectance matrix $\boldsymbol{P}$. If $\boldsymbol{O}$ was a full-rank square matrix, $\boldsymbol{W}$ could simply be acquired by inverse matrix $\boldsymbol{O}^{-1}$ of $\boldsymbol{O}$. However, since often $\boldsymbol{O}$ is not a square matrix, the pseudo-inverse (PI) of matrix $\boldsymbol{O}$ which is a generalisation of the inverse matrix should be adopted.

$$\boldsymbol{W}=\boldsymbol{W}_{PI}= \boldsymbol{P}\,\boldsymbol{O}^{+} \tag{3}$$

where $\boldsymbol{W}_{PI}$ represent the matrix $\boldsymbol{W}$ derived by pseudo-inverse estimation; $\boldsymbol{O}^{+}$ is the pseudo-inverse of matrix $\boldsymbol{O}$.

Another approach to find the matrix $\boldsymbol{W}$ is called Wiener estimation (WE). The matrix $\boldsymbol{W}$ in Equation 2 can be derived as:

$$\boldsymbol{W} = \boldsymbol{W}_{\boldsymbol{WE}} = \boldsymbol{K}_{\boldsymbol{r}}\boldsymbol{M}^{T}(\boldsymbol{M}\boldsymbol{K}_{\boldsymbol{r}}\boldsymbol{M}^{T} + \boldsymbol{K}_{\boldsymbol{n}})^{-1}, \text{ where } \boldsymbol{K}_{\boldsymbol{r}} = \text{cov}(\boldsymbol{P}) \tag{4}$$

where $\boldsymbol{W}_{\boldsymbol{WE}}$ represent the matrix **W** derived by Wiener estimation; $\boldsymbol{K}_{\boldsymbol{r}}$ denotes the covariance matrix of reflectance from training set; $\boldsymbol{K}_{\boldsymbol{n}}$ is the covariance matrix of noise. If the noise of different channels is independent, the $\boldsymbol{K}_{\boldsymbol{n}}$ is a diagonal matrix.

In order to improve the accuracy of the reflectance recovery approaches, a weighting matrix was induced as suggested by Babaei, Amirshahi and Agahian (2009, 2011).

$$\boldsymbol{Q}_{\boldsymbol{w}} = \begin{bmatrix} w_1 & 0 & \cdots & 0 \\ 0 & w_2 & 0 & \vdots \\ \vdots & 0 & \ddots & 0 \\ 0 & \cdots & 0 & w_k \end{bmatrix}_{k\times k}, \text{ where } w_k = \frac{1}{f_k} \text{ and } f_k = \Delta L^*, \Delta C^*_{ab}, \Delta H^*_{ab} \text{ or } \Delta E^*_{ab} \tag{5}$$

where $\boldsymbol{Q}_{w}$ is a square and diagonal matrix. The diagonal entries w_k in $\boldsymbol{Q}_{w}$ are the inverse of colorimetric difference f_k between the k_{th} sample in the training set and the target sample which its reconstruction is aimed. The colorimetric difference f_k was determined by four measures in turns, ΔL^*, ΔC^*_{ab}, ΔH^*_{ab} and ΔE^*_{ab} . Then, Equations 3 and 4 become:

$$\boldsymbol{W}_{wPI}= \boldsymbol{P} \cdot \boldsymbol{Q}_{w} \cdot (\boldsymbol{O} \cdot \boldsymbol{Q}_{w})^{+} \tag{6}$$

$$\boldsymbol{W}_{\boldsymbol{wWE}} = \boldsymbol{K}_{\boldsymbol{rw}}\boldsymbol{M}^{T}(\boldsymbol{M}\boldsymbol{K}_{\boldsymbol{rw}}\boldsymbol{M}^{T} + \boldsymbol{K}_{\boldsymbol{n}})^{-1}, \text{ where } \boldsymbol{K}_{\boldsymbol{rw}} = \text{cov}(\boldsymbol{P}\boldsymbol{Q}_{\boldsymbol{w}}) \tag{7}$$

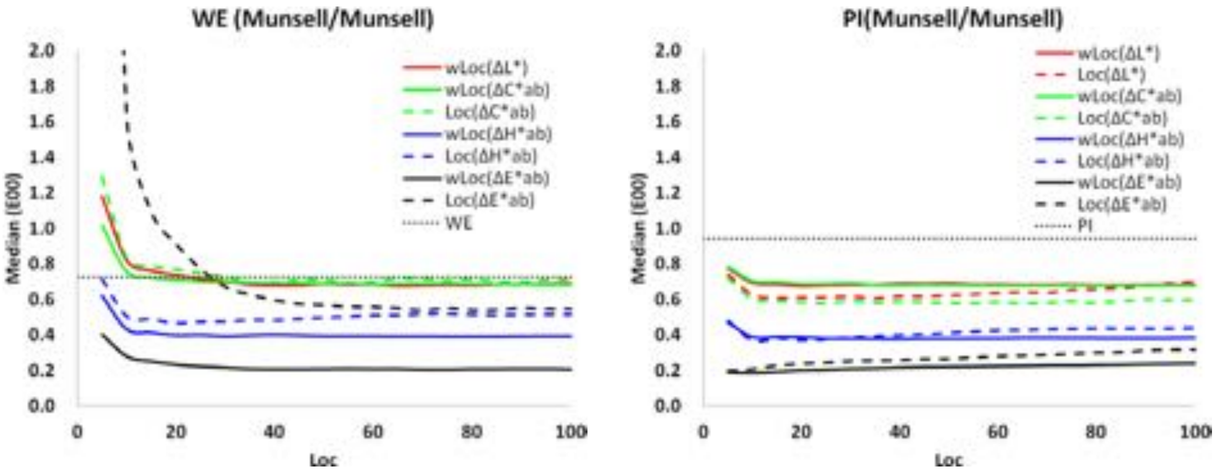
where the matrix $\boldsymbol{W}_{\boldsymbol{wPI}}$ and $\boldsymbol{W}_{\boldsymbol{wWE}}$ is weighted Wiener estimation and weighted pseudo-inverse methods respectively. In this study, the $\boldsymbol{K}_{\boldsymbol{n}}$ in Equations 4 and 7 was set to zero.

The localised training samples, selected from a large set of available training samples, have the smallest colorimetric difference from the testing samples. ΔL^*, ΔC^*_{ab}, ΔH^*_{ab} and ΔE^*_{ab} were used as the measure to determined the colorimetric difference in turns. Thus, six methods were compared: WE, PI, WE with localised training samples (WE_loc), PI with localised training samples (PI_loc), WE with localised training samples with a weighting factor (WE_wloc) and PI with localised training samples with a weighting factor (PI_wloc). The first two methods were conventional methods and the rest are the modified methods.

3. RESULTS AND DISCUSSION

Two datasets were used in this study: 1562 glossy paint samples from the Munsell Book of Color and 1063 textile samples from the Professional Colour Communicator (PCC). The six methods were each applied to generate reflectance from a target colour with XYZ under D65/10º condition. The recovered reflectance was then examined using XYZ under A/10º condition. The performances were evaluated in terms of median CIEDE2000 colour difference ΔE_{00} (Luo 2001). Note, that for perfect agreement the predicted and the measured XYZ values should be zero.

The dot lines in the figures represent the performance of conventional methods WE and PI. WE and PI gave median ΔE_{00} values of 0.72 and 0.94 respectively. The results indicate that number of trainings samples does not have an impact on their performance. However, the training performance of the modified methods with localised training samples improved with the number of samples increased. Most of the modified methods stabilised with 50 localised training samples. It is evident that further improved performance was obtained when weighting factor were applied even with a smaller localised training sample set. For both WE and PI methods modification with the use of ΔH^*_{ab} or ΔE^*_{ab} to select for the localised training samples and weighting factor was more effective than using other colorimetric difference.



(a) (b)

Figure 1: Effect of the number of localised training samples for (a) Wiener estimation WE and (b) pseudo-inverse PI methods in terms of median ΔE_{00} under illuminant A.

Table 1 shows the training and testing performance of the models using ΔH^*_{ab} and ΔE^*_{ab} as the attibutes to determine the localised training samples. The training perfromance of the modified methods are consistently outperformed the conventional methods. For examples, the WE method gave median ΔE_{00} values of 0.72 using the Munsell dataset as both the training and testing sets and the WE_wloc method gave 0.40 and 0.21 ΔE_{00} units using ΔH^*_{ab} and ΔE^*_{ab}

repectively. The testing performances were similar to those obtained from the conventional methods.

Table 1: Model Performance (median ΔE_{00} colour differences with maximum colour differences in parentheses; best performance is marked by an asterisk).

		Training performance		Testing Performance	
Train/Test	Factor	Munsell/Munsell	PCC/PCC	Munsell/PCC	PCC/Munsell
WE		0.72 (5.74)	1.13 (4.78)	1.51 (5.15)	1.29 (5.90)
WE_wloc	ΔH^*_{ab}	0.40 (5.68)	0.59 (6.60)	***1.45 (13.22)**	***1.17 (6.68)**
	ΔE^*_{ab}	***0.21 (3.26)**	***0.08 (3.42)**	1.63 (7.16)	1.31 (5.27)
PI		0.94 (5.53)	0.78 (4.50)	***1.23 (4.94)**	1.29 (6.23)
PI_wloc	ΔH^*_{ab}	0.38 (6.77)	0.58 (6.00)	1.44 (12.99)	***1.16 (6.34)**
	ΔE^*_{ab}	***0.22 (2.72)**	***0.07 (3.13)**	1.47 (4.72)	1.32 (5.11)

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4. CONCLUSIONS

This paper proposed modifications to the Wiener estimation and Pseudo-inverse methods for spectral recovery. It is suggested that applying a weighting factor and localised training samples generally improves the performance. ΔE^*_{ab} has shown to be the most effective measure for selecting localised training samples, and ΔH^*_{ab} provides better results than ΔC^*_{ab}, and ΔL^*. Wiener_wLoc and PI_wLoc methods require fewer samples to achieve a stable performance than the Wiener_Loc and PI_Loc methods. If the same dataset used as both training and testing sets, the performance of the modified methods improved to approximately 0.5 ΔE_{00} unit from the conventional methods which gave around 1.5 ΔE_{00} units. If different datasets used to train and test models, there is a very similar performance between modified and conventional methods. However, there is a strong indication that the use of weighting factor determined by ΔE^*_{ab} and localised dataset are particular effective when the number of training samples are less than 50.

REFERENCES

Babaei VS, Amirshahi SH and Agahian F, 2009. Reflectance reconstruction by adaptive Wiener restoration method: using color difference values as weighting matrix. *Proceedings of the 11th Congress of the International Colour Association*, Sydney (Australia).

Babaei VS, Amirshahi SH and Agahian F, 2011. Using weighted pseudo-inverse method for reconstruction of reflectance spectra and analyzing the dataset in terms of normality. *Color Research and Application*, **36** (4), 295-305.

Luo MR, 2001. The CIE2000 colour difference formula: CIEDE2000. *Proceedings of the 9th Congress of the International Colour Association*, Rochester (USA).

Shen HL, Cai PQ, Shao SJ and Xin JH, 2007. Reflectance reconstruction for multispectral imaging by adaptive Wiener estimation. *Optics Express*, **15** (23), 15545-15554.

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Colorimetry-free color management system applied to mobile phone displays

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ABSTRACT

The new color management system has been developed based on the color constancy phenomenon on reflecting surfaces and applied to mobile phone displays. In the experiment, a set of six Munsell color chips were matched with different mobile phone displays under the illuminant A and D65. The display RGB values of matches varied greatly with display, observer and illuminant. Then the color conversion matrices were derived from the matching results to achieve the same color appearance.

1. INTRODUCTION

The objective of color management system (CMS) is to ensure the color fidelity across different color devices. Since each device has its own color space, the goal of CMS is conversions of color representations from one to others. In many of CMSs, the conversion is done through device-independent color spaces such as CIE XYZ or CIE LAB as shown in Figure 1. In other words, CMSs are designed to achieve colorimetrically equal color.

However, in metameric color match, equal colorimetric values assure equal color appearance only to the standard observer but not to each observer in practical situations. Another and more serious problem of the current CMS is the effect of color adaptation to the illuminant. Even though spectral composition from the display is held constant, color adaptation to the illuminant may change the color appearance (Figure 2). This situation corresponds to *the color constancy failure on self-luminous displays*. To achieve the equal color appearance across different color of illuminants, appropriate color conversion is necessary.

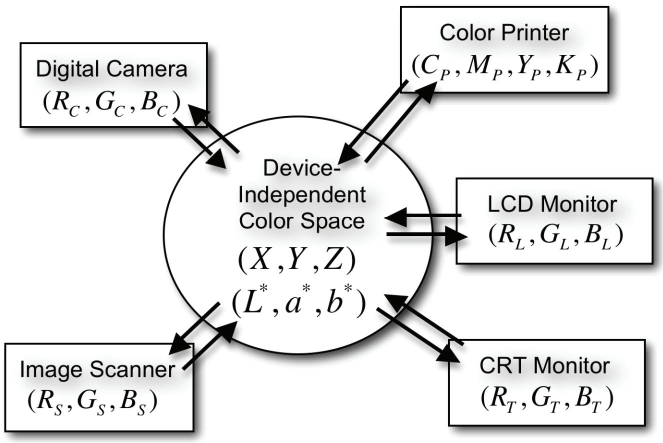

Figure 1. The idea of the typical color management systems.

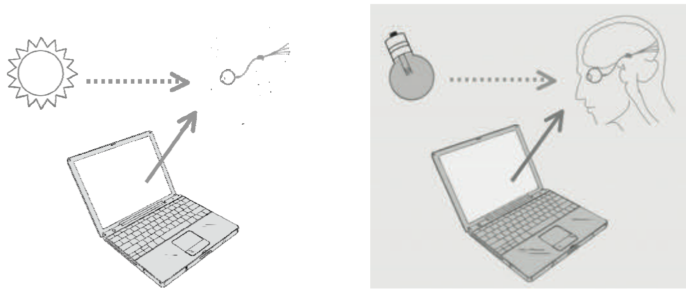

Figure 2. Color constancy failure on self-luminous displays.

2. COLORIMETRY-FREE COLOR MANAGEMENT SYSTEM

To solve the above problems, we have developed a CMS based on the color constancy phenomenon on reflecting surfaces (Ishibashi et al. 2009). Color matching with reflecting color chips should assure equal appearance on displays under different illuminants. As illustrated in Figure 3, the objective of the CMS is to derive a conversion matrix from one to another environments through a visual color match of display with the same set of color chips under each illuminant. Then the obtained conversion matrix m_{NA} is applied to (R'_N, G'_N, B'_N) to get (R'_A, G'_A, B'_A) which should achieve the same appearance in condition A as in condition N, as shown by [1]. In the equation, (R', G', B') denote the RGB values linearized by exponentiating with gamma γ as shown by [2]. The gamma is not defined photometrically but obtained by subjective visual tasks in the CMS. Thus another advantage of the CMS is a procedure where no colorimetric measurement is required.

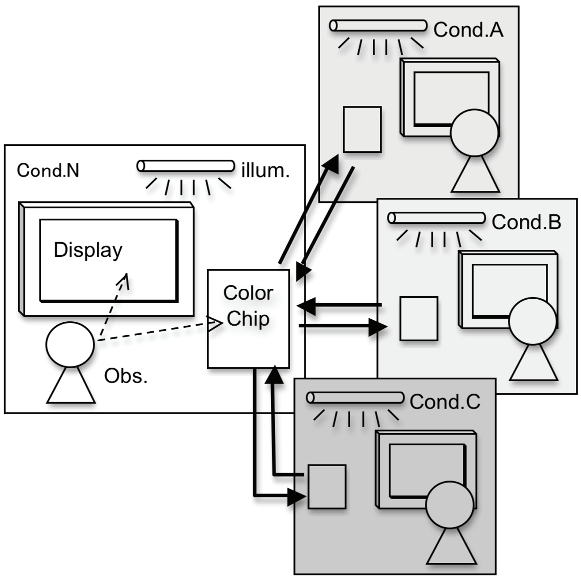

Figure 3. The idea of new color management system.

The procedure of CMS consists of two phases of observer's task. First, the display gamma is determined by visual match between a two-color checker stimulus and an uniform-color stimulus. Second, color chips are visually matched with display colors. These procedures are repeated in different environments (display, illuminant, and observer) using the same set of color chips. A collection of linear equations from color matchings with three or more color chips is expressed in a matrix equation as shown by [3]. Nine elements of the conversion matrix are calculated by applying $\mathbf{C}_N^+$, a pseudoinverse matrix of $\mathbf{C}_N$, as shown by [4].

$$\begin{pmatrix} R'_A \\ G'_A \\ B'_A \end{pmatrix} = m_{NA} \begin{pmatrix} R'_N \\ G'_N \\ B'_N \end{pmatrix} = \begin{pmatrix} a_0 & a_1 & a_2 \\ a_3 & a_4 & a_5 \\ a_6 & a_7 & a_8 \end{pmatrix} \begin{pmatrix} R'_N \\ G'_N \\ B'_N \end{pmatrix} \quad [1]$$

$$S' = \left(\frac{S}{S_{\max}} \right)^{\gamma_S} \qquad \text{where} \quad S = R, G, B \quad [2]$$

$$\mathbf{C}_A = \mathbf{C}_N \cdot \mathbf{M}_{NA} \quad [3]$$

where

$$\mathbf{C}_A = \begin{pmatrix} R'_{A1} \\ G'_{A1} \\ B'_{A1} \\ R'_{A2} \\ G'_{A2} \\ B'_{A2} \\ \vdots \\ R'_{Ai} \\ G'_{Ai} \\ B'_{Ai} \end{pmatrix}, \quad \mathbf{C}_N = \begin{pmatrix} R'_{N1} & G'_{N1} & B'_{N1} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & R'_{N1} & G'_{N1} & B'_{A2} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & R'_{N1} & G'_{N1} & B'_{N1} \\ R'_{N2} & G'_{N2} & B'_{N2} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & R'_{N2} & G'_{N2} & B'_{N2} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & R'_{N2} & G'_{N2} & B'_{N2} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ R'_{Ni} & G'_{Ni} & B'_{Ni} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & R'_{Ni} & G'_{Ni} & B'_{Ni} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & R'_{Ni} & G'_{Ni} & B'_{Ni} \end{pmatrix}, \quad \mathbf{M}_{NA} = \begin{pmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \\ a_6 \\ a_7 \\ a_8 \end{pmatrix}$$

$$\mathbf{M}_{NA} = \mathbf{C}_N^{+} \cdot \mathbf{C}_A \quad [4]$$

3. EXPERIMENTS

The CMS was applied to mobile phone displays of docomo N01a and F05c under two different illuminants, A and D65 (Furukawa et al. 2012). Color of mobile phone display was adjusted by two subjects, KF and ReI, to match six Munsel color chips, 5R6/6, 5Y6/6, 5G6/6, 5B6/6, 5P6/6, and N6. The display was covered by N5 paper except a square aperture of 2 degree. A square color chip of 2 degree was put on the N5 cover 1 degree away from the aperture.

Averages from six repeats of matching are shown in Figure 4 of the chromaticity diagram calculated by [5]. Matching results by two observers show large individual differences, suggesting their color matching functions are not the same. This indicates the same colorimetric value does not assure the same color appearance. Notice that all the chromaticities shift toward reddish yellow direction when the illuminant changes from D65 to A. This indicates that RGB values must be converted to those of reddish yellow so as to achieve the same extent of color constancy as on reflecting surfaces. Figure 5, as examples, show colors converted by [1] with the obtained matrix from one condition (KF, N01a, D65) to another (ReI, F05c, A). The converted colors locate near the colors of matched results, indicating a good performance of the proposed CMS on mobile phone displays.

$$r' = \frac{R'}{R' + G' + B'}, \quad g' = \frac{G'}{R' + G' + B'}, \quad b' = \frac{B'}{R' + G' + B'} \quad [5]$$

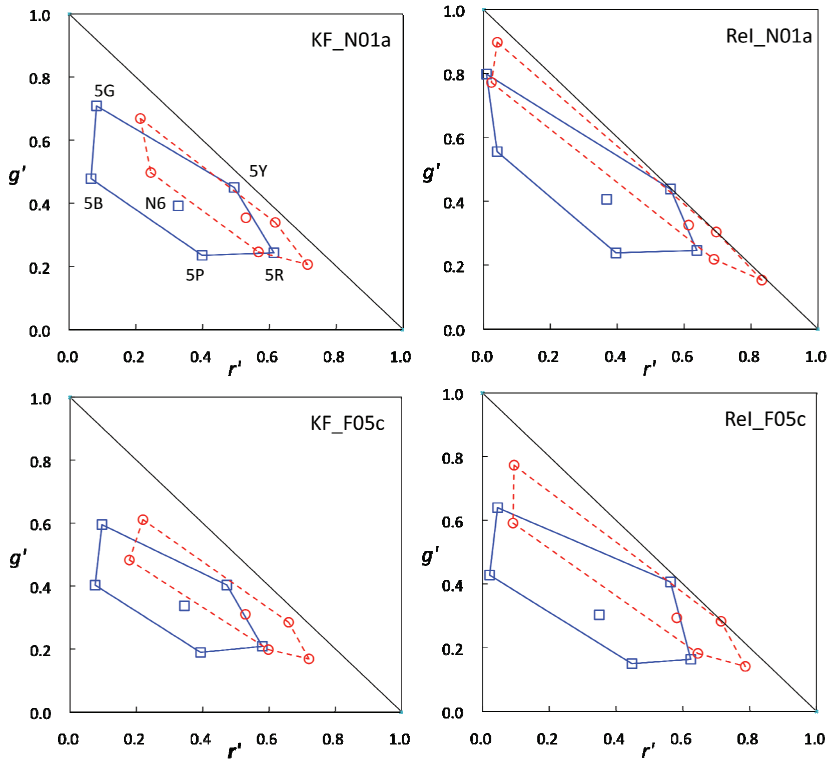

Figure 4. Color matching between a mobile phone display and Munsell color chips. Left, subject KF; right, ReI. Top, display of N01a: bottom, F05c. Squares, D65; circles, A.

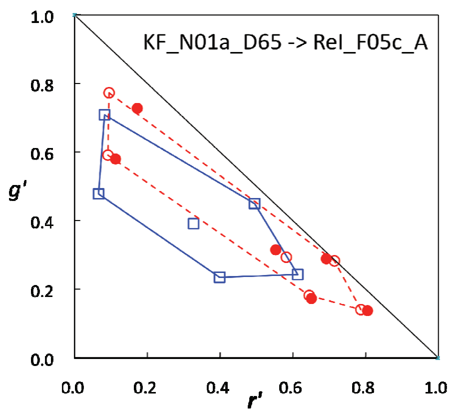

Figure 5. Colors converted by the obtained matrix for equal color appearance. Open symbols show matching results and solid symbols converted colors. Squares, KF-N01a-D65: circles, ReI-F05c-A.

REFERENCES

Furukawa, K., H. Shinoda, and H. Yamaguchi. 2012. Color management using color constancy on multiple mobile phone displays. *Journal of the Color Science Association of Japan* 36-suppl.: 70-71

Ishibashi, R., H. Shinoda, H. Yamaguchi, and K. Rattanakasamsuk. 2009. Colorimetry-free color management system based on the color constancy, *Journal of the Color Science Association of Japan* 33-suppl.: 38-39

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Imaging and rendering of human skin using an rgb color camera

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ABSTRACT

This paper proposes a method for the precise rendering and color re-production of human skin based on a multi-spectral reflection model and the reflection properties detected by imaging the human skin surface. First, we describe a reflection model for human skin based on a model for approximating the subsurface scattering light reflection of the human skin surface. After we obtain all the rendering parameters, we precisely create the computer graphics (CG) images using estimated parameters of the human skin. Also, we implement the proposed method using a graphics processing unit (GPU), assuming that a color monitor will be used as the display device for real-time rendering of the human skin. We render a realistic image of the human skin and visually confirm the validity of the proposed method.

1. INTRODUCTION

Recent advances in computer graphics technology can render an object that has complicated reflection properties. The technology is used for generating the re-produced image of various objects such as human skin. Knowing the reflection properties of human skin can be useful in several fields such as cosmetology. The human skin has complicated reflection properties due to subsurface scattering on the skin surface. In this study, to render human skin, we developed techniques based on a multi-spectral reflection model and the measurement of light reflection on human skin. The reflection model is described as a mathematical model based on the geometry of light reflection and the material properties on an object's surface.

In the entertainment fields such as video-gaming and movies, high-quality computer graphic (CG) has already been used to render humans[1)]. However, the method depends on the skill and subjectivity of the CG designer, which is not sufficient for precisely re-producing properties of human skin such as gloss and shading. In this study, we have quantified the reflection properties of human skin with a light reflection model and its model parameters. The light reflection model is described as a mathematical model of light reflection on an object's surface[2)]. The light reflection model is used for estimating the skin properties and rendering human skin.

First, we developed a reflection model for human skin based on an approximate model with subsurface scattering. Next, we developed a measurement device that can measure light reflection distribution of human skin. The model parameters were estimated from measured data as reflection properties of human skin. Then, we developed a rendering system that can generate three-dimensional (3D) CG images of human skin based on the estimated model parameters. Finally, we rendered a realistic image of human skin and visually confirmed the validity of the proposed method.

2. A REFLECTION MODEL OF HUMAN SKIN

Figure 1 shows the reflection geometry on the human skin surface. The light reflection process is described as the reflection model. It should be noted that the reflection properties of an object's surface depend on its surface material, and these properties are related to both spectrum and geometry. The reflection model is a mathematical model that takes into account the reflection geometry and surface reflection properties. Moreover, subsurface scattering occurs on the skin surface. Previous studies on rendering images of various objects were limited to color images using the RGB color identification system. An RGB color image is device-dependent and valid for only the fixed conditions of illumination and viewing. Multi-spectral data is more important and useful than color information for rendering images of human skin. The appearance of human skin can be described as a mathematical model of a multi-spectral reflection model. The model is developed based on a wrap-lighting model. The color signal $C(\lambda)$ from the surface of human skin is a function of the wavelength λ. The reflection model of skin is described as follows:

$$C(\lambda)=\left\{\alpha\mathbf{N}\cdot\mathbf{L}+\alpha\frac{\mathbf{N}\cdot\mathbf{L}+l}{1+l}S_s(\lambda)\right\}S(\lambda)E'(\lambda),\quad \mathrm{E?}\,\lambda)=\mathrm{E}(\lambda)\exp(-s\cdot\delta), \tag{1}$$

where α is the intensity of diffuse reflection on a skin's surface, **N** is the normal vector of the object's surface, **L** is the incident light vector, and **V** is the viewing vector. $S(\lambda)$ and $S_{ss}(\lambda)$ are the spectral reflectance and scattering spectral reflectance, respectively. $E(\lambda)$ is the spectral distribution of illumination. δ and s are opacity of the material and length of the light path, respectively.

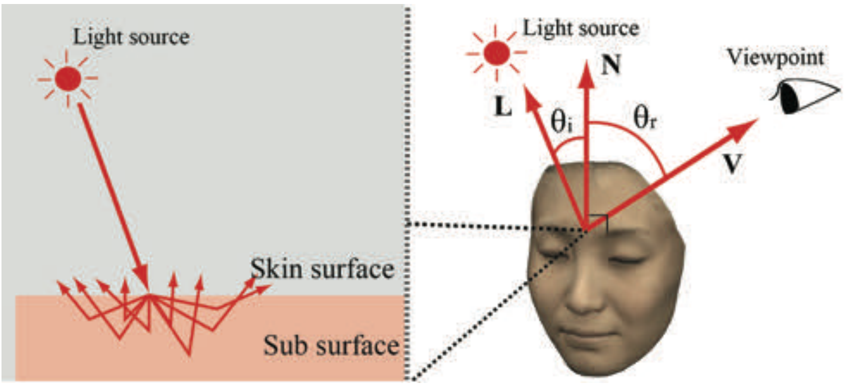

Figure 1. Geometric model of reflection from the skin's surface.

3. ESTIMATION OF REFLECTION PROPERTIES

The spectral reflectance and reflection properties are estimated from images with different illumination and viewing angles. The measuring system consists of a lighting system, two goniometric rotating arms, and an RGB camera system. The intensity at the skin reflection point depends on the subsurface scattering parameter and the constant coefficient *l*. That is, the model function with unknown *l* and α is fitted to the intensity data of the skin surface acquired at different angles of θ_i and θ_r.

4. ESTIMATION OF SPECTRAL REFLECTANCE

The principal parameters describing the surface reflection properties are the surface-spectral reflectance, the scattering parameter, and the reflection intensity. The spectral reflectance is estimated from the RGB camera sensor outputs. The sensor output $\boldsymbol{\rho}=[R,G,B]^T$ is described as follows:

$$\boldsymbol{\rho} = \int_{400}^{700} C(\lambda)[R_{\mathrm{R}}(\lambda)\ R_{\mathrm{G}}(\lambda)\ R_{\mathrm{B}}(\lambda)]^T d\lambda, \tag{2}$$

where $R_R(\lambda), R_G(\lambda), R_B(\lambda)$ are the spectral sensitivity functions of the RGB sensors and $C(\lambda)$ is the color signal from the skin surface.

To estimate the spectral reflectance as a continuous function in the visible light range (400–700 nm), we statistically analyzed the spectral distribution of the skin surface by measuring the actual human skin with both an RGB camera and a spectral photometer at the same scene. If we let $\bar{\mathbf{s}}$ be an $n \times 1$ matrix of spectral reflectance, and assume that the basis function vectors $\mathbf{b}_1, \mathbf{b}_2, \mathbf{b}_3$ are determined by finding three principal components of the spectral reflectance of human skin, then, an estimate matrix $\bar{\mathbf{s}}$ of spectral reflectance can be determined by $\bar{\mathbf{s}} = w_1\mathbf{b}_1 + w_2\mathbf{b}_2 + w_3\mathbf{b}_3$. The scalars w_1, w_2, w_3 are weight coefficients of basis functions. This model is effective in the sense that the number of unknown parameters can be reduced significantly when spectral reflectance is represented by only a small number of basis functions. Figure 2 shows the estimation results of measuring surface-spectral reflectance, where the broken curves represent the estimated spectral reflectance, and the solid curves represent spectral reflectance measured by the spectro radiometer.

5. IMAGE RENDERING

After we obtained all the rendering parameters, we precisely created the CG image based on measurement data. The re-produced human skin was rendered under omni-directional illumination distribution in several scenes. To improve rendering performance, we made a reflectance map from the omni-directional scene illumination. The reflectance map is described as $I_{\mathrm{diffuse}}(\lambda,\theta,\phi)$, where (θ,ϕ) is a polar coordinate system. The color signal $C(\lambda)$ under omni-directional illumination is described as follows:

$$\begin{aligned} C(\lambda,\theta,\phi) &= \alpha I_{\mathrm{diffuse}}(\lambda,\theta,\phi) S(\lambda) E(\lambda,\theta,\phi) \\ &= \alpha \left\{ \mathbf{N}\cdot\mathbf{L}(\theta,\phi) + \frac{\mathbf{N}\cdot\mathbf{L}(\theta,\phi)+l}{1+l} S_{\mathrm{s}}(\lambda) \right\} S(\lambda) E(\lambda,\theta,\phi) \end{aligned} \tag{3}$$

The tristimulus values X, Y, and Z of the spectral radiance are calculated from $C(\lambda,\theta,\phi)$. The model was implemented in the rendering system for human skin using an omni-directional illumination spectral distribution. Finally, Figure 4 shows a CG images created using the estimated parameters.

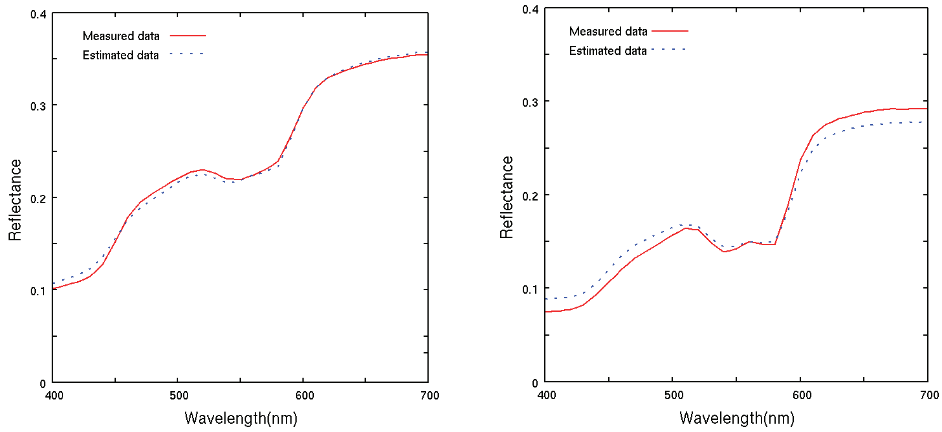

Figure 2. Estimation results of spectral reflectance (left: cheek, right: lip).

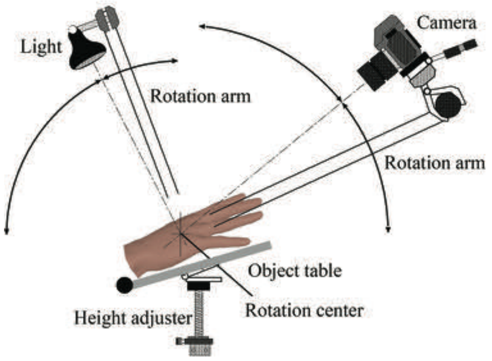

Figure 2. Measurement system.

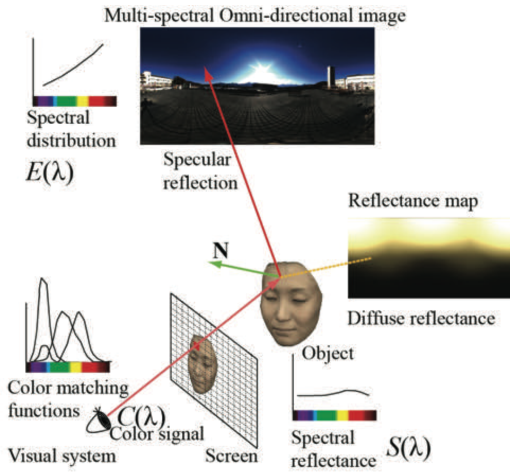

Figure 3. Rendering system for human skin.

Figure 4. CG image of human skin created using estimated parameters.

6. CONCLUSIONS

We proposed a method for estimating various parameters of a reflection model that uses image data of the surface of human skin. First, the spectral reflectance was estimated from the image data. Next, reflection properties were fitted to the reflection model of the human skin. The performance of the proposed method was examined in detail in an experiment using real human skin. We showed the estimation results for the spectral reflectance and reflection model parameters. The overall feasibility of the proposed method was confirmed based on computer graphics images created using the estimated parameters.

ACKNOWLEDGEMENTS

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REFERENCES

1) P. Hanrahan and W. Krueger: Reflection from layered surfaces due to subsurface scattering, Proc. of SIGGRAPH, (1993), 165-174

2) N. Tanaka, K. Mochizuki and J. Woo: A Real-time Rendering Method of Art Objects Based on Multi-spectral Reflection Model, Proc. of IASDR, (2009), 4 pages

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Preferred Skin Color of Oriental Women with Different Settings of Correlated Color Temperature and Luminance Level on a Display

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ABSTRACT

It is important to establish preferred skin color reproduction in display industry. In the present study, two psychophysical experiments were conducted to determine the preferred skin color ranges in terms of the correlated color temperatures (CCTs) and luminance levels on the screen. The preference scores were analyzed and the preference map of skin color plotted in CIE a^*b^* plane was produced. The experimental results were given to demonstrate the preferred skin color under different conditions and an accurate preferred skin color center was established.

1. INTRODUCTION

Human complexion analysis plays an important part in achieving image quality. For display color reproduction, skin color adjustment can be designed according to the subjective evaluation. However, most of the previous studies of the preferred skin color on the displays only considered the specific condition, such as sRGB system at a peak point of 6500 K and a gamma value of 2.2 [1, 2, 3]. In this study, two psychophysical experiments were conducted to determine the preferred skin color regions in terms of the CCTs and luminance levels on sRGB-gamut display.

2. EXPERIMENT I

The psychophysical experiment was conducted to find the chromaticity threshold of the preferred Oriental complexion on a display.

2.1 Experimental procedure

A skin color region extracted from SOCS data [4] were used to establish a gamut range large enough to cover skin colors from 4000 K to 25000 K. This was done to apply chromatic adaptation transformation CAT02 [5] to transform the tristimulus values, X, Y, Z under test illuminants from 4000K to 25000K to the tristimulus values, X_c, Y_c, Z_c under reference illuminant D_{65}. Then a set of nine predetermined color centers uniformly chosen within the skin color ellipse in CIE a^*b^* plane (see Figure 1).

Four facial images of Oriental women were used as test images. The skin colors of each image were mapped toward the nine predetermined color centers respectively, while the residual colors are maintained. Then nine rendered images were displayed on a well color-calibrated LCD randomly at a time in a room having 64 lux. They were examined through the experiment under combinations of four CCTs (5000 K, 6500 K, 9300 K and 10000 K) and each at luminance levels of 60 cd/m^2, 100 cd/m^2 and 200 cd/m^2 set on a LCD. Totally twelve condition profiles were produced. Five color experts participated in this experiment. They evaluated each test image two times. Each observer viewed nine test images on the display to choose the most liked and disliked ones. These images were randomly displayed in different locations on the display.

2.2 Results and discussion

Figures 2-4 show the probability (%) of the most preferred images. Figure 2 shows the evaluating results of different test images. Similar result is found in each image. The "E" point with (a^*, b^*) value = (10.4, 18.1) or (C*, h) value = (20.8, 60.1) is the most preferred for all observers. Figures 3 and 4 also show the "E" point is the most preferred. There is no significant difference in preference due to the variability of different images, CCTs and luminance levels.

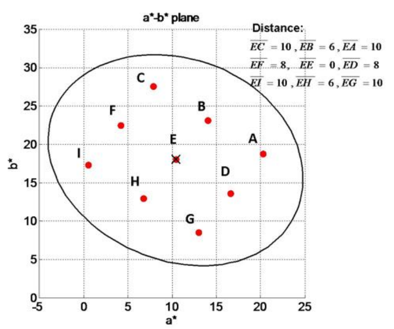

Fig. 1 Nine predetermined color centers

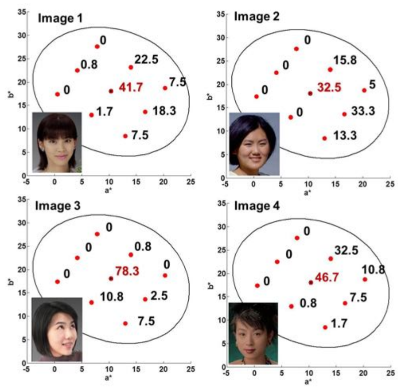

Fig. 2 The probability (%) for each test image

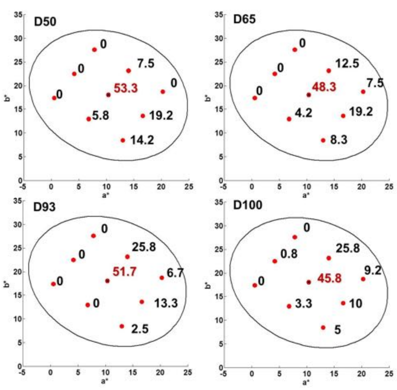

Fig. 3 The probability (%) for each CCTs

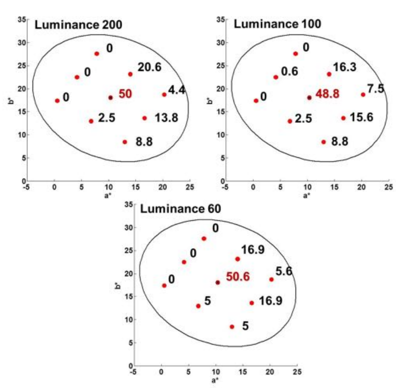

Fig. 4 The probability (%) for each luminance level

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For each rendered image, color difference (ΔE^*_{ab}) between each individual's preferred skin color center and their mean skin color center was averaged to analysis inter-observer variability. The average ΔE^*_{ab} from all observer judgments over all images is 3.83. The results also show that there are not many differences between the skin region under different CCTs at the luminance levels studied.

3. EXPERIMENT II

Experiment II was aimed to refine the potential skin color region around predetermined preferred skin color center obtained in Experiment I and to realize the relation between the distribution of skin color center and the score of preference.

3.1 Experimental procedure

Four facial images of Oriental women were used. Sixty-one facial image candidates for each image surrounding the color center "E" obtained in Experiment I were generated. Two sets of reference image were chosen from all candidates by 5 experts visually.

A well color-calibrated LCD was used in a room having 64 lux. The test LCD was set under the setting of 200 cd/m^2 and 9300 K which is the most common conditions for TV systems in East Asia. The test images were displayed on the display in a random order. Observers will grade the degree of preference using a six-point category scale, where Grade 1 was defined as extremely dislike and Grade 6 extremely like. Eight male and six female observers participated in this experiment. They all passed through Ishihara color vision test. Each observer did the same experiment twice.

3.2 Results and discussion

Figure 5 shows the evaluating scores of test images and the red square is the most preferred. The average of category scaling results from all observers in Figure 5 shows the highest degrees of skin-color preference is the "R" point with (a^*, b^*) value = (16.2, 19.6) or (C^*, h) value = (25.4, 50.5). The hue angle is smaller than the center point "E" obtained in Experiment I and the chroma is higher. Figure 6 illustrates the skin-color preference map. As the ellipse becomes smaller, the rendered skin colors become more preferred. The shape of the ellipse hints that hue tolerance is smaller than chroma tolerance.

4. CONCLUSIONS

Two psychophysical experiments were conducted to investigate the preferred skin color reproduction on sRGB display in terms of considering both CCTs and luminance levels. The first results indicate that the preferred degree of Oriental women's skin colors on a display is independent on different images, CCTs and luminance levels. The (C*, h) value = (20.8, 60.1) is the most preferred skin color on sRGB-gamut display.

Next, a preference map of preferred skin color of Oriental woman was determined. The

(C*, h) value = (25.4, 50.5) gave the highest degrees of skin-color preference. The more accurate preferred skin color center is slightly redder and more vivid. The inter-observer variances in skin color preference are larger in chroma component than hue component. In this article, we have investigated the preferred skin color under different conditions on a display and found the more accurate preferred skin color center.

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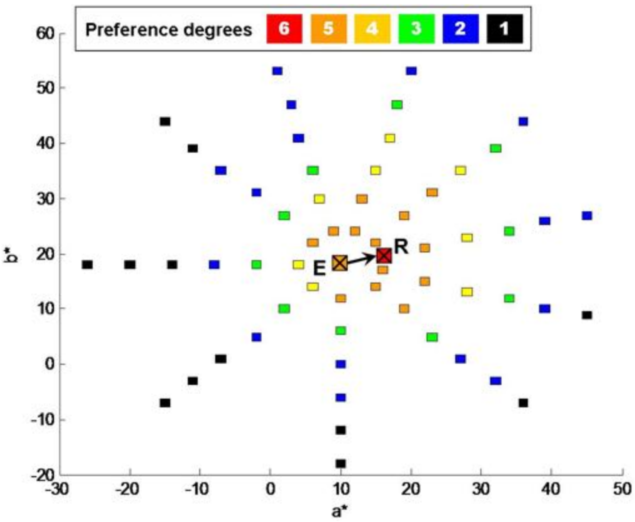

Fig. 5 The category scaling results

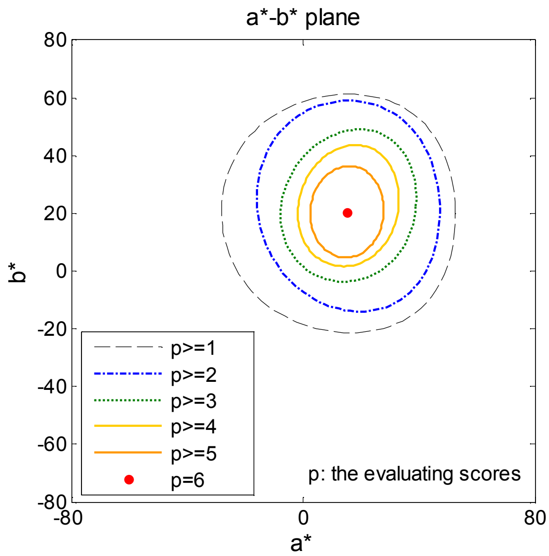

Fig. 6 The skin-color preference map

REFERENCES

1) Zeng, H. and Luo, R.: Colour and Tolerance of Preferred Skin Colours on Digital Photographic Images, Color Res. Appl. (2011).

2) La´ szlo´ Beke, Ga´ bor Kutas, Youngshin Kwak, Gee Young Sung, Du-Sik Park, Peter Bodrogi1 (2008) "Color Preference of Aged Observers Compared to Young Observers", Color Res. Appl.; 33: 381-394.

3) Tünde Tarczali, Du-Sik Park, Peter Bodrogi, Chang Yeong Kim: Long-Term Memory Colors of Korean and Hungarian Observers, Color Res. Appl. (2006) 31: 176-183.

4) ISO/TR 16066:2003 (E), "Graphic technology — Standard object colour spectra database for colour reproduction evaluation (SOCS)".

5) M. R. Luo, B. Rigg, K. J. Smith: CMC 2002 colour inconstancy index; CMCCON02, Coloration Technology (2003) 119: 280–285.

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Color Management for Packaging, Multicolor Process Printing Methods in Oman

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ABSTRACT

This work is to put some guides for packaging designer to improve color control in the stage of design. Especially when using color management techniques. The relationship between design on screen and final print will be revised to improve color translations between different devices. Multicolor Process Printing MCPP Method is used to achieve better color matching. Applying spot colors to avoid registration problems. Printing across the three process- Flexo, gravure, Litho will be easier for packaging product. So we used multicolor process printing method.

1. COLOR MANAGEMENT

In this work color management is applied using multicolor process printing method. In this method the gamut of process CMYK inks can be expanded through the use of spot colors such as red, green, or violet. Also the method provides more consistency, as a single special color is easier to control on press over a long run (as opposed to maintaining a four-color process mix). Spectral data have been measured using a precise spectrophotometer on 2 Test samples. The samples consist of a food product cover printed on poly propylene film in 5 and 6 colors. Samples were printed on 4 process colors and 2 spot colors. Gravure printing was adopted.

2. THE USED TWO METHODS OF MULTICOLOR PROCESS PRINTING

1. The first method is called “N-Color”.
2. The second method is called “CMYK+N”

For the “N-Color” method leaving the domains of process colors, hexachrome, and/or hi-fi, we come to the world where any shade of ink may be used to print: the packaging industry. While in “CMYK+N” we deal with C-M-Y-K plus Orange & Green, and C-M-Y-k plus Red, Green & Blue Inks.

In the profiling software, there are several grades each offers different program features and calculation options. At the high end, the Full version of the software enables to calculate "N-color" profiles. "N-color" might be better stated as "Any-color". Briefly, the lesser priced packages can deal with C-M-Y-K, C-M-Y-K plus Orange & Green, and C-M-Y-K plus Red, Green, & Blue. These are not considered "N-color". Leaving the domains of process colors, hexachrome, and/or hi-fi, we come to the world where any shades of ink may be used to print: the packaging industry.

2.1 N-Color Method

"N-color" profiling allows for profiles to be created with any color set. . "N-color" enables this functionality. In addition to "N-color" capability, the profiling tool includes a utility that allows the user to "swap" one color for another within a profile without the need to redo all the tedious up-front printing and measurement tasks. Instead there is a simple test involving only a few measurements that can predict how the gamut and profile will change if an ink is substituted. This capability is of enormous value in the packaging industry.

A professional color management system is used to generate ICC profiles for multicolor process printing. Using ICC profiles enables to apply multicolor process printing method which intern effects final work precision. Some profiling software enables to design a special target to support CMYK process inks and Special colorants. Plug-ins must be applied when using Photoshop, in order to correct monitor previewing as a soft proof. Design software with multicolor process must guarantees efficiency and economy: You have the tools to use the least number of colors, and therefore plates, for every job. That is because the grey balance and the color mapping are utterly independent and flexible. Those formulas do not have to include C, M, Y, or K.

2.2 Figures and tables

Table 1. Spectral L a b* data for N-Colors Sample with 5 colors.*

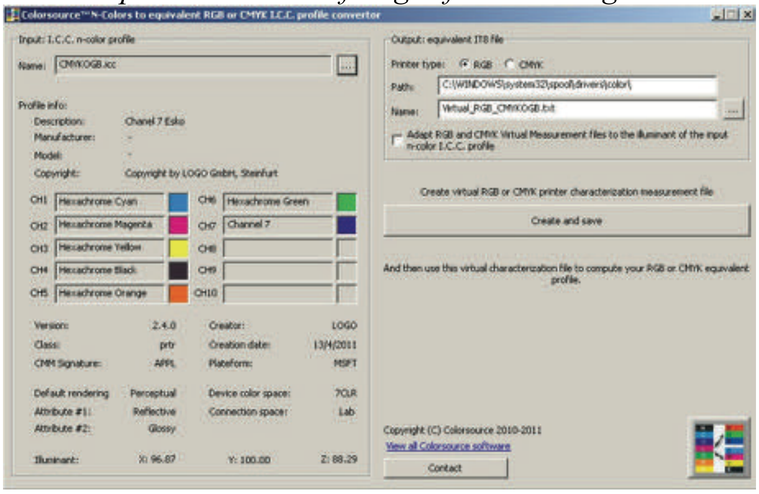
Color	**Sample 1**		
	L*	a*	b*
C1	53	70	59
C2	64	-31	-19
C3	60	5	35
C4	13	2	0
C5	95	-7	95

Table 2. Spectral L a b* data for CMYK+N colors with total of 6 colors.*

Color	**Sample 1**		
	L*	a*	b*
C1	40	-44	23
C2	62	-41	59
C3	95	70	95
C4	62	-44	-50
C5	52	80	-8
C6	13	2	0

Shape 1. Samples of CMYK+N (to the left) and N-Color Design (to the right).

Shape 2. MCPP Profiling software dialog Box.



2.3 Methodology

Two designs were produced just with MCPP using a standard setup intended for normally design. No special adjustments were made and no highlight, shadow, contrast or gamma settings were applied on the file. The color management system was profile maker Pro with Colorsource software.

Having assigned the profiles, Design (1) was then converted to N-Color ICC profile. Design (2) was converted to CMYK+2spot ICC profile.

After these corrections, the two design files were converted from RGB to CMYK+N and N-Color for gravure printing.

3. RESULTS AND CONCULOSION

Final Result of investigation performed in the Sultanate of Oman shows that errors of the delta E using spectral color management in multicolor process printing method got better than it would have been without the use of spectral color management. Also the use of color management enabled to produce multicolor target reference which is used to create color profiles for multicolor process printing in packaging industry.

We conclude that Packaging Designer should perform color management system which support of “N-Color” printing method instead of using a regular system dealing with “CMYK+N” colors.

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REFERENCES

Harrell, Tyler. 2007. Color Management in Packaging, IPA Bulletin, September/October 2007

Sharma, Abhay. 2008. *Color Management for Packaging: Spectral Colors & Beyond*. In Flexo Global.

N-Colors Repro and Printing with Colorsource Software. 2011. Colorsource Company, Available on http://www.color-source.net/en/Colorsource_software.htm.

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Improvement of Organic screen printing ink for Thai Traditional Fabric

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Abstract

The purpose of this thesis is to develop the screen ink from nature. This kind of ink is produced by natural agent instead of synthetic, banana gum which acts as an adhesive agent like resin, tapioca flour, sodium chloride and silver nano as additive agent and colorants from plants. Boil the proportions of the ink; 200 milliliters of banana gum, 15 grams of cassava and 100 milliliters of colorant at 100 degree Celsius. After boiling, test for viscosity of the ink and screen on homespun cloths;

The result of the experiment found that the different boiling time provided different value of viscosity. The 5-minute boiling outcome ink with the value of viscosity at 11,180 cent points can provide the most completion of the details. Among the homespun cloths. Ink type 1 density more than type 2

1. Introduction

Green and healthy societies remain an important yet concerning issue in human life. It is generally agreed that the current tendency for new products is toward naturalism. Organic printing ink is one of alternative in the matter to prevent not only worker and consumer from illness, but also pollution from increasing. Although the organic printing inks are released, there is currently a severe lack of an organic ink for screen printing process served for Thai traditional fabric.

There are three stages in this study- ink making, printing process, and survey of conservative attitude. In the first stage, an organic screen printing ink was developed. The main ingredients were organic colorants, banana's gum, and tapioca starch. The organic colorants used in this experiment were extracted from leaf flower fruit root etc. for color. The ingredients were mixed in the proportion of one part of colorant solution to two part of banana's gum solution and were boiled at $100^{O}C$ for 10 minutes. During boiling, the tapioca starch was added for control of a viscosity of ink at 11,180 centipoint. Two ink formulation, with and without nano-silver, were employed.

The result from this research Therefore, our ink is one of the environmentally friendly products that preserve a world for the future.

2. Experiment

2.1 preparing dye

For green , dye was made from mango leaf, charcoal

For yellow, dye was made from turmeric, chrysanthemum seed

For red, dye was made from rosella, dragon fruit

For brown, dye was made from Cananga leaf, Earleaf acacia

For black, dye was made from rambutan peel

Group 1 pigment from turmeric, charcoal, rosella…. were made by using drying method

Group 2 dye from mango leaf, dragon fruit, cananga leaf, earleaf acacia and rambutan peel were made by grinding and mixing with water

2.2 For preparing banana gum replacing resin It was achieved by cutting banana tree into small piece and mixing with water. Afterwards this was spinned and filtered.

2.3 Ink composition

Type 1

Banana gum 100 milliliter
Dye 250 milliliter
Cassava flour 20 gram
sodium chloride

Type 2

Banana gum 100 milliliter
Dye 250 milliliter
Cassava flour 20 gram
sodium chloride
Silver nano

2.4 Boiling these ink composition at 100^{O} c and stirred these around five minute. Then measured viscosity oh ink and mix with silver nana around two table spoons for anti fungus.

2.5 These ink were applied to print on cotton fabric. The density and color of print images were measured by using spectrophotometer then these data were applied to analysis.

3. Result

Table 1 average of density of solid patches on two different cotton fabrics printed by using different dyes.

Color	**Density**		
	Type 1	**Type 2**	**Difference**
Green			
Mango leaf	0.30	0.26	0.4
Charcoal	0.26	0.25	0.1
Yellow			
turmeric	0.53	0.40	0.13
chrysanthemum seed	1.09	1.08	0.01
Red			
rosella	0.62	0.54	0.08
dragon fruit	0.32	0.25	0.07
Brown			
Cananga leaf	0.40	0.36	0.04
Earleaf acacia	0.66	0.63	0.03
Black			
rambutan peel	0.92	0.80	0.12

The results from table 1 show that all densities of two different inks which are ink with non silver nano and ink with silver nano were slightly different.

Color measurement on cotton fabric

*Table 2 comparison of CIE L*a*b* on cotton fabric printed with two different inks*

Color	CIE L*a*b*					
	Type 1			Type 2		
	L*	a*	b*	L*	a*	b*
Green						
Mango leaf	72.35	-7.32	34.20	75.72	-7.12	36.30
Charcoal	86.07	-3.94	14.06	85.84	-3.63	14.28
Yellow						
turmeric	85.12	-5.25	40.44	86.27	-4.87	31.37
chrysanthemum seed	76.71	-5.68	76.92	78.64	-3.09	77.72
Red						
rosella	60.41	23.66	0.78	65.28	21.08	1.81
dragon fruit	77.86	17.88	-1.22	81.65	12.33	1.19
Brown						
Cananga leaf Earleaf	77.38	0.61	15.38	79.40	0.23	13.44
acacia	63.63	5.10	16.97	64.26	5.00	17.06
Black						
rambutan peel	40.53	4.26	3.00	46.15	4.33	3.32

The results from table 2 show that all inks were in high level of lightness which can be explain in CIE L* of all ink. These results can be implied that all ink had high level of saturation of dye.

The results from sampling group (General public is explored , N=30)

Table 3 average and standard deviation of results

Quality of Ink	Results		
	$\overline{X}$	SD	Meaning
Quality	3.85	0.75	agree
Color tone	3.70	0.51	agree
Development opportunity	3.84	0.75	agree
Benefit to environment	4.85	0.48	Strongly agree
Apply to other fabric	3.67	0.82	agree
Sale promotion to product	3.83	0.75	agree

From table 3 specialists had strongly agreed in the benefit to the environment in the highest. In addition quality of ink, development opportunity and sale promotion to product are in the second highest. Color tone and apply to other fabric are in the third highest.

Author's preference: Oral presentation: □
Poster presentation: □
Both: □

Choice of category: 5 Color Science and Technology ; Display and Printing .
(Topic)
(Subtopic)

REFERENCES

H.Kipphan, 2001,**"Handbook of Print Media"**, Springer-Verlag, Heidelberg, p. 155.

John Stephens, 1996, **Screen Process Printing, Blueprint An Imprint of Chapman & Hall**, England, Second edition, p. 223.

John Stephens, 1996, **Screen Process Printing, Blueprint An Imprint of Chapman & Hall**, England, Second edition, p. 231.

Samuel B.Hoff, 1997, **Screen Printing A Contemporary Approach**, Delmar Publishers , U.S.A., p. 114.

John and Margaret Cannon Dye Plants and dyeing Published in association with The Royal Botanic Gardens, Kew

poster

Goniometric multi-spectral imaging for digital archive using a multi-band camera

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ABSTRACT

We propose a method for estimating the multi-spectral reflection properties of an object based on gonio-spectral measurements for digital archives. In this study, we develop a multi-band imaging system for measuring the light reflection distribution on an object's surface. The device consists of a lighting system, goniometric rotating arms, and a vision system with a two-shot 6-band camera. In this study, we develop a spectral calibration method for a multi-band camera system using the statistical analysis of spectral reflectance. In addition, reflection model parameters are estimated using sensor measurements for the reflection intensity of an object surface under different conditions of illumination and viewing. Finally, we render a realistic image of the object, and visually confirm the validity of the proposed method.

1. INTRODUCTION

The present paper shows an estimation algorithm for the multi-spectral surface reflection properties of an object using a two-shot type multi-band camera. RGB color data from an imaging device are dependent on the camera sensitivity and scene illuminance.

In this study, we developed a measurement method that is independent of the measuring environment such as camera sensitivity and illuminance by making a multi-spectral reflection model and a goniometric multi-band camera system. Then, we measured the spectral reflectance, which is a physical property of the material (which is independent of the camera device and illuminance) on an object's surface. In addition, we measure reflection model parameters that represent quantified reflection properties of the object's surface. Using the measurements, we first propose statistical algorithms to estimate the multi-spectral reflectance of the object's surface from the camera outputs. In the estimation, camera device characteristics and the influence of the illuminance are removed from the system conversion matrix. Second, reflection model parameters are estimated from the sensor measurements for the reflection intensity of the object's surface under the different conditions of illumination and viewing. Third, a three dimensional (3D) color re-production system is proposed. The system can re-produce shades and glosses of the object's surface. Finally, we render a realistic image of the art object and present a comparison of 3D computer graphics (CG) and the original real object.

2. MULTI-SPECTRAL REFLECTION MODEL

The surface reflection on an object is described using the geometric relationship between light, the object, and the visual system. Figure 1 shows the reflection geometry of the Torrance–Sparrow model [1)]. The color-signal $C(\lambda)$ of the visual system from the surface of a reflective object is described as follows:

$$C(\lambda) = \alpha \cos\theta_i S(\lambda)E(\lambda) + \beta \frac{F(n,\theta_H)D(\mu,\varphi)G(\mathbf{N},\mathbf{V},\mathbf{L})}{\cos\theta_r} E(\lambda), \quad (1)$$

where the first and second terms are the diffuse and specular reflection, respectively. α and β are the weighting coefficients of the diffuse and specular reflection component, respectively, and $S(\lambda)$ and $E(\lambda)$ are the spectral surface reflectance and spectral distribution, respectively. In addition, λ is the wavelength, F is the Fresnel function, n is the refractive index of the object surface, D is the distribution function of the micro-facet, μ is the surface roughness parameter, φ is the phase angle of the micro-facet, G is the attenuation coefficient, **V** is the viewing vector, **N** is the normal vector of the object surface, the vector **L** is the incident light, θ_i is the angle between **N** and **L**, and θ_r is the angle between **N** and **V**. The normal vector of the micro-facet is **H**, while θ_H is the angle between **L** and **H**.

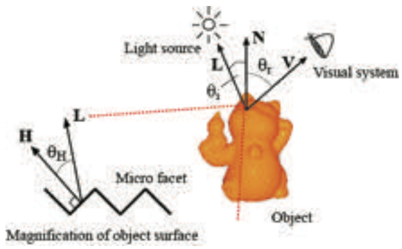


Figure 1. Reflection geometry of the model

3. MEASURING SURFACE REFLECTION PROPERTIES

The reflection model parameters are estimated as the surface reflection properties. The device consists of a light source, two goniometric rotating arms, and the two-shot type Multi-band digital camera system. We use a multi-band camera for multi-spectral imaging. The multi-band system is realized with a comb-type spectral filter and an RGB digital camera. The camera is used to take two shot images. In the first shot, an image is taken with a comb-filter. In the second shot, another image is taken without a comb filter. Figure 2 depicts the schematic diagram of the measuring system.

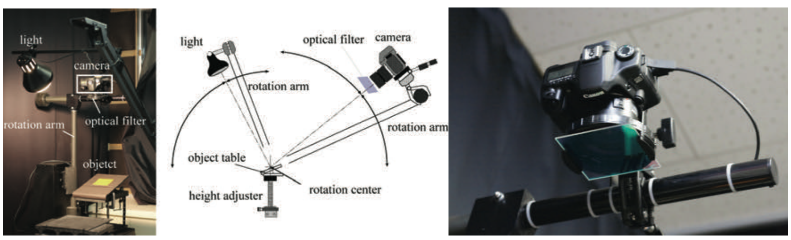


Figure 2. Schematic diagram of the system

4. ESTIMATION ALGORITHM OF REFLECTION PROPERTIES

We propose a statistical analysis method for the estimation of spectral reflectance using the color chart [2)]. To make a database of spectral reflectance, 176 color patches are simultaneously measured with a multi-band camera and a spectrum photometer. The correspondence relation of six-band camera outputs and spectral reflectance are estimated from measured data.

The spectral reflectance is sampled at 5-nm intervals in the visible light wavelength region (400–700 nm). Image data from the device are used to estimate model parameters on the object surface. Unknown parameters α, β, and μ are estimated as follows:

$$\sum_j \left[\alpha \cos\theta_{ij} + \beta \frac{F(n,\theta_{Hj})D(\mu,\varphi_j)G(\mathbf{N}_j,\mathbf{V}_j,\mathbf{L}_j)}{\cos\theta_r} - \rho_{Gj} \right]^2 . \tag{2}$$

5. IMAGE RENDERING

We developed the rendering system using a 3D color management system. In the system, the CG image is rendered based on human's visual properties (Figure 3). In this system, after we obtain all the rendering parameters, we can precisely create the CG images under ambient light conditions. The proposed method is implemented on a graphics processing unit (GPU), assuming a color monitor as the display device.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \int C(\lambda) \begin{bmatrix} \bar{x}(\lambda) \\ \bar{y}(\lambda) \\ \bar{z}(\lambda) \end{bmatrix} d\lambda . \tag{3}$$

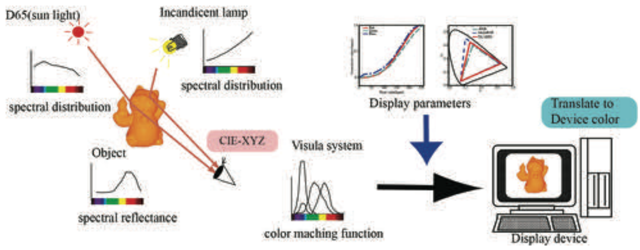
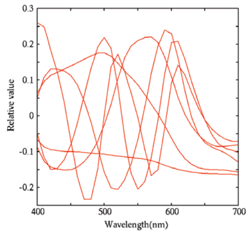


Figure 3. Color re-production based on human visual system

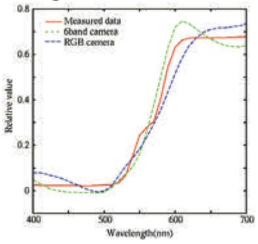
6. EXPERIMENTAL RESULTS

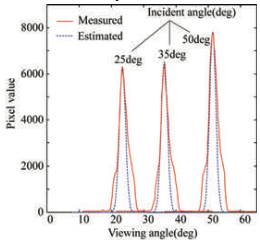
A painted object is measured and re-produced using our proposed method. First, the color chart is measured with the multi-band camera and spectrum photometer to calibrate the imaging system (Figure 4(a)). Figure 4(b) shows the basis function of the color chart. Second, the reflection intensity distribution is measured for the real object with the device. The object is painted with orange acrylic paint. Figure 5(a) shows the estimated spectral reflectance from the object. The red line is a direct measurement using the spectrum photometer, while the green line is the estimated result using the six-band camera. Figure 5(b) shows the estimated results of the reflection intensity. The red line represents the measurement values, while the blue line shows the estimated results using the reflection model. The object is re-produced using the proposed method. Figure 6 illustrates the rendering results of the painted object. In addition, Figure 6 shows the comparison between 3D CG and the original real object.



(a) Color chart (b) Basis functions

Figure 4. Color chart and Basis functions





(a) Reflectance (b) Reflection intensity

Figure 5. Estimated results of reflection properties

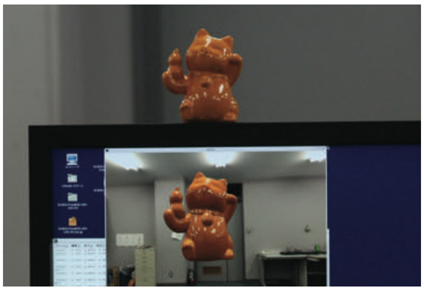


Figure 6. Comparison between the real object and re-produced CG image

7. CONCLUSIONS

We have proposed a method for estimating the multi-spectral reflectance and various reflection model parameters using a multi-band camera without a camera sensitivity function. The device used to measure the reflection intensity is developed for the estimation of model parameters. Moreover, we developed a rendering system with a 3D color management system based on human visual properties. To show the validity of the system, we compared the real object with the re-produced CG.

ACKNOWLEDGEMENT

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REFERENCES

1) K. E. Torrance, et al.: Theory for off-specular reflection from roughened surfaces, J. of OSA, Vol. 57, (1967) 1105-1114.
2) N. Tanaka, et al.: A Real-time Rendering Method of Art Objects Based on Multi-spectral Reflection Model, Proc. of IASDR, (2009), 4 pages.

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poster

The image quality index in consideration of the visual characteristics for a color noise

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ABSTRACT

Objective image quality value is important for many applications, especially an image processing of digital camera. Most digital cameras include a denoising process for color noise. It determines the image quality of the camera. Therefore it is important to define an image quality index associated with color noise. Although there are several image quality indexes, there are few for color noise. In this paper, we propose image quality indexes for color noise using the results of subjective experiments in terms of the visual characteristics for a color noise We have studied the visual characteristics for a color noise. In our image quality indexes, we take the adaptation effects of the spatial frequency into account. We make noisy images applying noise models, and compare our image quality indexes and other image quality indexes. These comparisons show the characteristics of our image quality indexes. We discuss about what kind of the visual characteristic has affected image quality.

1. INTRODUCTION

The information about image quality is important when the developer select better denoising algorithm for digital camera. Conventionally, the root mean square error (RMSE) is often used as an image quality index. There are image quality indexes that took into account the human visual system (HVS) such as S-CIELAB (Zhang and Wandell 1997) and SSIM (Wang et al. 2004). The SSIM uses local image statistics. The S-CIELAB uses the contrast sensitivity function (CSF) as the HVS property. The CSF is used as the HVS response of spatial frequency. The CSF of color is measured through perceptual experiments using various frequency stripes with opponent colors (Mullen 1985). The chromatic CSF shows that the signals are more visible at lower spatial frequency. However, it is not known whether these indexes are appropriate for measuring color noise or not. In this study, we use the visual perception properties for color noise obtained from our previous study (Shohara and Kotani 2011) and propose the image quality indexes for color noise. There are two kinds of image quality indexes with and without reference. We treat the image quality indexes with reference.

2. PERCEPTION OF COLOR NOISE

2.1. Color Noise Model

The noise model is additive noises defined as follows:

$$\mathbf{G}(x, y) = \mathbf{I}(x, y) + \mathbf{n}(x, y), \quad (1)$$

where **I** represents image color at position (x, y), and **n** represents the additive color noise defined by the noise model. We use two noise models (LabGauss and LabVec) as **n**. Both noise models generate equiluminant chromatic noises. The LabGauss noise is an additive Gaussian color noise in the CIELAB's chromatic space (ab-plane). The standard deviation (sigma) is expressed by σ_{ab}. The LabVec is a vector Gaussian noise. As described in Fig.1, the LabVec noise is generated along the specific direction (θ) on an ab-plane with the sigma (σ_{VC}). In the both noise model, the center of ab-plane is specified by the background color.

2.2. Subjective Experiments

The subjective experiments were conducted in terms of obtaining the color noise perception properties that depends on background colors, background luminance, spatial frequencies and color vector noise directions. The details of the experiments and the results are described in Shohara and Kotani (2011). We use these previous results to define the following equations.

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3. IMAGE QUALITY INDEX FOR COLOR NOISE

3.1. Perceived Color Difference for Noise

Color noise perception depends on background colors, luminance, chromatic direction and spatial frequency. We express the perceived color difference of noise D_p as:

$$D_p(\mathbf{C}_c,\mathbf{C}_n)=\max\left(\frac{|\cos(\phi)|}{k_{LC}}\frac{\sigma_{CP}(\theta,a_c,b_c)}{\sigma_V}\frac{\sigma_{LP}(L_c)}{\sigma_{ab}}dC,dL\right), \quad (4)$$

where $\mathbf{C}_c$ is a background color (L_c,a_c,b_c). $\mathbf{C}_n$ is a pixel color that may be a noise (L_n,a_n,b_n). k_{LC} is the noise perception ratio between achromatic and chromatic. Here, k_{LC} is 8. The θ means the relative directions of color noise $\mathbf{C}_n$ for the background color $\mathbf{C}_c$:

$$\theta=\operatorname{atan}((b_n-b_c)/(a_n-a_c)),\quad 0\le\theta<2\pi. \quad (5)$$

The ϕ and the θ have a relationship expressed by $\phi=\operatorname{mod}(\theta+\pi/4,\pi/2)-\pi/4$. The σ_{ab} and the σ_V are experimental parameters concerned with σ_{CP} and σ_{LP}. We use $\sigma_{ab}=10$, $\sigma_V=12$. The *dC* and the *dL* are Euclidean color distance expressed by:

$$dC=\sqrt{(a_n-a_c)^2+(b_n-b_c)^2},\quad dL=|L_n-L_c|. \quad (6)$$

The σ_{CP} is the perceived color noise level for background color, it is obtained from experiments. The regression function is:

$$\sigma_{CP}(\theta,a_c,b_c)=\sqrt{K_1\cos^2(\theta-K_2)+K_3}, \quad (7)$$

$$K_j(a_c,b_c)=\sum_{i=1}^{2}\left(k_{a_{ij}}\cdot a_c{}^i+k_{b_{ij}}\cdot b_c{}^i\right)+k_{c_j}\cdot a_c\cdot b_c+k_{d_j},\ (j=1\sim3), \quad (8)$$

where $k_{a_{ij}}$, $k_{b_{ij}}$, k_{c_j} and k_{d_j} are coefficients, their value of each being shown in Table 1. The larger σ_{CP} value indicates that the color noise is easier to perceive. The σ_{LP} is the perceived color noise level for background luminance, it is expressed by:

$$\sigma_{LP}(L_c)=\sum_{i=0}^{4}\left(kl_i*\log(L_c)^i\right), \quad (9)$$

where the kl_i (i=0~4)s are parameters, their value of each are shown in Table 2.

3.2. Contrast Sensitivity Effect

The contrast sensitivity function (CSF) is the HSV property of spatial frequency. Using our previous results, we express the spatial frequency dependency of color noise G_{sf} as:

$$G_{sf}(f_n)=S_{JND}(f_B)/S_{JND}(f_n), \quad (10)$$

$$S_{JND}(f)=\exp(a_1\cdot\log(f)+a_2),\quad a_1=0.8252,\quad a_2=0.0706. \quad (11)$$

The G_{sf} is the perceptual gain, it depends on the spatial frequency of noise. The f_B is the spatial frequency of our experiments in terms of D_p, we use $f_B=12.93$ [cpd].

3.3. Masking Effect

The adaptation of contrast sensitivity of noise is able to be thought as masking effects of noise. We treat the adaptation effect of contrast sensitivity as the noise masking effect. The noise masking effect is expressed by the gain M_{sf}:

$$M_{sf}(f_n,f_l)=a_m\left(\exp(-f_k^2)-\exp(-4f_k^2)\right)^2+1,\quad f_k(f_n,f_l)=k\cdot f_n/f_l+1,\quad a_m=(E_p-1)/E_o, \quad (12)$$

where, the f_l is the local spatial frequency of the original image, the f_n is the spatial frequency of the noise. The k is the parameter of the equation $M_{sf}(f_k)$, here $k=\sqrt{\log(4)/3}$. The E_p and the E_0 are defined according to Blakemore and Campbell (1969). $E_p=2.0$ and $E_0=0.2232$ here. We use the local spatial frequency as the adaptation frequency.

3.4. Spatial Frequency of Local Image

The spatial frequency of the local image is used in the feature detection studies. The SIFT feature detection (Lowe 1999) uses difference of Gaussian (DoG) to select the significant scale of local image. We also use DoG to know the local spatial frequency.

3.5. Perceived Color Noise (Proposed Model)

We propose the perceived color noise level (PCN) as the image quality index for color noise. The PCN shows the level of visual color noise of the noisy image. The PCN is expressed by:

$$PCN = M_{sf} \cdot G_{sf} \cdot D_p \, . \tag{13}$$

We also propose a modified S-CIELAB index using the D_p as the standard color difference.

Table 1 Coefficients of the equation (8)

var.	value	var.	value	var.	value
$k_{a_{11}}$	1.95	$k_{a_{12}}$	-3.71*10^{-1}	$k_{a_{13}}$	1.33*10^{-1}
$k_{a_{21}}$	-7.68*10^{-3}	$k_{a_{22}}$	2.31*10^{-3}	$k_{a_{23}}$	4.02*10^{-4}
$k_{b_{11}}$	-0.514	$k_{b_{12}}$	-5.53*10^{-1}	$k_{b_{13}}$	-2.05*10^{-1}
$k_{b_{21}}$	-9.17*10^{-4}	$k_{b_{22}}$	-1.10*10^{-3}	$k_{b_{23}}$	-4.43*10^{-3}
k_{c_1}	-5.86*10^{-3}	k_{c_2}	3.98*10^{-3}	k_{c_3}	-2.29*10^{-3}
k_{d_1}	158	k_{d_2}	37.2	k_{d_3}	34.0

Table 2 Coefficients of the equation (9)

var.	value	var.	Value	var.	value
kl_0	128	kl_2	86.7	kl_4	1.28
kl_1	-175	kl_3	-17.7		

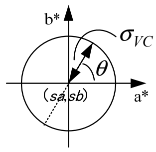

Figure 1. The sigma proportion of the LabVec noise.

4. EXPERIMENTS

We compare the PCN to other image quality indexes as S-CIELAB and RMSE, measuring several types of noisy images. We use the images in the LIVE database (Sheikh et al. 2006, available online). The noisy images are obtained by adding four types of noises to each image.

4.1. Preparing Images

Four types of additive color noise are generated using equations (7) and (8). Type 1 noise is a vector noise that is less perceived. The color noise direction $\theta_{\min}$ of Type 1 noise is the degree when the σ_{CP} has smallest. On the other hand, Type 2 noise is a vector noise that is easily perceived. Type 3 noise is the LabGauss noise. Type 4 noise is the vector noise with random direction θ_{rand}. The sigma is 12 in all types of noises. Fig.2 shows these noisy images. The objective noise levels of these images are different. If we arrange these images in the good order of subjective image quality, it is, Original ~ Type 1 >> Type 4 > Type2 ~ Type 3.

4.2. Results

We measured four image quality indexes for the four types of noisy images. The results are shown in Table 3 and Fig. 3. Although the RMSE values are similar at Type 1 and Type 2, the visual noise level is different. The S-CIELAB shows an opposite manner to the subjective results at Type 2. It is clear that the RMSE and S-CIELAB do not explain the color noise appearance. The proposal methods, S-CIELAB+*Dp* and PCN, express the values with the same order as subjective results.

Figure 2. Original image "bikes" and noisy images. Left image is one of the images in the database. Others are zoomed image of the red rectangular region.

Table 3 Image quality indexes of noisy image "bikes"

	Original	Type1	Type2	Type3	Type4
S-CIELAB	0	3.1610	2.5443	4.6625	2.7945
S-CIELAB + D_p	0	1.9442	3.9257	5.0345	2.9398
RMSE	80	3.0327	3.0351	3.7780	3.0354
PCN	0	2.6037	6.4713	8.2274	5.2950
D_p	0	3.1828	7.9015	3.1882	6.4889

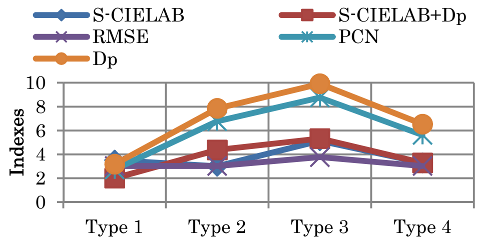

Figure 3. Average image quality indexes of the images in the database.

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5. DISCUSSION

The PCN includes HVS properties as CSF, contrast masking and color appearance. It is similar to the S-CIELAB+ D_p except for contrast masking. Therefore the proposed indexes, S-CIELAB+ D_p and PCN, have similar properties. It is not surprising that our indexes show the same order as appearance. Because the additive noise properties of Type 1 and 2 already include the perception properties expressed by same equation (7). Although it seems that the color noise appearance can be expressed by difference D_p or others involved with D_p, these indexes sometimes conflict at a local part of an image with appearance. The noise appearance is a complicated phenomenon concerned in a chromatic adaptation, a texture perception and a context recognition. Our indexes consider some effects of initial retina level vision. The color noise appearance seems to be affected largely by the initial vision properties.

6. CONCLUSION

The image quality index PCN could provide us the perceptual noise level of the image. It is based on the subjective experiments of color noise appearance. The image quality index S-CIELAB+D_p made the better performance to S-CIELAB for noisy images. The PCN should be tested in detail to have robustness. We will confirm the PCN with more subjective experiments.

REFERENCES

Blakemore, C. and f. W. Campbell, 1969, On the existence of neurons in the human visual system selectively sensitive to the orientation and size of retinal images, *J. Physiol.*, 203:237-260.

Lowe, D. G., 1999, Object recognition from local scale-invariant features, *Int. Conf. Computer Vision (ICCV1999)*, 2:1150-1157.

Mullen, K. T., 1985, The contrast sensitivity of human colour vision to red-green and blue-yellow chromatic gratings, *The Journal of Physiology*, 359:381-400.

Sheikh, H. R., Z. Wang, L. Cormack and A.C. Bovik, LIVE Image Quality Assessment Database Release 2, Available online, http://live.ece.utexas.edu/research/quality, Accessed: June 27, 2012.

Sheikh, H. R., M. F. Sabir and A. C. Bovik, 2006, A statistical evaluation of recent full reference image quality assessment algorithms, *IEEE Transactions on Image Processing*, 15(11):3440-3451.

Shohara, M. and K. Kotani, 2011, Modeling and application of color noise perception dependent on background color and spatial frequency, *Proc. Int. Conf. Image Processing (ICIP 2011)*, 1689-1692.

Wang, Z., X., A. C. Bovik, H. R. Sheikh and E. P. Simoncelli, 2004, Image quality assessment: From error visibility to structural similarity, *IEEE Trans. Image Process*, 13:600-612.

Zhang, X. and B.A.Wandell, 1997, A spatial extension of CIELAB for digital color image reproduction, *SID Journal*, 5(1):61–63.

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Edge Enhancement Filter for the People with Protanopic and Deuteranopic Vision

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ABSTRACT

This paper describes an image processing method to improve visibility of photographic images for the people with color vision deficiencies, particularly protanopic and deuteranopic vision (red-green color blindness). The aim of the proposed method is to help color deficient people distinguish confusable colors adjacent to each other in the images. A modified version of unsharp-mask filtering (commonly called *unsharp masking*) is presented in this paper. It can enhance only edges between regions with confusable colors that are inseparable for the people with color vision defects. Also it can make moderate and practically unnoticeable enhancements for the people with normal (trichromatic) vision. The proposed method for the protanopic vision enhances colors along M and S axes of LMS color space, by means of the addition of L value to M and S values. On the other hand, for the deuteranopic vision, colors along L and S axes of LMS color space are enhanced, by means of the addition of M value to L and S values. Several enhancement results of the proposed method are shown in this paper.

1. INTRODUCTION

Color vision defects occur when cone cells in the retina of the eye fail to function normally. It occurs by some genetic factors and therefore affects a significant number of people. In Japan, for example, it is estimated that about 5 percent of males and about 0.2 percent of females have color vision problems. Globally, there are more than 200 million people who are estimated to be with color vision defects. Such people have difficulties in telling colors apart, e.g. “red and green”, “black and brown”, “pink and sky blue” and “pea-green and yellow”.

To help color deficient people differentiate and separate out colored objects from their background, several color-modification methods have been reported: Anagnostopoulos et al. (2007), Asada et al. (2011), Doliotis et al. (2009), Ichikawa et al. (2003), Meguro et al. (2009), Nakauchi and Onouchi (2008) and Yokota et al. (2009). This paper is also written on the same topic as these research articles.

One of the important themes in this research area is how to cope with both visual effects for color deficient vision and normal color vision. Adequate color modifications for a particular individual with color vision deficiency are often excessive for many other people with normal color vision. If original colors are considerably modified to tell colors apart for color deficient vision and changed into quite different colors, people with normal color vision will feel strange when they see the quite modified colors. Such modified colors also lose original meanings of colors. For example, a red color means “important”, “attention”, “danger”, “hot”, “stop sign” and so on, but these cognitive means will be lost when a red color is changed into the other colors.

To resolve above-mentioned problems, the author proposes a simple idea: Color modification is only made to the edges between regions with confusable colors. By doing so, colors in the other regions are almost stable and the edge enhancement is only noticeable for color-defective vision (unnoticeable for normal vision). The author's idea can be realized by proposed edge enhancement method that is adjusted for protanopic and deuteranopic vision (red-green color vision defects) and considers both color-defective vision and normal color vision.

2. METHODS

A proposed method achieves edge enhancement by unsharp-mask filtering (commonly called *unsharp masking*). This filtering consists of three steps:

STEP 1: An unsharp image is computed by convolving the input image with Gaussian filtering.

$$\bar{f}(\mathrm{j,k}) = f(\mathrm{j,k}) * w_G(\mathrm{j,k})$$

STEP 2: The differences between the input image and the unsharp image are computed by subtraction.

$$s(\mathrm{j,k}) = f(\mathrm{j,k}) - \bar{f}(\mathrm{j,k})$$

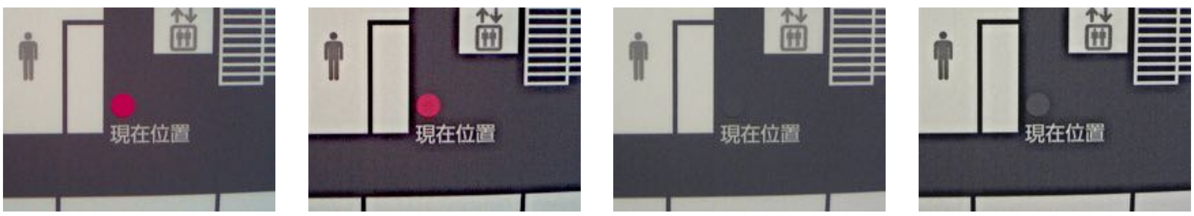
STEP 3: The subtraction image (also called the *residual image*) is added back to the input image, which results in an edge enhanced image.

$$g(\mathrm{j,k}) = f(\mathrm{j,k}) + c \cdot s(\mathrm{j,k})$$

The proposed method achieves above-mentioned steps in LMS color space, in contrast to original (normal) unsharp masking in gray scale or RGB color space. For the protanopic vision, the proposed method implements STEP 1 and 2 through the filtering and the subtraction along L axis. At STEP 3, the L component of the difference image is added to M and S components of the input image. On the other hand, for the deuteranopic vision, STEP 1 and 2 are implemented by the filtering and the subtraction along M axis. Then the M component of the difference image is added to L and S components of the input image at STEP 3.

3. RESULTS

Figure 1 shows an example to illustrate that the proposed method enables protanopic vision to distinguish and separate red circle from its black background. (C) and (D) are the results of protanopic simulation on the basis of Viénot et al. (1999).



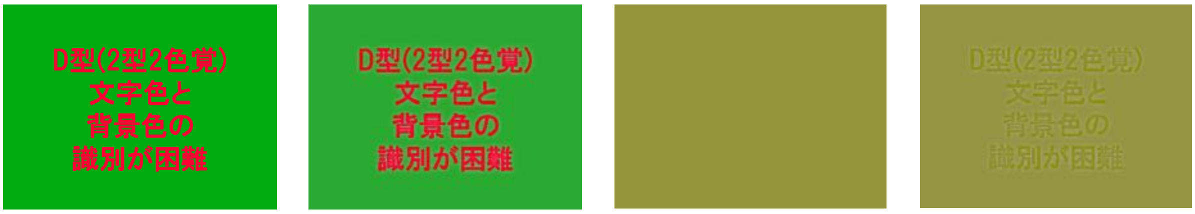
(A) (B) (C) (D)

Figure 1. Proposed method can enhance a red circle in a black background that is unnoticeable for the protanopic vision: (A) Original image, (B) enhanced image, (C) protanopic simulation of original image A and (D) protanopic simulation of enhanced image B.

Figure 2 and 3 show enhancement examples of colored letters by the proposed method. Figure 2 illustrates that pink letters in a sky blue background are not distinguishable for protanopic vision and figure 3 illustrates that red letters in a green background are not distinguishable for deuteranopic vision. The proposed method can make these letters visible and there are hardly any differences between original colors and modified colors when the people with normal (trichromatic) vision see them. The protanopic simulation shown in figure 2 and deuteranopic simulation shown in figure 3 are also based on Viénot et al. (1999).

(A) (B) (C) (D)

Figure 2. Pink letters in a sky blue background are unnoticeable for the protanopic vision. They can be enhanced by the proposed method as shown. There are very few differences between A and B in color: (A) Original image, (B) enhanced image, (C) protanopic simulation of original image A and (D) protanopic simulation of enhanced image B.



(A) (B) (C) (D)

Figure 3. Red letters in a green background are unnoticeable for the deuteranopic vision. They can be enhanced by the proposed method that makes few differences between A and B in color: (A) Original image, (B) enhanced image, (C) deuteranopic simulation of original image A and (D) deuteranopic simulation of enhanced image B.

4. CONCLUSION

The proposed method is expected to make something that are expressed visually and shared between people with color deficient vision and normal color vision, such as web pages, brochures, presentation materials and signage. If you use the proposed method for impediment removals of visual environment, you will not need to examine color accessibilities (whether neighboring colors are distinguishable to color deficient people), because the proposed method enhances the edges between regions with confusable colors automatically.

REFERENCES

Anagnostopoulos, C.-N., G. E. Tsekouras, I. Anagnostopoulos, and C. Kalloniatis. 2007. Intelligent modification for the daltonization process of digitized paintings. In *the 5th International Conference of Computer Vision Systems (ICVS 2007)*, *Proceedings*, ed. by Applied Computer Science Group, Bielefeld University, Germany: ISBN 978-3-00-020933-8.

Asada, K., M. Kobayasi, and S. Furukawa. 2011. A portable assistance tool for color-deficient individuals with real-time color changing function, In *AIC Color 2011*, *Proceedings*, ed. by V. M. Schindler, and S. Cuber. Zurich: pro/colore: 260-263.

Doliotis, P., G. Tsekouras, C. N. Anagnostopoulos, and V. Athitsos. 2009. Intelligent modification of colors in digitized paintings for enhancing the visual perception of color-blind viewers. In *IFIP International Federation for Information Processing* 296; *Artificial Intelligence Applications and Innovations III*; ed. by L. Iliadis, I. Vlahavas, and M. Bramer,; Boston: Springer. 293–301.

Ichikawa, M., K. Tanaka, S. Kondo, K. Hiroshima, K. Ichikawa, S. Tanabe, and K. Fukami. 2003. Web-page color modification for barrier-free color vision with genetic algorithm. *Lecture Notes in Computer Science* 2714: Springer-Verlag, 2134-2146.

Meguro, M., R. Hoshino, Y. Hibara. 2009. Color conversion method to perceptible images for color vision deficiencies by using combinatorial optimization. In *NCSP'09 international workshop on nonlinear circuits and signal processing*, *Proceedings*, Tokyo: Research Institute of Signal Processing, 285-288.

Nakauchi, S., and T. Onouchi. 2008. Detection and modification of confusing color combinations for red-green dichromats to achieve a color universal design. *Color Research and Application* 33(3), 203-211.

Viénot, F., H. Brettel, and J.D. Mollon 1999. Digital video colourmaps for checking the legibility of displays by dichromats. *Color Research and Application* 24(4): 243-252.

Yokota, S., A. Sasaki, H. Hashimoto, and Y. Ohyama. 2009. Automatic color conversion method for color-defective vision about presentation slides. *IEEJ Transactions on Electronics, Information and Systems* 129(4): 686-695.

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Estimation of human skin properties using smartphone

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ABSTRACT

This paper describes a method for estimating the optical properties of human skin surfaces based on multispectral imaging using a smartphone camera in natural scenes. First, we assumed that the spectral reflectance of the human skin surface can be described as a linear combination of some basic functions. The system conversion matrix from the camera output to the spectral reflection is estimated using a color chart and a spectrophotometer. Second, to estimate the multispectral reflectance of the human skin from uncalibrated smartphone camera outputs, we developed a simple calibration method that making a conversion matrix from an RGB color space of the uncalibrated camera to the RGB color space of the calibrated camera. Third, the melanin index and the hemoglobin index are estimated from the absorption properties of the spectral reflectance from the camera output. The total estimation method was implemented in the smartphone. Finally, to estimate and render the human skin, we implemented a reflection model of the human skin to the GPU of the smartphone.

1. INTRODUCTION

The color of human skin is determined by the optical properties of several materials such as the melanin and hemoglobin in skin[1)]. Knowledge of the optical properties of human skin can be useful in several fields such as cosmetology. To gain an understanding of the characteristics of the skin surface, it is essential to obtain information on spectral reflectance[2)]. However, the human skin surface has inhomogeneous reflection properties. Consequently, spectral imaging is the most useful method for measuring the properties of the skin surface. We need to generalize spectral imaging for easy use in any environment. Therefore, we decided to use a smartphone.

In this study, we proposed a spectral imaging method using a smartphone camera. The proposed method can calibrate camera sensitivity and illumination environment with the color chart. Moreover, we simultaneously estimated the hemoglobin, melanin, and blood oxygen saturation, which are surface properties of the skin surface. Finally, we showed a CG rendering system for the smartphone with an estimated spectral reflectance.

2. CAMERA MODEL OF THE SMARTPHONE

Generally, the camera of a smartphone has an automatic exposure and an automatic white balance function. The camera output is modeled in the visible wavelength [400–700 nm] as follows.

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \int_{400}^{700} E(\lambda)S(\lambda) \begin{bmatrix} r_{\mathrm{r}}(\lambda,t) \\ r_{\mathrm{g}}(\lambda,t) \\ r_{\mathrm{b}}(\lambda,t) \end{bmatrix} d\lambda \quad (1)$$

$E(\lambda)$ is the spectral distribution of light sources, $S(\lambda)$ is the spectral reflectance of the objects, $r_{\mathrm{r}}(\lambda,t), r_{\mathrm{g}}(\lambda,t), r_{\mathrm{b}}(\lambda,t)$ are the spectral sensitivity functions of the sensor *RGB*, and *t* is the time parameter.

3. ESTIMATED METHOD OF THE SPECTRAL REFLECTANCE

In this study, we used two cameras. The first one is a camera system that was calibrated to remove the influence of spectral sensitivity and illumination environment beforehand. The second one is an uncalibrated camera having spectral sensitivity and illumination. For the model, sensitivity properties change over a time *t*. We measured a k-colored color chart in both the calibrated and uncalibrated cameras. The camera output of the calibrated camera assumes a matrix $\mathbf{\Lambda}_{\mathrm{C}}$ of 3**k*. The camera output of the uncalibrated camera assumes a matrix $\mathbf{\Lambda}_{\mathrm{U}}(t)$ of 3*k, including the sensitivity change t by the automatic exposure and white balance of the camera. We describe the relations of the camera output for both in the following expression using the color conversion line **T**.

$$\mathbf{\Lambda}_{\mathrm{C}} = \mathbf{T}(t)\mathbf{\Lambda}_{\mathrm{U}}(t) \quad (2)$$

We estimated **T** as $\mathbf{T}(t) = \mathbf{\Lambda}_{\mathrm{C}}\mathbf{\Lambda}^{+}_{\mathrm{U}}(t)$ using the pseudo-inverse matrix Λ_{c} of matrix Λ_{c}. In this study, we obtained a conversion matrix **T**(*t*) in time *t* by measuring a color chart that becomes the standard at the time of photography. We can calculate the heaviness coefficient matrix as in the next expression when we express an image of the uncalibrated camera of a number of pixels n in matrix $\mathbf{C}_{\mathrm{U}}$ of 3*n.

$$\mathbf{W}(t) = \mathbf{M}\mathbf{\Lambda}_{\mathrm{C}}\mathbf{\Lambda}^{+}_{\mathrm{U}}(t)\mathbf{C}_{\mathrm{U}} \quad (3)$$

If **W**(*t*) can be calculated, the spectral reflectance can be estimated once we know the spectral reflectance of the human skin. We can render the CG of the human skin using the multispectral reflection model[2)]. The system is implemented to the graphics processing unit (GPU) on the smartphone[3)].

4. ESTIMATE OF PIGMENTS OF THE SKIN SURFACE

In previous studies, several methods have been proposed for estimating the melanin index and

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the hemoglobin index from the spectral reflectance [3]. In this study, we propose a method to more easily estimate the melanin index, hemoglobin index, and blood oxygen saturation. We measured the targeted value of these parameters using a skin measurement system that was made by employing a skin measurement system (KONICA MINOLTA CM-600d and skin measurement software CM-SA). In this study, we measured many samples to determine the spectral reflectance of the skin. We describe the spectral reflectance as a 61*1 vector $\mathbf{s}_1, \mathbf{s}_2, \ldots, \mathbf{s}_n$ in the visible wavelength [400–700 nm]. The relation of the melanin index m_1, $m_2, \ldots, m_n$, hemoglobin index $h_1, h_2, \ldots, h_n$ and blood oxygen saturation $b_1, b_2, \ldots, b_n$ with the spectral reflectance is described as

$$[m_1, m_2, \ldots, m_n] = \mathbf{T}_m [\mathbf{s}_1, \mathbf{s}_2, \ldots, \mathbf{s}_n] \quad (4)$$

$$[h_1, h_2, \ldots, h_n] = \mathbf{T}_h [\mathbf{s}_1, \mathbf{s}_2, \ldots, \mathbf{s}_n] \quad (5)$$

$$[b_1, b_2, \ldots, b_n] = \mathbf{T}_b [\mathbf{s}_1, \mathbf{s}_2, \ldots, \mathbf{s}_n] \quad (6)$$

where $\mathbf{T}_m, \mathbf{T}_h, \mathbf{T}_b$ is a 1*61 conversion matrix obtained from the spectral reflectance for the quantity of the pigment. If these can be calculated, we can estimate the quantity of each pigment of the skin from the spectral reflectance. We can calculate $\mathbf{T}_m, \mathbf{T}_h, \mathbf{T}_b$ using the least-squares method from the measurement data of each unit.

5. EXPERIMENTAL RESULTS

Using the smartphone camera, we performed experiments that estimated the surface reflection properties from an image. For the smartphone, we used a Motorola Atrix4G phone. In this experiment, we estimated surface reflection properties such as the spectral reflectance of the skin surface, melanin index, hemoglobin index, and blood oxygen saturation. We measured the spectral reflectance of 226 sets of skin surface pigments as training data for machine learning. In this experiment, we estimated surface reflection properties of the skin of subjects. Figure 1 shows the measurement position of the human skin and the estimated result of the spectral reflectance. Figure 2 shows the rendering result of the human skin with the estimated spectral reflectance. Table 1 shows estimation results of the melanin index, hemoglobin index, and blood oxygen saturation.

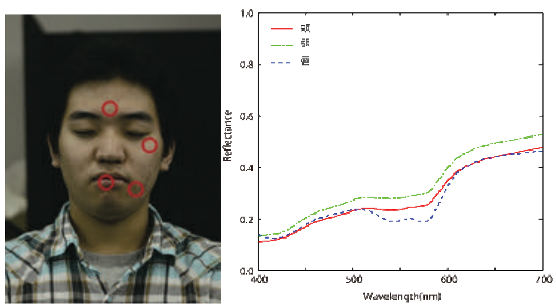

Figure 1 Measurement positions and estimated results of the spectral reflectance

Figure 2 Rendering result of the human skin with the estimated spectral reflectance.

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Table 1 Estimated result and measured data of pigment of the skin surface

	Melanin index	Hb index	HbSo2(%)
Measured data (forehead)	1.17	1.69	41.7
Estimate data (forehead)	1.18	1.7	40.7
Measured data (Cheeks)	1.17	1.54	44.5
Estimate data (Cheeks)	1.19	1.56	44.6

6. CONCLUSIONS

We proposed a method for estimating the spectral reflectance and several optical reflection properties using a smartphone camera. To estimate the multispectral reflectance of the human skin from the outputs of an uncalibrated smartphone camera, we developed a simple calibration method that makes a conversion matrix from the RGB color space of the uncalibrated camera to the RGB color space of the calibrated camera. The melanin index and the hemoglobin index were estimated from the absorption properties of the spectral reflectance from the camera output. To estimate and render the human skin, we implemented the reflection model of the human skin on the GPU of the smartphone.

REFERENCES

1) Y. Masuda et al: An innovative method to measure skin pigmentation, Skin Research and Technology, Vol. 15, pp.224-229, 2009.

2) N. Tanaka et al: Color Image Rendering of Human Skin Based on Multi-spectral Reflection Model, Vol. 36, suppl., pp.242-243, 2012.

3) R. Fernando et al., GPU Gems: Programming Techniques, Tips and Tricks for Real-Time Graphics, Addison-Wesley Professional, 2004.

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Color Conversion in a Tolerance Quadrangle for Energy Saving

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ABSTRACT

In recent years, different color temperature is used in different environment or different demand of users, and color temperature conversion is applied in many fields just like lighting, color displays, and many other fields. In the previous literature, when we adjust the white point of device to the target color temperature, we have many choices on the isotemperature line. One method to find the maximal luminance on the isotemperature line is that the point is intersected by the isotemperature line of the target color temperature and the gravity-center line of the color boundary apexes. Moreover, according to specifications for the Chromaticity of Solid State Lighting Products in 2008, that proposed by American National Standards Institute (ANSI). A tolerance quadrangle of color temperature is proposed for lighting product variation. From the view point of the color gamut volume, when the luminance reduces, the apexes of color gamut boundary expand along the three lines of gravity-center. Therefore, the color gamut boundary expands outward as the luminance reducing. When the apex of the color gamut boundary first meets the point of intersection between the line of gravity-center and the quadrangle defined by ANSI, this point is the maximal luminance solution of color temperature conversion. This method can gain more energy, and also can be applied in energy saving of LED lighting and display.

1. INTRODUCTION

In lighting, color displays, and many other fields, color temperature (CT) is used for characteristics of visible light. At one light source, the color temperature is the temperature of Planckian's radiator, whose radiator and chromaticity are the same. Thus, color temperature is used to represent the chromaticity of a light source. Many nature and artificial light sources, whose chrmaticities aren't on the Planckian locus. Hence "correlated color temperature" (CCT) is used to describe the temperature of blackbody, whose chromaticity is the nearest that of light source. In other words, CCT is used to instead of Planckian locus, describe its characteristic of a light source. In order to achieve images and temperature accurately between different media device, many researches of CT and CCT applications are proposed [2]. Color temperature conversion is one way of improving color management for image displays. Although the methods of using gain of R, G, B to achieve the CT or the white point in displays are directly and cost effective. Actually, the brightness will decrease when converting a white point to another. According to specifications (C78.377-2008) for the Chromaticity of Solid State Lighting Products proposed by ANSI [3] and the 7-step MacAdam ellipses [4], human's perception of different color and images has tolerance that is defined by MacAdam ellipses. ANSI proposed the tolerance quadrangles of solid state lighting in different color temperature. In this paper, the theory of converting the original white point to another color temperature with the maximal brightness inside the tolerance quadrangle of that color temperature is proposed. Finally, the simulations and experiments are compared to prove our theory.

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2. METHOD

According to specifications (C78.377-2008), a tolerance quadrangle in different color temperature is proposed for the Chromaticity of Solid State Lighting Products. We can calculate the tolerance quadrangle by solving (2-1) and (2-2), excluding eight nominal CCTs (2700K, 3000K, 3500K, 4000K, 4500K, 5000K, 5700K, 6500K) listed in Table 1 in the specification C78.377-2008 of ANSI.

$$\Delta T = 0.0000108 \times T^2 + 0.0262 \times T + 8 \qquad (2\text{-}1)$$

$$D_{uv} = 57700 \times (\frac{1}{T})^2 - 44.6 \times (\frac{1}{T}) + 0.0085 \qquad (2\text{-}2)$$

Where T is target CCT, and the isotemperature line of target CCT marked as a dotted line intersects the black body radiation curve marked as a dash line at point B in Figure 1(a). A is located on isotemperature line of target CCT by the distance D_{uv} from point B on the Planckian locus in Figure 1(a). D_{uv} with + sign and - sign are for above and for below the Planckian locus respectively. The tolerance quadrangle is marked as solid line showing in Figure 1(a). ΔT is color temperature tolerance. The lines T+ΔT and T-ΔT are the two isotemperature lines intersect the Planckian locus. The other two lines of the quadrangle are the distance of 0.006 above and below from the point A in Figure 1(a).

When we convert the original white point to another point, the brightness will decrease. The apex of color gamut boundary would expand along the center of gravity line of primaries [1]. According to the color mixing theory, the apexes of tri-primaries color are constructed by arbitrary two chromaticity of tri-primaries color fully opening and the various brightness of the other primary. These three apexes are all on the gravity line of the tri-primaries. And these three apexes compose a triangle showing as the left figure of Figure 1(b). When the brightness decreases, the triangle will expand along the center of gravity line of tri-primaries proportionally, and the area of triangle will increase. When the triangle first meets the tolerance quadrangle of one color temperature, the intersection point P has the maximal brightness among the region of the tolerance quadrangle as Figure 1(b) showing.

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3. SIMULATION AND EXPERIMENTATION RESULT

The simulations were based on measurement data of a 24 inch LCD (Viewsonic VX2433wm). The chromaticity coordinates of tri-primary colors, R, G, and B, are (0.6562, 0.3257), (0.2777, 0.6215), and (0.1462, 0.0704) respectively. The brightness of tri-primary colors are 40.988, 140, and 13.526 respectively. 5000K was taken as the color temperature target, and the four apexes of tolerance quadrangle are (0.3376, 0.3616), (0.3551, 0.376), (0.3515, 0.3487), and (0.3366, 0.3369). The tolerance quadrangle area was divided into 433 sampling points uniformly. The brightness of simulations for the four apexes of tolerance quadrangle are 167.6229, 156.271, 141.8841, and 150.1461 respectively. The brightness of measurement for the four apexes of tolerance quadrangle are 168.76, 160.4, 145.28, and 153.14 respectively. All the simulations and measurements are shown in Figure 2. The average color difference of 433 points in LAB color space between the simulations and measurements is 0.9351. The errors may come from the light leakage of LCD, and the ambient light.

4. CONCLUSIONS

This paper introduced the concept of CCT to obtain the maximal brightness when we convert one color temperature to another. The tolerance quadrangle of one color temperature is proposed to gain more energy. The method is converting one color temperature to a specific color temperature with maximal brightness at the first intersection point between the tolerance quadrangle and the triangle expanding from the gravity-center line. The simulations and measurements show that the first intersection point is coincident. In the future, we will try to solve the impact of light leakage to get more exactly result. Moreover, the method can by applied for LED lighting, display, and many other applications for saving energy.

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REFERENCES

[1] T.-W. Huang, *"Optimize Maximal Brightness and Correlated Color Temperature for Multi-primary color displays",* Taiwan, (2009)

[2] Honam, L., Hyungjin, C., Bonggeun, L., Sewoong, P., and Bongsoon, K., *"One-dimensional conversion of color temperature in perceived illumination,"* Consumer Electronics, IEEE Transactions on 47, 340-346 (2001).

[3] American National Standards Institute , *" Specifications for the Chromaticity of Solid State Lighting Products"* ANSI_NEMA_ANSLG C78.377-2008 (2008)

[4] Mike Wood ," MacAdam ellipses", Out of the wood(2010)

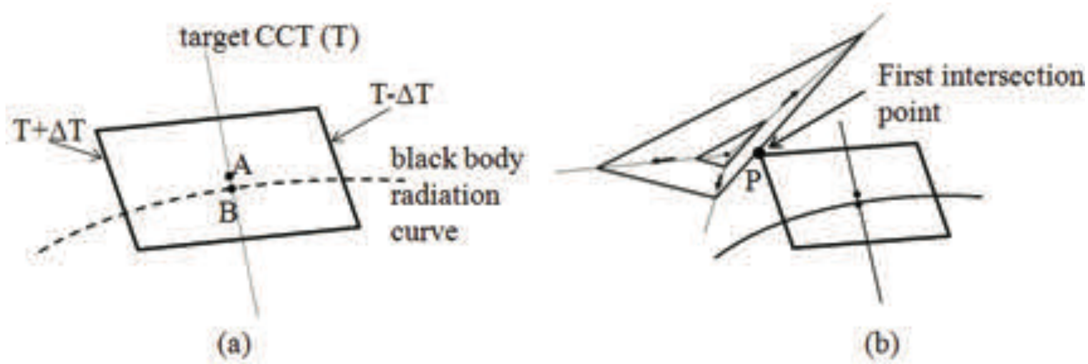

Figure 1. (a): The tolerance quadrangle of target CCT. (b): The intersection point between the color gamut boundary and the tolerance quadrangle of Figure 1(a).

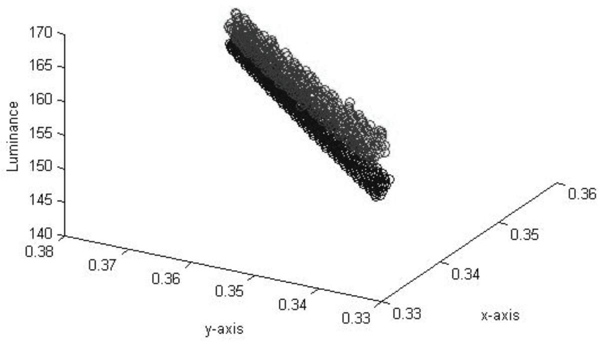

Figure 2. The simulation and measuring data of LCD (black: simulation, gray: measurement)

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Estimation and Simulation of Spectral Reflectance Based on Subtractive Color Mixing

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ABSTRACT

In this paper, we proposed a new spectral reflectance model, named Checker-based spectral reflectance (CSR) model, for its estimation and simulation. The spectral reflectance of objects, in this CSR model, is defined as the linear combination of three real observed spectrums of Macbeth color checker; that is, C, M, and Y color blocks, with an error term. The coefficients of the linear combination can be directly derived from the sRGB channel values of pixels in an image without any complicate computation.

The method of natural neighbor interpolation is applied to solve the error term in this model for improving its accuracy; moreover, we also proposed a series of mathematical spectrums, called Ideal Spectral Reflectance Family (ISRF), to refine the parameter estimation in error term.

Some experiments were performed with the test samples from Gretag Macbeth digital SG color checker. The results show that the average of MSE (mean square error) is 0.0050, the maximum is 0.0837, and the minimum is zero. Furthermore, the color differences (ΔE_{2000}) between the real spectrums and simulated ones under the illuminant of daylight 6500K were also evaluated. The average difference is 2.215, the maximum is 14.577, and the minimum is zero.
Keyword: Spectral reflectance, Tristimulus values, Macbeth color checker, Natural neighbor interpolation.

1. INTRODUCTION

In recent years, many researchers proposed methods to present the spectral reflectance of objects that describe the image color in more detail and with more accuracy than the traditional R, G, and B values.[1] However, measuring the spectral reflectance of an object by an optical device is quite expensive and difficult; therefore, various approaches to the reflectance estimation were proposed. One example would be principle component analysis method.[2]

In this paper, we propose a model of spectral reflectance of the object, Checker-based Spectral Reflectance (CSR) model that new method is developed for the estimation of spectral reflectance of the object. Taking the spectral reflectance of color No.16 (Yellow), No.17 (Magenta), and No.18 (Cyan) of Macbeth color checker as the bases[3], providing proper weighted coefficients and applying the method of natural neighbor interpolation[4], we can obtain an accurate spectral reflectance. The method we designed can directly derive the spectral reflectance of the object from acquiring the RGB values of the pixel in the digital image.

The remainder of this paper is divided into three sections. The second section of this article is our method in full detail of the model and formulas derivation. This is followed by experimental results in Section 3, with a thorough description of procedures, instruments, results, and evaluations. Finally, the conclusions and future works are drawn in Section 4.

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2. SPECTRAL REFLECTANCE RECONSTRUCTION

The CSR model, parameter estimation and the formula derivation are elaborated in the following section.

2.1 CSR Model

Firstly, the spectral reflectance model of objects indicating a pixel is defined by the following equations:

$$R(\lambda) = [c_C \cdot B_c(\lambda) + c_M \cdot B_{\mathrm{M}}(\lambda) + c_Y \cdot B_{\mathrm{Y}}(\lambda)] + E(\lambda)$$
$$c_C = (1 - \mathbf{R})/3$$
$$c_M = (1 - \mathbf{G})/3$$
$$c_Y = (1 - \mathbf{B})/3 \text{,} \quad (1)$$

where $R(\lambda)$ is spectral reflectance. c_C, c_M, and c_Y are the coefficients generated by RGB channel values of pixel, they ranges between 0 and 1/3, because we normalized $c_C + c_M + c_Y = 1$. $B_C(\lambda)$, $B_M(\lambda)$, and $B_{\mathrm{Y}}(\lambda)$ are three CMY spectral bases according to Macbeth color checker No.18 (cyan), No.17 (magenta), and No.16 (yellow), named as spectral absorptive bases. $E(\lambda)$ is the error between real spectral reflectance and reconstructed ones. The wavelength λ varied from 400nm to 700nm at 5 nm intervals.

Eq. (1) can be expressed in the matrix form as Eq. (2):

$$\boldsymbol{R} = \boldsymbol{c} \cdot \boldsymbol{B} + \boldsymbol{E} \text{,} \quad (2)$$

In the Eq. (2), $\boldsymbol{c} \cdot \boldsymbol{B}$ can be directly calculated, however; ***E*** must be obtained through the process of parameter estimation, and we will discuss it in section 2.2.

2.2 Parameter estimation

To obtain the error values, firstly, we construct parameter estimation from coefficients and natural neighbor interpolation method as follows:

$$\boldsymbol{E} = \boldsymbol{F}(\boldsymbol{c}) = \left\{x \in \mathbb{R}^3 \,|\, d(x, x_j) \le d(x, x_j) \forall = 1 \dots n\right\}, \quad (3)$$

where ***F*** is interpolation function, x is an element of 3-dimensional space, and $d(\mathbf{a}, \mathbf{b})$ denotes the Euclidean distance between the points **a** and **b**. If we take **c** into Eq. (3), the ***E*** can be obtained.

Secondly, we took the spectral reflectance of Macbeth color checker, spectral power distribution (SPD) of the daylight 6500K, and CIE 1931 2-deg color matching functions (CMF) into Tristimulus formula so that the XYZ values are calculated. Furthermore, we transform its color space and normalize it to CMY coefficients.

Thirdly, taking CMY coefficients, three bases, and original the spectral reflectance of

Macbeth color checker into Eq. (1), we can get a set of error values.

Finally, we took a set of CMY coefficients and error values into Eq. (3), and we could generate 61 of parameter estimation formula $F_1, F_2, F_3 \dots F_{61}$, etc.

We use Macbeth digital SG color checker as data to test our parameter estimation, however; the result show that there are 96 data Not a Number (NaN) because of 24 spectral reflectance training data cannot surround all color gamut, and the interpolation values falls outside of color gamut.

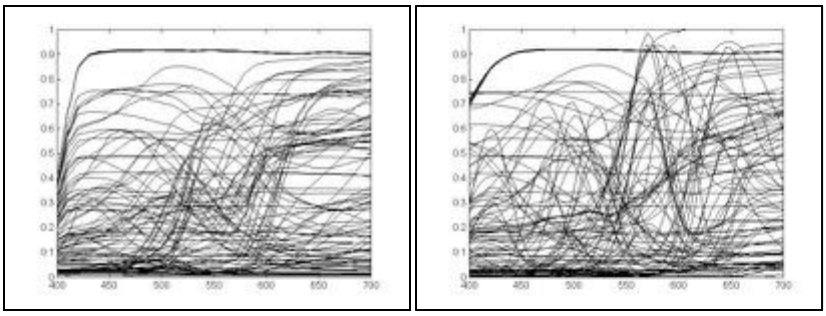
In order to improve the accuracy of parameter estimation, we proposed Ideal Spectral Reflectance Family (ISRF) to the original spectral reflectance data and generated new ones. The ISRF means a set of virtual curve created by mathematical function, six types are applied: Gaussian1 (peak), Gaussian 2 (flat), Inverse-Gaussian, Right Sigmoid Gaussian, Left Sigmoid Gaussian, and Flat. After proposing the ISRF, there have no one NaN.

3. EXPERIMENT AND RESULTS

In this experiment, we took Gretag Macbeth digital SG Color checker® as a standard subject. We estimated the spectral reflectance of the color checker under the 6500K daylight and compared with original spectral reflectance data to evaluate the performance by Mean square error (MSE) and color difference formula ΔE_{2000}.[5]

Firstly, we took the spectral reflectance of SG Color checker® to calculate the CMY coefficients under the daylight of 6500K for SPD, CIE 1931 2-deg CMF. Secondly, we took CMY coefficients into Eq. (3) to estimate the error values. Finally, taking CMY coefficients, bases, and error values into Eq. (1), the spectral reflectance is reconstructed.

Then we use MSE to evaluate our model and compare the color difference between our reconstruction and original testing data under daylight 6500k using ΔE_{2000}. The results are shown as Figure1, Table 1, and Table 2.



(a) **(b)**

*Figure 1. Spectral reflectance of **(a)** original **(b)** reconstruction SG color checker*

Table 1. Evaluation of MSE and Color difference

	MSE	Color difference
Maximum	0.0837	14.577
Minimum	0.0000	0.000
Average	0.0050	2.215

Table 2. Color difference

range	Percent (%)
0 ~ 0.5	32.14 %
0.5 ~ 3.0	44.29 %
3.0 ~ 12.0	22.14 %
12 ~	1.43 %

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By inputting Macbeth digital SG color checker as testing data, the accuracy of the estimated spectral reflectance is quite high in this research. The experimental result shows that the average of MSE is 0.0050, the maximum is 0.0837, and the minimum is zero (0.0000). Under daylight series 6500K illuminants, experimental result is evaluated by ΔE_{2000}, color difference less than 3 is 76.43%, larger than 12 is 1.43%, the average is 2.215, the maximum is 14.577, and the minimum is 0.000. It reveals that the result is satisfactory but there is room for improvement for some colors in the future research.

4. CONCLUSIONS AND FUTURE WORKS

The CSR estimation of spectral reflectance that we proposed is simply modeled by a linear combination of three basic spectrums of C, M, and Y colors respectively. Such bases are considered as the kernel to represent the reflective characteristic of objects, and are derived and estimated with the principle of subtractive color mixing. The outcomes of our method in reconstruction of spectral reflectance of 6500K daylight were satisfactory.

There are some further works to be studied in the future. Firstly, we just discuss the SPD for daylight series 6500k, however; much other kind of illuminants could be taken into our research. Secondly, we could compare the result generated from PCA method with our reconstruction to evaluate the accuracy of our model, and to refine our model if it needed.

REFERENCES

[1] Berns, R. S., F. H. Imai, P. D. Burns, and D. Y. Tzeng. 1998. Multi-spectral-based color reproduction research at the Munsell Color Science Laboratory. In *SPIE 1998*, *Proceedings*, ed. by Bares, J. Bellingham: SPIE, 14-25.

[2] Westland, S., and C. Ripamonti. 2004. *Computational Colour Science using Matlab*. New York: John Wiley and Son.

[3] Munsell Color Science Laboratory. 2011. Spectral data: Macbeth Colorchecker. Available online, www.cis.rit.edu/research/mcsl/online/cie.php. Accessed: May 20, 2012.

[4] Abed, F. M., S. H. Amirshahi, and M. R. Abed. 2009. Reconstruction of reflectance data using an interpolation technique. *Journal of the Optical Society of America A* 26(3): 613-624.

[5] Sharma, G., W. Wu, and E. N. Dalal. 2005. The CIEDE2000 color-difference formula: Implementation notes, supplementary test data, and mathematical observations. *Color Research Application* 30(1): 21-30.

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An effective training of neural networks for categorical color perception

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ABSTRACT

The automatic color recognition technology which can correctly discriminate a categorical color under various environments the same way as human is required. If we make the computer vision system can recognize color the same way as human, we must consider humans visual characteristics such as categorical color perception or color constancy in color recognition system. In this previous research, the authors did categorical color naming experiment for getting the color perception model. In this result, we find that the vote of the subjects was split for one pattern, and such pattern was observed in many. For this reason, we regard that humans percept the multiple colors for specific colors and we must make the color perception model can recognize similarly. In getting the model, the relationship between the chromaticity of color chips under different illuminations and human categorical color perception for the color chips under the illumination has be learned using a structured neural network. In this paper, we propose a new model with the modified training data for high recognition performance and perception the multiple colors. In addition, we evaluate the model performance using images taken in various illuminants conditions. As a result, we show that the categorical color recognition by the proposal model was increased accuracy.

1. INTRODUCTION

Humans often use color information in everyday communications. We can distinguish subtle differences between several similar colors. On the other hand, we use rough color category such as red or blue when we tell a color to others. This is categorical color perception that is used in the latter case (Berlin 1999).On the other hand, an object color is not only exclusively distinguish by the reflection spectrum from the surface object is but also greatly influenced by the ambient environmental conditions. We humans, however, can stably perceive an inherent an object color even reflection spectrum from the object changes according to spectrum of ambient light. This is called color constancy. The automatic color recognition technology which can correctly discriminate a categorical color under various environments the same way as human is required. Therefore it is difficult that to acquire the auto color perception model that recognize as well as humans without depending on the illumination. Yata et al. create the categorical color perception model using neural-network that used training data gotten in categorical color naming experiment (Yata 2008). But the model still has two problems. First, the recognition accuracies of some of the categories are low because of biased training data. The 424 OSA color chips, used in the experiment categorical color naming, are not uniform for each category. Second, the training data structure used in the model is not suitable to percept near the color category boundary. In this study, a number of trainings on each category to uniformly and improve the training data structure. We propose a new categorical color perception model that can recognize better than the traditional model. And we evaluate performance of our model for natural images with a camera.

2. A METHOD OF UNIFRMLY TRAINING OF EACH CATEGORY

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We propose a method of uniformly training of each category. The number of our training data is skewed for each category. The proposed method controls a number of trainings on each data, for the times of training of each category are uniformly. There are two steps to calculate the number of trainings. First, determine the weights on the amounts of learning on each category. i is a number of category, w_i is a weight of each category, P is a total number of data patterns, p is a number of data pattern, d_{ip} is a percentage of votes, D is a total output value. The weight in each category is given by eq.(1).

$$w_i = D / \sum_{p=1}^{P} d_{ip} \qquad (1)$$

Second, determine training times about each data. C is a total number of categories, t_p is a training times of pattern p. Training times is given by eq.(2).

$$t_p = \sum_{i=0}^{C} d_{ip} w_i \qquad (2)$$

Figure 1: The numbers of training on each category. Blue bars show before uniforming, orange bars show after uniforming, and red line shows the average.

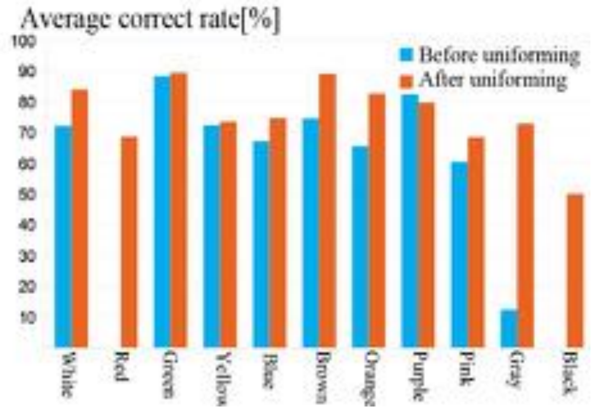

Figure 2: The performance comparison of average correct rate of answers under ten unknown illuminants.

The numbers of training on each category are shown in figure 1. The performance comparison between before and after uniforming is shown in figure 2. The graph indicate the average correct rate of answers of the models which under ten unknown illuminants. We see from figure 2 that the proposal model can get better perception than the previous model.

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3. PERECEPTIONS FOR THE COLORS NEAR CATEGORICAL BOUNDARY

Table1: The result of categorical color naming experiment which focuses on percentages of numbers of categories response for each pattern.

Numbers of categories	1	2	3	4	5
Percentages (%)	48.27	37.97	11.95	1.77	0.08

The result of categorical color naming experiment which focuses on the percentages of numbers of categories response for each pattern shows Table 1. The majority of patterns take the more than one category as shown in Table 1. For this reason, the divided patterns should be considered as the colors near categorical boundary.

Table2: Example of improved training data.

	White	Gray	Blue
Training values for the previous model	0.5	0.25	0.25
Training values for our proposal model	1.0	1.0	1.0

The previous model uses percentage of responses for each of categories in categorical color naming as the training data. In cases where the training values for divided patterns were low, it is difficult to output all color names of colors near the categorical boundary. So the training data for proposal model take the maximum value "1.0," regardless of the response percentages. Examples of improved training data shown in Table 2.

Table3: Performances comparison between before improving the training data and after.

Model	Correctly	Precision	Recall
Previous model (%)	92.3	65.9	84.8
Proposal model (%)	94.6	74.9	87.9

The previous model determines results which color names by the maximum output of neural networks. By contrast, the new model needs to recognize more than one category. Therefore, the results of the proposal model are determined from the categories which output more than a controlled threshold. The value which gets the best result of the color names accuracy rate is defined as the threshold. The results of categorical color naming are used as the correct color names in this process. We evaluate the results for colors near the categorical boundary in percentages of correctly, precision and recall. Table 3 shows the performances comparison between before improving the training data and after. The proposal model can gets better perception by improving training data. In the results, the model can recognize the multiple color categories with good precision.

4. PERFORMANCE EVALUATION FOR NATURAL IMAGES WITH A CAMERA

The performances for natural images with a camera on various illumination environments are evaluated. We use images of color checker which has twenty four patches as input images for evaluating the proposal model. The correct color names of twenty four patches are determined based on subjective evaluation by three peoples. We use four illuminations: three LED lamps, and the sunlight. Table 4 shows the performance of proposal and previous models under the four illuminations. The proposal model gets better performance under the all illuminations.Figure3 shows the results of color recognition by the proposal model.

Table4: The performances of the natural images under the four illuminations.

	CIE-*xy* (*x*, *y*)	Previous model		Proposal model	
		Numbers of correct	**Percentages of correct**	**Numbers of correct**	**Percentages of correct**
LED1	(0.444, 0.412)	11	45.8	21	87.5
LED2	(0.367, 0.372)	15	62.5	23	95.8
LED3	(0.342, 0.360)	13	54.2	22	91.7
SUN	(0.417, 0.380)	15	62.5	23	95.8

Figure3: The results of color recognition by the proposal model. The left is the input image and the right shows the output colors from the proposal model.

5. CONCLUSIONS

The purpose in this study is to get better performances of color name recognitions. So, we propose two methods: uniformly training of each category, and improving the training data structure to recognize colors near the categorical boundary. The proposal model gets better perception in each category through the influence of the uniforming. And the model can recognize some color names of colors near the categorical boundary correctly. The results of evaluation, the proposal model demonstrate superior performance of color recognition for natural images with a camera.

REFERENCES

Berlin, B., P. Kay. 1999. *Basic Color Terms: Their Universality and Evolution.* University of California Press.

Noriko Y., K. Uchikawa, T. Nagao.2008. Categorical Color Perception for Image Segmentation using Neural Network .*Transactions of Information Processing Society of Japan.* 49(SIG 4(TO 20)): 1-7.

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Development of a skin analysis system based on the 3D facial avatar

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ABSTRACT

This paper describes a skin analysis system that analyzes human facial skin condition using 3D model data of a facial avatar. The prototype of commercial skin analysis system was developed as a result of the study. Current skin analysis systems typically use 2D images captured by high resolution digital cameras under various illumination conditions. The light sources for current skin analysis systems include white flash light, UV-A flash light(365 nm UV light), and polarized light. While the current systems are concerned about obtaining the high-resolution 2D images to acquire fine facial skin images for accurate skin analysis, this study is concerned about how to increase reality in skin analysis procedures. We have therefore developed a novel skin analysis system that operates directly on 3D facial model.

1. INTRODUCTION

Several skin analysis systems that use high resolution 2D images for skin diseases diagnosis have been recently developed. Those systems usually consist of high-resolution imaging devices with multiple light sources. The main purpose of imaging devices for current skin analysis systems is to capture and deliver fine and accurate spatial information of human faces for further analysis procedures, and therefore it usually requires high-definition 2D facial images as input data. However, to provide more natural and immersive user interfaces, it would be necessary to directly operate on 3D facial models with high-quality skin texture images. We therefore developed a facial skin analysis system based on 3D facial avatars that is capable of detecting facial freckles, measuring facial glossiness, and determining facial color. Our system consists of four stereo cameras for 3D facial model construction and several LED type light sources as shown in figure 1 and figure 2. A 3D facial model is constructed using two or more images captured by the stereo cameras and rendered using three different texture maps that have been obtained under different light sources such as daylight, UV light, and polarized light respectively.

(a) (b)

Figure 1. Capture system:(a)front of 3D scanner and controller, (b)stereo camra module

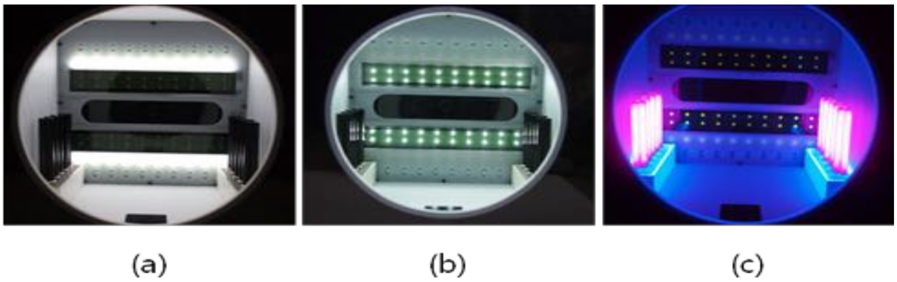


Figure 2. Light sources:(a) daylight(white, 5500 ˚K), (b) polarized light, (c) UV-A light

2. 3D FACIAL MODEL GENERATION

Figure 3. shows the process of 3D facial model generation. We used multi-camera calibration algorithm to perform camera calibration in a pre-processing step. The calibration algorithm used a small 3D reference rig[1] to obtain the parameters of the stereo cameras. Extrinsic and intrinsic camera parameters could also be recovered only by capturing the reference rig. When the system captures a user's face using the stereo cameras(Olympus E-PM1 was used), face segmentation is performed first to obtain the facial area from the images. Face segmentation is conducted by using color codebook in which background color has been stored. Color codebook is data set of background colors. It is used to subtract face. As a result of subtraction, binary masks is generated shown in Figure 3 (c). Pairwise stereo matching algorithm is then applied to generate two different disparity maps one for the two images captured by two cameras in the left side and the other by two cameras in the right side. The two disparity maps are then combined to generate the final disparity map and a texture map is generated by projecting 3D point onto the captured images.

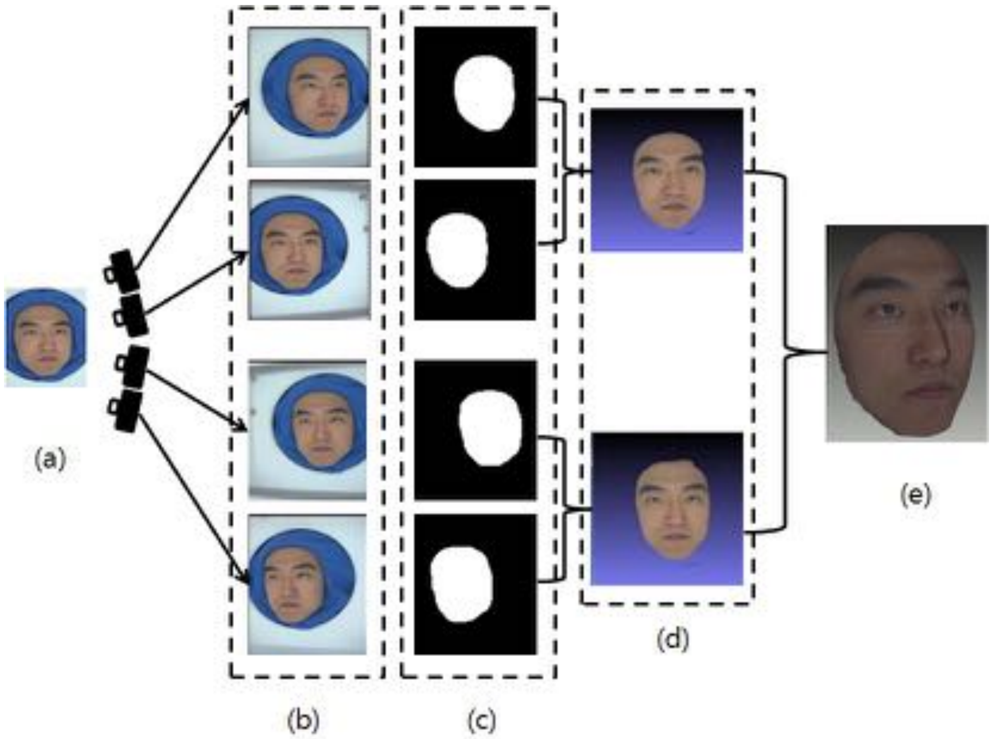
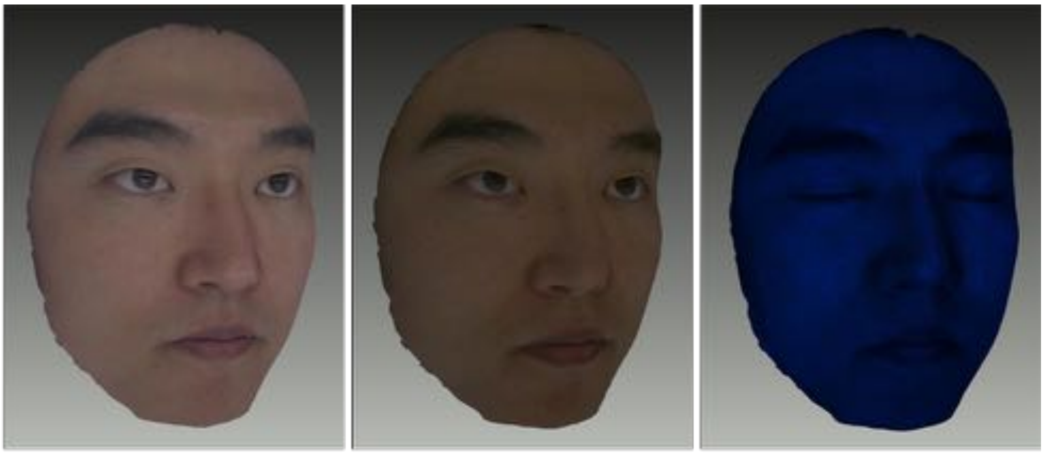


Figure 3. 3D model generation:(a)capturing face images, (b)captured images, (c) masks, (d)left and right temporary models, (e) final 3D model

[1] 3D reference rig is small cube that is printed periodic circle array on each face of cube.

3. SKIN ANALYSIS 3D MODEL

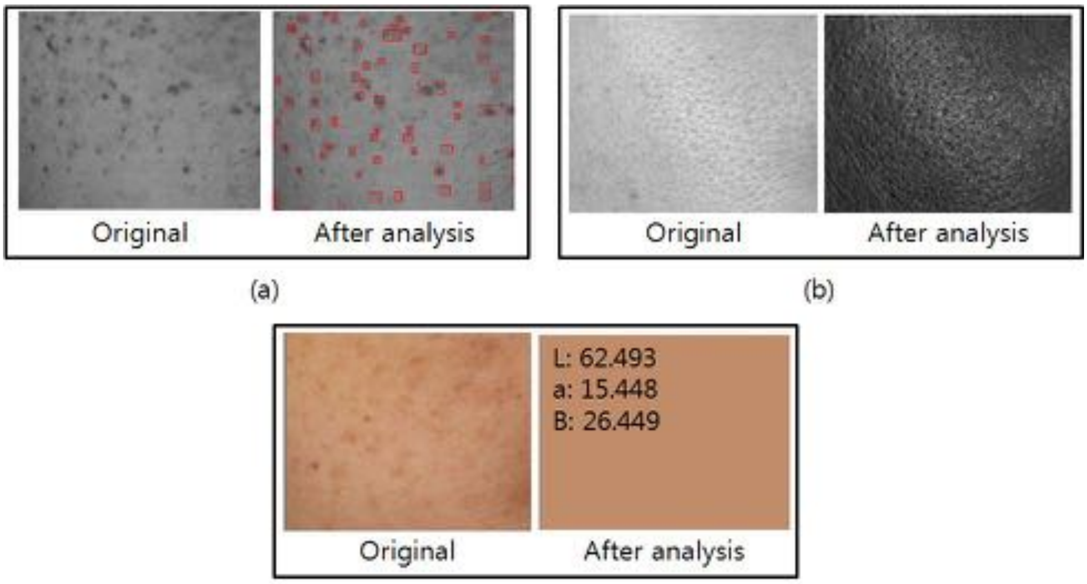
Our system generates three different types of texture maps that contain textures obtained under different light sources such as standard light, UV light, and polarized light. It has been recognized that standard light textures are suitable for measuring skin color and tone, UV light textures for detecting pores and assessing hydration of the skin and hyper-pigmentation, and polarized light textures for observing epidermis and skin surfaces. Figure 5 shows examples of original 3D model textures and results of freckles detection, glossiness estimation, and skin color measurement.



(a) (b) (c)

Figure 4. 3D model textures:(a) under the general light, (b)unter the polarized light, (c) under the UV light

True color reproduction based on digital device characterization is a key technology to increase analysis accuracy and produce promising results. Our system supports ICC profile to provide characterized 3D model textures and used LUT(Look-Up Table) for fast color transformations. Our system could reproduce actual skin colors and therefore provides more convincing skin analysis capability.



(c)

Figure 5. Result of skin analysis:(a) excessive pigmentaion, (b) glossiness, (c) skin color

4. CONCLUSION

In this paper, we developed a novel skin analysis system that operates directly on 3D facial models and performs facial skin analysis. 3D facial model with three different types of textures could produce more satisfactory results. We are currently downsizing the hardware to commercialize the system and working on code optimization and parallel processing using GPUs for real-time operation.

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REFERENCES

Jae-Hean Kim and Bon-Ki Koo(2011), Multi-camera Calibration Using Multi-view Constraints, Korea-Japan joint workshop on Frontiers of Computer Vision.

Beeler, T., Bickel, B., Sumner, R., Beardsley, P., and Gross, M(2010), High-quality single-shot capture of facial geometry. ACM Trans. Graphics (Proc. SIGGRAPH), 40.

Digital Photographic GmbH(VISIA[tm] System), http://www.visia-complexion-analysis.com

Sharma G(2003), *Digital Color Imaging Handbook*, CRC Press.

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Colours of Architectural Metal Surfaces

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ABSTRACT

Contemporary buildings interact with human beings mainly through their surface. Among all the types of existing surfaces, metallic materials seem to play a very important role. A study recently conducted by the "Colour and Light in Architecture" Research Unit of Iuav University of Venice, after classifying these materials and their color, has tried to frame the types of the stage effects that metal surfaces are capable of producing. We have identified three different effects: 1) the metallic color can be used to impress and stun the observer; 2) the metallic color can be used to dematerialize the mass of the building, to reduce its presence in the context; 3) the metallic color can be used to create harmonious relationships with the surrounding environment through the use of color contrasts or color agreements.

The paper aims to describe the methodology we have used and the results we have obtained, with particular attention to the cultural references taken into consideration for the identification of the research parameters. The ultimate goal of the paper is to describe the three different color effects produced by the metal surfaces by drawing on a sample of metal-buildings constructed in the last years.

1. CLASSIFICATION OF THE COLOURS OF METALS

In the book *Facciate Metalliche* (Metal Façades), published by the Italian Utet Scienze Tecniche in 2012, the author of this research proposed a classification of the colors of metallic materials for façade claddings. According to Pietro Zennaro's classification of technological expressiveness of materials (P. Zennaro, 2011), there may be natural and artificial colors.

Natural colors can be original or entropic. The original color belongs to the material which has not undergone treatment or other types of alteration. The entropic color belongs to the material which has undergone changes due to external agents (i.e. oxidation, pollution, temporary effects related to light etc..). Artificial colors are due to application or removal of material and superficial work.

2. METHODOLOGY OF THE RESEARCH

The first step of the research involved the collection of case studies. We chose buildings of recent construction, located around the world. The main characteristic of the building was related to its external surface that has to be covered with metal for more than 70%. Of course the surface of the building could be made with any metallic material. We collected approximately 60 case studies, trying to have at least one building for each classified material.

The second step of the research involved the analysis of the case studies. We took at least two photos of each building. Thanks to a photo editing software we selected the main colors emerging from any single image. These colors were placed into a diagram and compared with the possible color harmonies or color contrasts, according to Johannes Itten's Color Theory.

The next step consisted in putting together similar results. So we found cases in which the study showed a research for a monochromy of the entire environment: those cases were catalogued as “colors that dematerialize the building”. In other situations we found buildings where we had color harmonies or color contrasts (with 2 or more hues). These cases were collected into two different categories: “colors that impress the observer” and “colors for harmonious environmental relationships”.

3. COLOURS THAT IMPRESS THE OBSERVER

As we all know, contemporary architecture often tries to impress (K. Gasparini, 2009). This can be done in very different ways. One of these ways is represented by the use of shocking colors, quite common on painted metals. A similar effect can be obtained working with color contrasts. In Itten’s Color Theory “the seven contrasts are: 1. Contrast of hue; 2. Contrast of light and dark; 3. Contrast of warm and cool; 4. Contrast of complements; 5.Simultaneous contrast; 6. Contrast of saturation; 7. Contrast of extension” (J. Itten, 1982, p. 34).

Shocking colors are generally high saturated: crimson red, fuchsia, lemon yellow, primrose yellow etc.. Jean Nouvel is well known for a provocative use of these colors. Let see for example the metal façade of the Quai Branly Museum in Paris (2006) or the famous Red Kilometer along A4 motorway in Italy. Another significant example is the new Enzo Ferrari Museum in Modena (Italy, 2012) by Future Systems, the last work of Jan Kaplický built after his death. The building is characterized by its large yellow cover made of aluminum strips that follow the sinuous curves of the shape designed by the Czech architect.

Color contrasts can be created working on different part of the façade of the building. A typical situation in which we have a contrast of hue is represented by the presence of red, yellow and blue. This is a solution often practiced. In the ECAL School of Art in Renens (Switzerland, 2007) Bernard Tschumi alternates external aluminum venetian blinds colored in red, yellow and blue on a background of light gray corrugated metal skin. It is also possible to exploit the contrast of saturation. The corrugated surface of the Experimental Factory in Magdeburg by Sauerbruch & Hutton (2003) exploits this principle being painted with regular bands of orange, pink and blue. Orange and pink are high saturated, while blue is lighter, probably “cut” with gray, so that the first two colors are dominant. The building as a whole appears to be wrapped in colorful ribbons, almost packaged as a gift.

4. COLOURS THAT DEMATERIALIZE THE BUILDING

In some cases the surface quality of the metal skin creates an effect of dematerialization of the building envelope and the building itself seems to disappear in the surrounding context. It happens, for example, in the buildings designed by Dominique Perrault who uses the metal fabric to make *non-walls* that lose the material consistency of concrete or brick mass and become filters, evanescent skin, almost immaterial.

We have found two ways to achieve this particular effect: 1) the research for monochrome that produces a sort of camouflage through the use of green or blue surfaces merging themselves in the natural environment (water, sky, grass, vegetation, etc..); 2) the use of shiny and high reflective surfaces, almost like big mirrors that cancel their physical presence by reflecting the color of everything around them.

The large flat blue façade of the Art Gallery of Ontario in Toronto by Frank Gehry (2008) is an example of the first way. In the play of color it seems to disappear, absorbed by the blue sky and becoming a theater stage for the early twentieth century brick façades that stand in front of it. Similarly, the green façade of the Team Disneyland in Anaheim, California (1996), is a large slab that blends its color with the sky and the surrounding vegetation.

The case of Nemo, the Museum of Science and Technology in Amsterdam designed by Renzo Piano in 1997 is emblematic. Located in the port of the Dutch city, beneath it lies the body of water, above it the sky reflected on the water. The building is entirely clad in green oxidized copper. Observed through an out of focus lens, the mirrors of water and sky are expanded in a panoramic view and the building tends to disappear in the background. The pattern formed by the copper plates disappears, the green color is partially absorbed in the blue water and partially in the blue sky.

Large surfaces made of stainless steel, aluminum or titanium belong to the second way. They act like large reflective mirrors that are tinged with the surrounding colors: the colors of buildings, asphalt, green, sky, water, etc.. Particular environmental conditions can cause specific effects: for example the presence of a blanket of snow covering the surrounding environment and a particularly clear winter sky cause the aluminum surfaces to become white. However, he most revealing example is represented by the Aplix Factory near Nantes by Dominique Perrault (2000). Its facade is clad in mirror polished stainless steel and shaped with serrated ridges. The steel surface reflects the sky and the green fields surrounding and then cuts them at the horizon line with a very dark line of trees that look like a large black spot extending along the entire facade. The building blends with nature and becomes the emblem of a factory that wants to declare itself eco-friendly.

5. COLOURS FOR HARMONIOUS ENVIRONMENTAL RELATIONSHIPS

Environmental relationships can be made with color harmonies or color contrasts, according to Itten's Color Theory. Color harmonies may be of two, three or four colors, identified by the vertices of a regular polygon inscribed in the famous color wheel.

In some cases the designers, taking inspiration from the lessons of the past, use the color of the metal to deal with the sky, creating contrasts of primary colors. This is what happens with the Berlin Philharmonic by Hans Scharoun (1956-63): the building is mostly covered with embossed gold aluminum that defines the shape of the building with a perfect contrast of primary colors: yellow, gold and blue. Les Folies buildings in Parc de la Villette (Paris, 1992), designed by Bernard Tschumi, are coated with bright red vitreous enamel in a perfect contrast with the blue sky. Where the green of nature prevails over the other colors, the designer often chooses the contrast of complements. In the *building-sculpture* for the Graffiti Museum, at the Caves of Niaux (Switzerland, 1993), Massimiliano Fuksas uses the red-orange of rust cor-ten steel, creating a contrast of complements between the rusted metal skin that emerges from the rock and green trees of the valley below. The same type of contrast is found in the colors chosen by MVRDV for the headquarters of the company RVU TV in Hilversum (The Netherlands, 1997). Even in this case, the cladding is in cor-ten steel while the hill on which the building stands is covered by a deep green lawn. Even UNStudio in the Agora Theater in Lelystad (The Netherlands, 2007) tried a similar effect: the orange building contrasts with the green of the lawn and with the blue of the sky.

Color harmonies and contrasts can be found also in the relationships between the buildings. For the Amitié residential complex in Montreuil (1993), the architects Dubosc & Landowski have chosen a blue painted steel surface. The building stands on a plot in the historic center of the city, next to a series of buildings characterized by brick or plaster vertical surfaces and roofing tiles from Marseilles. The relationship that develops between the blue metal and the materials of the surrounding buildings corresponds to chromatic harmonies between the primary colors. A top view with a glimpse of the road that separates the new building from the existing ones shows the three colors: the metal façade is blue, tiles are red and the facades are predominantly on shades of yellow.

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6. CONCLUSIONS

The results obtained from this research demonstrate that the methodology implemented can potentially be applied to other materials or situations. The research can also be useful to better understand how buildings can relate to the surrounding environment. This aspect is very important because it can help us to understand how to improve the environmental quality of places through the use of color. In particular we understand how the color can be used to get some scenic effects. Through these tools we can have a check on the modulation of the surfaces of the building according to specific requirements of color balance that can be inferred from the surrounding environment. This can lead to the adoption of appropriate solutions to improve certain aspects of the perception of the places, in a particular and in a general way, because as stated by Marc Augé "the great global architecture is part of the current global aesthetics, which is an aesthetic of distance, which tends to make us ignore all the effects of breakage. To tell the truth, is the context to be changed, is the context to be global" (Augé, 2009, p. 15).

REFERENCES

Albers, J. 1975, *Interaction of Color*. New Haven: Yale University Press

Arnheim, R. 1954, *Art and Visual Perception: A Psychology of the Creative Eye*. Berkeley and Los Angeles: University of California Press

Augé, M. 2009, *Non-lieux*, 2nd Edition, Paris : Editions du Seuil.

Gasparini, K. 2009, *Design in superficie. Tecnologie dell'involucro mediatico,* Milan: Franco Angeli.

Itten, J. 1961, *The Art of Color*, New York: John Wiley & Sons.

Premier, A. 2012, *Facciate Metalliche*, Turin: UTET Scienze Tecniche.

Zahner, L. W. 1995, *Architectural Metals: a guide to selection, specification and performance*, New York: John Wiley & Sons.

Zahner, L. W. 2005, *Architectural Metal Surfaces*, New York: John Wiley & Sons.

Zennaro, P. 2011, "Il colore delle superfici" in Premier, A., editor, *inSuperficie. Percezione e realizzazione delle superfici architettoniche contemporanee*, Verona: Knemesi.

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A Study of The Relationship Between Urban Colour and Public Art: Exemplified by the Treasure Hill Environmental Color

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PREFACE

Public Art, which integrates visual art, space and environmental construction, has been a worldwide trend in the past twenty to thirty years. When art enters a city's public space, it doesn't just offer citizens more opportunity to interact with it, but certainly brings a change to the environment. In early years, Taiwan's government deemed public art only a form of statues or memorials, whose positions and usage weren't normally settled until the construction work was finished. Compared to the selection of material, the relation between an artwork and environmental color was often neglected; therefore, a tight "partnership" or connection between an artwork and a public construction work wasn't really common back then.

In 1992, Taiwan first had its own official policy for public art funding. All the public buildings were expected to commission public art as a way to beautify the buildings and environment, and a public art budget shouldn't be lower than one percent of the building's construction scheme. Since public art functions as a drive for developing urban space and providing more art experience for citizens, public art is no longer a sole "piece of art" in public space but strides to build a city's image and takes more responsibility to play a role in citizens' aesthetic experience and lifestyle. For decades, the government has constantly increased funds on public art, which has now developed into a diversity of forms and an "innovative" style. The current public art policy in Taiwan has further accepted non-material, reachless works and the events-based interventions into its public art domain.

ENVIRONMENTAL COLOR AND PUBLIC ART DEVELOPMENT

The survey in environmental color started in 1960, and since then, it has represented an aesthetic combination and relationship between a region's culture and environment, and has also stridden to take the whole environment into account. However, with the fast-paced urbanization, which accelerates the deterioration in the living quality, Taiwan's citizens have had more solid awareness of environmental preservation and demanded better living quality, which then prompts the government to pay more attention to the color usage in the environment. Though the government included and emphasized "The Urban Color Schemes" in its civic aesthetic policy in

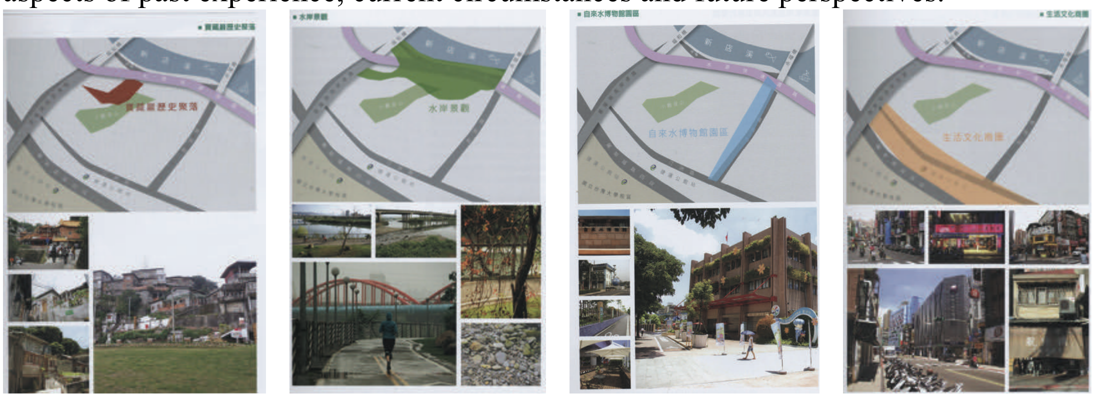
2009, there hasn't seemed to be any progress in the exact way of planning and executing the scheme. Neither is there any light for the decision of color choice in public space and the way of using colors to harmonize outdoor space.

As the capital, Taipei has endeavored to establish its images and marketing schemes, and its public art development has also taken the lead for the fact that it possesses larger proportion of public constructions. The 2010 *Taipei Flora Expo* further prompted the scheme of "*Beautiful Taipei*", hoping to effectively integrate and unite the capital's differing districts aesthetically. Taking part in the public art scheme in the Treasure Hill area, the author of the thesis got to observe the development in public art in the Gong-guan district.The thesis is based on the two public art schemes, *The Floating Color Codes in Treasure Hill,* which differs from the previous public art cases that didn't really take color survey as the priority. The scheme is the first public art case that specifically targets at "environmental color" issue.

The Floating Color Codes in Treasure Hill

An urban transformation or landmark formation in the hands of artists and architects is a rather common form of urban reformation. With the policy of aesthetic lifestyle policy promoted by the Council for Cultural Affairs in 2009, the Urban Color Schemes has been highly concerned by the governing bodies. Nevertheless, there hasn't seemed to be any constructive progress in the execution of the Color schemes nor a solid consideration for the exact choice and usage of colors in public space. Even though there is a growing people-public art interaction in Taiwan's public space, environment color is often the "blind side" in a public area, and people are prone to ignore the visual value and effects of colors.

The author was invited by the Taipei City Council as the artist in residency at the Treasure Hill Artist Village, where the author's major task was to develop a public art scheme specializing in environmental color, which combined colorists art creativity, survey, and education, launching a cross-seasonal field study and creativity in the aspects of past experience, current circumstances and future perspectives.



The project was based in the following places: Hsintian Creek Coastal Area, Treasure Hill Historic Village, Taipei Water Park, and Gong-guan district. To enforce cross-field cooperation and effectiveness, the team of The Floating Color Codes in Treasure Hill was composed of the members from the field of arts, landscape architecture to architecture. During the period of the environmental color survey, through daily and seasonal photographic recording, the environmental survey began and gradually built its database of historical and current colors, which is expected to provide a future reference for the development in environmental colors.

From 2010 to end of 2012, the survey continuously set up the data of environment al color in Gong-guan. The research method comprised of references and field study of environmental color, sampling and filing color-related data which included investigation, collection, and representation of both natural and artificial colors. Moreover, the research also featured the induction and analysis of interview documents and assessment of the relationship and effectiveness among public art artists, viewers and overall environment.

The scheme's methodology referred to the French Color Geographer, J.P. Lenclos' environmental color survey mode, sampling and analyzing the natural and artificial environmental colors in the areas of *Gong-guan coastline* and *Treasure Hill Community*. Moreover, combining the visual investigation methodology of S. Kobayashi, the scheme aimed to understand the changeable and unchangeable factors in environmental colors and further created a chroma-wheel of the fundamental colors in *Gong-guan* by sampling environmental colors, drawing, representing and photographing. The scheme would serve as a reference for Treasure Hill's future cultural conservation and organization.

The main objective of the scheme's environmental color survey was to capture the major color combinations and components in Treasure Hill so as to elaborate the relation between the architectural colors and regional geography including regional material and climate. Besides, the connection between man-made architectural colors and regional culture like regional custom, and tradition is also valued. Through studying the connections, our team obtained reference and database for the public art project, which was more likely to integrate into its surroundings in better harmony.

During the period of the environmental color survey, the public could participate in workshops to further explore the environmental colors around the Treasure Hill area. With various art activities, participants learned to distinguish natural and man-made colors around Treasure Hill, and further had better knowledge in fundamental, environmental and decorative colors. Within a year, the environmental survey began and gradually built its database of historical and current colors.

AFTERMATH AND SUGGESTIONS

In the cultural and historical Treasure hill area, many "overlooked" colors in public space were revealed through the study of the surroundings' basic tone of color. Later, we added artistic, public, educational, and extensive values to the color scheme with art placement. We further bridged people's perception to colors and past experience through a serious of color workshops, which aimed to encourage people's involvement in art activities in Gong-guan.

Through the public art project, *Floating Color Code it Treasure Hill*, it's concluded that environmental color should correspond to cultural preservation, and a sound communicative platform should be established for the residents, who are expected to express opinions, gain more sense of belongings to the reformed community. With the environmental chromatogram and color samples gathered from the research, we look forward to supporting culture and heritage conservation in Treasure Hill as well as setting a reference for future study of art's intervention in the environment.We sincerely advise the governing bodies to practically integrate colors into people's lives, and further invite the public to take part in the discussion of color relationship between public and environmental color so as to further enhance cities identity and cultural value.

REFERENCE

[1] J.P. Lenclos（1990）, *Couleurs de la France*, Moniteur, Paris.

[2] . Shigenobu Kobayashi,（1994）*景観の色とイメージ。ダヴィッド社*.

[3] Shigenobu Kobaya shi（1998）*Colorist—A Practical Handbookfor Personal and Profssional Use*。Kodansha.

[4] Chang Hwei-Lan (2011) *The Floating Color Codes in Treasure Hill*,Taipei : Taipei City Department of Cultural Affairs.

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Investigation on Chinese Colour Naming by College Students

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ABSTRACT

Colour naming depends on factors such as language, age, gender, nation, culture background, colour preference, and so on. The purpose of this investigation is to attempt to understand the relationship between the colour naming and the above mentioned factors. In the experiment, four colour series, i.e. pink, blue, orange, and cyan, in which each colour has a known English name, were selected. 66 Chinese college students were asked to name those colours in the four series in Chinese. The results indicated that: (1) Some colours were failed to be given Chinese names, the percentages of successfully named colours in four series were respectively 82.9% (pink), 85.9% (blue), 67.4% (orange), and 66.3% (cyan). (2)The percentages of colours with the same name in four series were respectively 21.1% (pink), 25.9% (blue), 12.5% (orange), and 14.0% (cyan). (3) Colour preference and association. (4) Similarities and differences between English and Chinese colour naming: generally, both in English and Chinese, colour names are associated with plants, minerals, materials, and natural scenes, but animal colours such as fish colour etc. are rarely used in Chinese names.

1 INTRODUCTION

We explored colour naming ability amongst college students in China, which factors affect colour preference and tested the similarities and differences between Chinese and English colour names (See Peng[1] (2007) and Xiang[2] (2011)).

Related researches focus on four aspects: relation between colour terms and cognition, colour naming, colour preference, and similarities and differences between different languages. Currently there are three views on the relation between colour terms and cognition: 1) colour naming universality which means that colour terms and cognition are mutually independent 2) linguistic relativity hypothesis which believes that colour terms affect colour cognition and 3) a combination of 1 and 2.

Whereas most research has focused on children (see Preyer[3] (1905), Winch[4] (1910), Lin et al.[5] (2001) and Liu et al.[6] (2004)) we worked with college students whose colour cognition had already matured. (Zhang et al.[7] (2007) worked with undergraduates from Yi, Bai and Naxi nationalities.) We also differed from other work by using four colour series, i.e. pink, blue, orange, and cyan rather than the colour patches more commonly used. Each colour was chosen from RGB to Color Name Reference (Walsh)[8] and had a known English name. There is no such reference in China. Previous researches have also mainly been concerned with correct percentages of colour naming; our work attempted to understand the relationship between the colour naming and factors such as language, gender, nation, cultural background, colour preference, and so on.

2 METHOD

In this experiment of 66 participants, whose ages varied from 18 to 23 years old, 45 were northerners and 21 southerners (i.e. different cultural background); 23 were females and 43 males (i.e. different genders). All participants had normal colour vision.

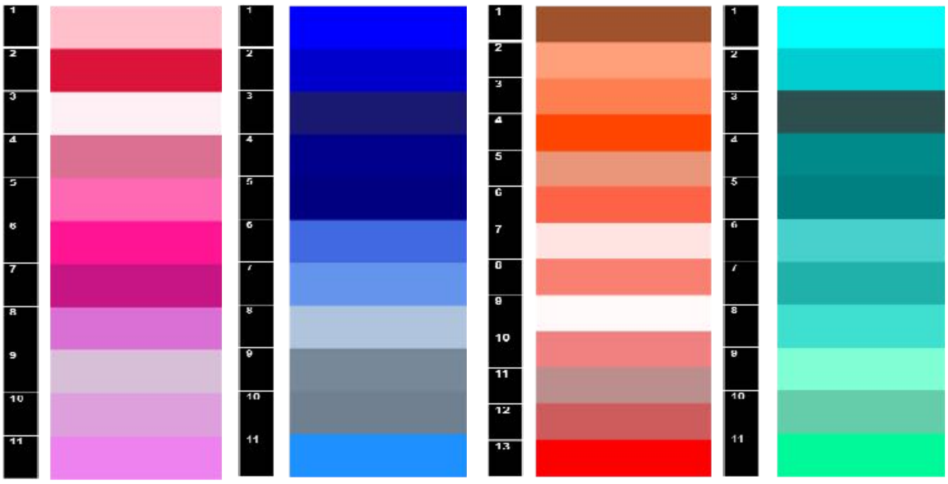

Figure 1. The 46 colours used from four of the colour series (P:pink B:blue O:orange C:cyan).

As Figure 1 showed, the 46 colour patches were presented on a large screen by a projector. The volunteers viewed the 46 colour patches together under indoor lighting conditions. They were required to name the 46 colour patches and secondly asked to write down the colours which they liked and disliked and to give their reasons.

3 RESULT & DISCUSSION

To explore which colour series is easy or difficult to name the participants were asked to attempt to name each colour. The percentages of successfully named colours in the four series i.e. pink, blue, orange, cyan were analysed.

Table 1. Mean percentages of colour naming and standard deviation in four serie.

series	P series	B series	O series	C series
mean percentages of colour naming(%)	82.9	85.9	67.4	66.3
standard deviation（10^{-2}）	11.3	6.7	17.4	14.5

To determine if the numbers in four series exhibited significant differences in colour naming, χ^2 (chi-squared tests) were conducted. Those in P and B did not show significant differences whereas O and C demonstrated significant differences. This indicated that the naming of colours in the P and B series was much easier than in O and C series.

The occurrence of same naming of colours by participants was analysed, see Table 2.

Table 2. The mean percentages of the same name of colour naming and standard deviation.

series	P series	B series	O series	C series
mean colour naming percentage（%）	21.1	25.9	12.5	14.0
standard deviation（10^{-2}）	12.3	4.4	9.4	10.0

Further χ^2 (chi-squared tests) showed that significant variation occurred only within the P, O and C series. Table 2 shows that P and B series had higher mean percentages of colours with the same name than O and C series. Furthermore, the standard deviation suggests that the degree of dispersion of colour naming percentages from high to low was pink, cyan, orange, and blue. The mean percentages of southerners vs. northerners(S:N) and females vs. males(F:M) in four series were also calculated. Result showed that in S:N more southerners gave the same name in P (107.1%) and B (113.3%) than northerners, in F:M more males gave the same name in P (99.1%) and C (94.5%) than females. From this result we could conclude that colour naming was related to culture background and gender.

In the second part of the experiment participants were asked to write down the colours which they liked and disliked.

Table 3. The numbers of participants which colours they liked and disliked in four series.

preference	numbers of participants which colours they liked in four series				numbers of participants which colours they disliked in four series			
series	P	B	O	C	P	B	O	C
S:N (%)	85.7	75.6	160.7	153.1	115.4	128.6	42.9	26.8
F:M (%)	115.1	120.2	74.8	93.5	100.7	112.2	187.0	53.4

When considering the results comparatively we can say: northerners preferred colours in P and B series whereas southerners preferred colours in O and C series; females liked colours in P and B series whereas males preferred colours in O and C series. It was also noted that females disliked colours in P series and B series more than males and that females had a significantly greater dislike than males for colours in O series. Males had a significantly greater dislike of colours in C series than the females.

In general, the colours the 66 participants liked had higher saturation and greater brightness; they thought these colours were festive, fresh, lively, energetic. Alternatively the colours which were generally disliked had lower saturation and lower brightness; they thought these colours were depressing and dull.

To explore the effect of language on colour naming the Chinese and English names of the 46 colours were analysed. The degree of variety between the two languages can be seen from the following Chinese/English examples: Weak Purple/Hot Pink; Flesh Coloured/Light Salmon; Brownish Red/Tomato; Blackish Green/Dark Slate Gray.

Colour naming depends on factors such as language, cultural background and so on. Generally, both in English and Chinese, basic colour names are used and often preceded by an adjective (light, dark,). Chinese naming, however, more often uses other colours as adjectives (Blue Black, Blackish Green, GreyWhite). Both languages use the natural world as reference points (Grass, Salmon, Spring, Flesh, Coral) but English has more stand-alone names not using basic colour names (Salmon, Teal (species of duck), Snow, Turquoise, Navy (after uniform worn by navy personnel)).

Only when we get the similarities and differences between Chinese and English colour names, can we understand the culture between Chinese and English culture better.

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4 CONCLUSION

The participants, stimulus, and the purposes of our experiment were different from the previous work, which is meaningful to the future research. Based on our data, we could conclude that: (1) The percentages of successfully named colours (82.9% (pink), 85.9% (blue), 67.4% (orange) and 66.3% (cyan)) showed that the colours in B series could be named most easily whereas colours in C series were most difficult; (2) The percentages of colours with the same name in four series showed that colour naming was related to cultural background and gender; (3) Colour preference was related to gender and cultural background; (4) There were similarities but sometimes significant differences between English and Chinese colour naming arising from living habits, culture, language habits, and so on.

Our data drew preliminary expected conclusions, and our research which laid a foundation for further study was in a creative open-source way.

REFERENCES

1. Peng Hong. 2007. Analysis of similarities and differences between the Chinese color words and English words in the cultural connotation. *Journal of Xinyu Junior College.* China: 63-66.
2. Xiang Rui. 2011. An exploration into connotative differences between Chinese and English colour words under the international background. *Journal of Hubei Radio and Television University.* China: 98-99.
3. Preyer W. 1905. The senses and the will. *D.Appleton and Company*, N. Y:4-14.
4. Winch W H. 1910. Colour names of English school children. *Amer.J.of psychol*.453-482.
5. Lin Zhongxian, Zhang Zenghui, Han Buxin. 2001. Development of colour naming among young children of different nationalities in China. *Acta Psychologica Sinica.* China, 33(4):333-337.
6. Liu Shaoying, Ge Liezhong, Zhu Yao. 2004. A research of colour pereference of children aged 4 to 6[J]. Psychological Science. China, 27(3):669-670.
7. Zhang Qirui, He Xiumei, Zhang Jijia. 2007. A comparative study on the classification of basic colour terms by undergraduates from Yi nationaliry, Bai nationality and Naxi nationality. *Acta Psychologica Sinica.* China, 39(1):18-26.
8. Kevin J. Walsh. RGB to Color Name Reference. http://web.njit.edu/~walsh.

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Models of architectural mimicry

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ABSTRACT

The article is devoted to an analysis of the phenomenon of social mimicry in architecture. Qualitative and quantitative characteristics of social mimicry, its structure and forms are studied. The author distinguishes and describes such types of architectural mimicry as camouflage, vernacular, stylistic, and functional. The ways of interaction of prototypes and imitators are analyzed.

1. INTRODUCTION

In nature we often find mimicry – the similarity of one species to another. For example, yellow stripes on the bodies of some flies make them look like wasps; many species of non-venomous snakes resemble the deadly coral snake or rattlesnake, etc. As a rule, the appearance has a defensive function: a harmless animal poses as harmful and thus saves its life. There is a similar phenomenon in the social sphere – social mimicry, a protective adaptation of individuals by following the group in their behavior and thinking.

2. THE STRUCTURE OF ARCHITECTURAL MIMICRY

The model of social mimicry structurally has a resemblance to natural mimicry. It comprises three main elements: a prototype object, an imitator object and an operator (an individual, small or large social groups).

However, in social mimicry man is not very often an imitator by himself/herself. Man makes the product of his/her activity similar to something that is not an object in reality. Thus, the structure of architectural mimicry increases and comprises four elements but not three.

Such a complicated structure is realized in architecture in a peculiar way. Mimicry is understood as close similarity between one architectural object (imitator) and another architectural or non- architectural object (prototype) that "deceives" the operator. Mimicry takes place when the operator begins to ascribe the properties of the prototype object to the imitator object.

3. THE CHARACTERISTICS OF THE MODEL OF MIMICRY

The model of social mimicry has qualitative and quantitative indices.

The discursive characteristic of the model, i.e. its connotative vectors, is a qualitative index. As a rule, mimicry manifests itself in the characteristics that are noticeable enough: shape, color. The underlying characteristics, e. g. the position and number of the elements, more often remain unchanged.

The effectiveness of the model, in other words, the capability of developing and the typical stages of development, is a quantitative index that shows the frequency of using the corresponding model of social mimicry and makes it possible to compare the frequencies of different models.

4. THE FORMS OF ARCHITECTURAL MIMICRY

One should distinguish between chromatic and morphologic mimicries. Chromatic mimicry (homochromism) is a color similarity of architectural objects to the other constructions or objects. Morphologic mimicry (homomorphism) implies not only color but also morphologic resemblance of an architectural object to the environment.

5. THE TYPES OF ARCHITECTURAL MIMICRY

As a result of the variety of prototype objects social mimicry in architecture falls into several types: camouflage, vernacular, stylistic, and functional mimicry.

5.1. Camouflage Mimicry

In the case of camouflage mimicry the imitator copies the form (camouflage homomorphism) or the color (camouflage homochromism) of the existing natural environment. In spite of the fact that architecture is included in the group of non-fine graphic arts of which it is not typical to copy the shapes of objects in reality, camouflage homochromism can be very often found in the history of art. So, in ancient times temple complexes (ziggurats, pyramids) were homochromic to mountains and hills as on their tops prayers were said in honor of the Sky Gods. In Romantic architecture cave-houses and park-like grottoes covered by shells were widespread.

Camouflage homochromism became more popular in town architecture. Since the second half of the 20th century the principles of this model have been used to form the color environment of residential areas (Lenclos 2003a).

The effectiveness of the model of camouflage mimicry increased remarkably due to the appearance of supergraphics which unlike classical monumental painting turned out not to be connected with the tectonics of frontages. Supergraphics camouflages architectural objects as non-architectural ones, very often as natural objects – sky, trees, flower buds, ice blocks. The object that is used as a prototype is noticeable in the discourse (in advertisements, publication, the description of projects) and is often reflected in the name if there is any.

It should be mentioned that in camouflage mimicry the prototype and the imitator can fail to coincide in size. The imitator very often turns out to be larger than the object that is copied. For instance, the duplication of the geometry of the desert flower Hymenocallis which is widespread in the Persian Gulf Region is reflected in the design of the tower Burj Dubaj (the United Arab Emirates).

The model and the imitator in case of social mimicry do not always have one and the same distribution area. For instance, the model of a building in a European city can become an iceberg. This very prototype was chosen as the image of a residential area in the docks of Aarhus in Denmark by the architect Julien de Smedt and CEBRA architects in cooperation with Louis Paillard and the company SeArch.

5.2. Vernacular Mimicry

Unlike camouflage mimicry, vernacular (from Latin *vernaculus* – "domestic, native") mimicry doesn't imitate the form (vernacular homomorphism) or the color (vernacular homochromism) of the natural objects, but the products of a certain culture. This type of mimicry presents an attempt to "build in" a construction in the actual architectural context by adding to it some specific elements of the culture.

If architecture is considered to be a special language, buildings of every region will be like a dialect of this language. The vocabulary of the architectural area contains unique signs that differ from the universal elements of the architectural language one way or another.

So, in Old Russian towns there are a lot of buildings that copy the shape of towers of a fortress wall, the texture and the color of the material of walls and roofs.

Another example of vernacular homochromism is the use of patterns and flowers of folk embroidery in architectural decoration. "Ample Pattern" (Uzoroche) took place in the decoration of many Russian churches.

Similar motives can be found in houses of the brick and Russian style of the 19th century. Brick and the absence of plaster of frontages make one and the same main red color of walls that contrasts with patterns. Multicolor polichromy of red brick and white flat, piers and window framing in rotation imitates folk patterns and often has a complicated picture reminding cross-stitch embroidery, basket weave, plaiting, curb, belts, a brick ornamental pattern in the form of a belt with triangle recesses (begunets).

The architecture of the soviet period is marked by the more primitive decoration of two-color brick laying (Грибер 2008).

In the history of architecture there are a lot of cases, when the author makes his construction look like the object of some other culture. The cases when the prototype and the construction are separated in space and belong to different cultures we will define as the cases of heterochromatic vernacular mimicry. A new construction in this case imitates alien shapes, copies an architectural structure which is typical of different architectural space. Such a building seems to be taken from another architectural context.

Cult constructions are influenced by homochromatic vernacular mimicry to a considerable extent. They are built according to the shape and typological architectural peculiarities which are understood as the clear symbol of the national religion. So, buildings of synagogues do not form one visual line. The architecture of these cult constructions does not conform with hard and fast canons, however, in most cases imitates the Moresque style.

5.3. Stylistic Mimicry

Stylistic mimicry is an imitation of architectural forms of a certain epoch or style. Stylistic mimicry always has a time vector. As a model for the imitation there may be chosen a form, that has been already experienced in architecture, or a new undeveloped form. Therefore stylistic mimicry may be retrospective or prospective.

The retardation in the development of the local architecture has several reasons. The main one is the lower level of technological and financial supply. That's why prospective mimicry is often accompanied by the imitation of new expensive construction technologies, materials and design. Thus, in the small-town architecture of the 1930s the imitation of Constructionism was widespread.

Stylistic mimicry is the permanent attribute of eclecticism. This style combines details of different historical epochs and forms its symbols as "there is a habit of connecting certain notions with a style" (Кириченко 1978: 98). Imitating the details of some epoch eclecticism creates its atmosphere.

5.4. Functional Mimicry

Functional mimicry stands for masking of some existing construction under the influence of the social environment. Functional mimicry usually spreads intensively at turning points of history.

In Smolensk, for instance, functional mimicry manifested itself in the period of the Polish invasion that influenced the development of the architecture in the territory in the first half of the 17th century. After the seizure of Smolensk, Uniates and Catholics began to arrive. The expansion of Catholicism was accompanied by the building of catholic churches in the territory of the town. Special cult constructions were rarely built. The reconstruction of available orthodox churches took place more often. To latinize the population Poles made catholic churches out of some local ones: a Jesuitical catholic church appeared in the town on Voznesenskya Hill (1611), a Dominican catholic church – on Kozlovskya Hill (1614), a catholic church (in the 1610s) instead of Trinity Church at Klovka, Mikhailovsky catholic church near Blonya and a catholic church in place of exploded Monomakhov Cathedral which was used as a Uniate cathedral later. The changes affected only outside attributes. Russian temples were partially reconstructed or only decorated under the influence of Early Baroque fashionable in Europe at that period (Белогорцев 1949: 30).

Another wave of mimicry can be observed in the architecture of the period of nationalism. In the course of nationalization many public and inhabited buildings were not used for their direct purposes. The information on the old functions was removed in different ways. The easiest way was to get rid of old symbols or to replace them by new ones. But more often buildings were repainted.

6. CONCLUSION

On the whole, the forms of architectural mimicry are characterized not only by diverse effectiveness and connotative vectors but also by various strategies of the interaction of the prototype and the imitator. In the case of camouflage mimicry prototypes are the natural objects (sky, water, trees, ground), in the case of vernacular mimicry – the products of culture, that do not react to their imitators. Functional mimicry is characterized by such an interaction, when the prototype and the imitator present a model for each other and become alike in the course of the evolution. Stylistic mimicry is like a typical parasitic case: an unadapted organism imitates a socially adjusted model. In this case the model may partially lose its protection (in nature it happens if some beasts eat the imitator and then attack the model). In the course of the evolution the model diverge from the imitator, and the latter tries to catch up with it.

REFERENCES

Белогорцев, И. 1949. *Архитектурный очерк Смоленска.* Смоленск: Смолгиз.

Грибер, Ю. 2008. *Эпистема цвета в смоленской архитектуре и живописи.* Смоленск: Маджента.

Кириченко, Е.И. 1978. *Русская архитектура 1830-1910-х годов.* М.: Искусство.

Lenclos, J.-P., D. Lenclos. 2003. *Couleurs du monde. Géographie de la couleur.* Paris: Le Moniteur.

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Preferable LED Lamps for Appearance of Skin Color of Human Face

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ABSTRACT

This study aims to determine the preferable LED lamps for the appearance of skin color of human face and to derive the preference evaluation structure. In the first experiment, subjects compared and evaluated the preference of skin color of two head mannequins under lighting conditions of 15 pairs of different lamps. In the second experiment, subjects evaluated the impression of the face of the head mannequin under 11 lighting conditions. In the first experiment, the result in 3000K shows that the preference of the skin color of the human face under all kinds of the LED lamps is better than the halogen lamps. In the second experiment, the result shows that the preference of the skin color of the human face is determined by the "familiarity" primarily, the "sophistication" and the"health".

1. INTRODUCTION

Recently, LED lamps have been installed in many buildings such as houses, restaurants and stores. The appearance of a human face in these buildings depends on the property of the LED lamps, color temperature and spectral distribution and so on.
This study aims to determine the preferable LED lamps for the appearance of skin color of human face and to derive the preference evaluation structure. We conducted two subjective experiments on the appearance of the skin color under some lighting conditions using head mannequins.

2. METHOD

In the first experiment, we made the experimental apparatus composed of 2 boxes which could equip lighting on the ceiling of each. We prepared two female head mannequins which was put on makeup (forehead; 7YR 7.25/4, cheek; 7YR 6.75/4). The experimental apparatus and the female head mannequin are shown in Figure 1. We also prepared 9 kinds of LED lamps which differed in correlated color temperature (*CCT*), color rendering index (*CRI*) and the distance from the blackbody curve for the color temperature (D_{UV}), the halogen lamp and the D_{65} fluorescent lamp. The lamps for the experiment equipment are shown in Table1. "high *CRI*-1" and "high *CRI*-2" lamps have high color rendering property with different spectral power distribution from each other. Firstly, subjects observed the head mannequin in the left box under a lighting condition. Next, they observed another one in the right box under another lighting condition, and evaluated the preference of skin color of the head mannequin compared with the left one with 7 steps categorical scale ('very good', 'good', 'somewhat good', 'same', 'somewhat bad', 'bad', and 'very bad') under the lighting conditions of 15 pairs of different lamps. Scheffe's method of paired comparison was employed for statistical analysis.

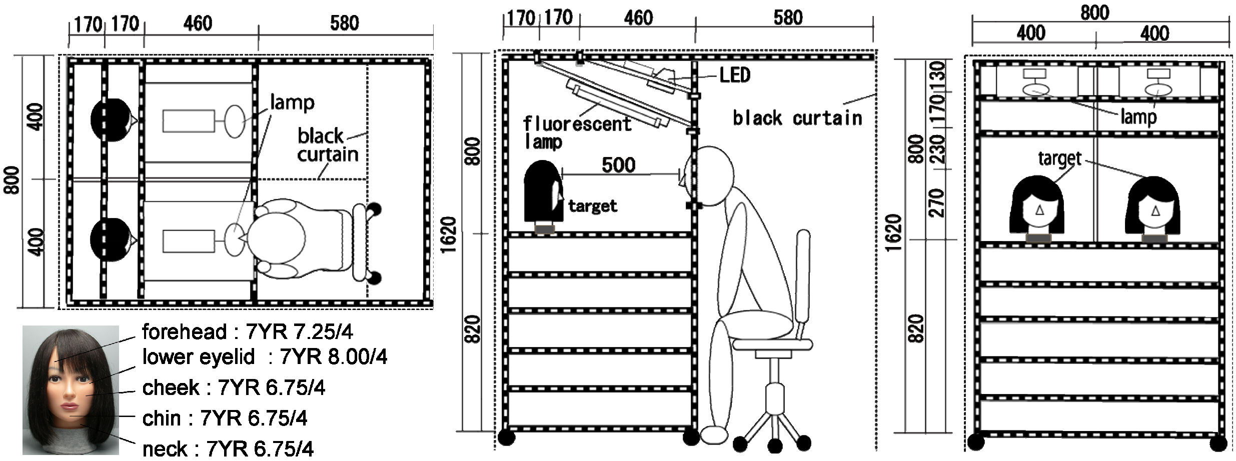

Figure 1 Experimental apparatus and female head mannequin

Table 1 Lamps for experimental equipment

number	the kind of lamps	*CCT*	*CRI*	*DUV*	*PS*	manufacturer and product number
1	LED lamp : high CRI-1	3000K	96	1.13	97	Panasonic・prototype
2	LED lamp : high CRI-2	3000K	93	1.63	95	Panasonic・LGB71773
3	LED lamp : high power	3000K	79	2.86	84	Panasonic・LGB71771
4	halogen lamp	3000K	91	4.93	95	Panasonic・JDR110V65WKM/7E11
5	LED lamp : high CRI-1	4000K	95	1.39	93	Panasonic・prototype
6	LED lamp : high CRI-2	4000K	90	-5.10	94	Panasonic・prototype
7	LED lamp : high power	4000K	75	-0.04	68	Panasonic・prototype
8	LED lamp : high CRI-1	5000K	97	3.08	91	Panasonic・prototype
9	LED lamp : high CRI-2	5000K	93	5.18	82	Panasonic・LGB71772
10	LED lamp : high power	5000K	69	3.92	40	Panasonic・LGB71770
11	D65 lamp	6500K	95	-0.18	82	TOSHIBA・FL20S・D-EDL-D65

In the second experiment, subjects evaluated the impression of the face of the head mannequin in terms of “skin tone”, “complexion”, “sophistication”, “health”, “activity” and “familiarity”, and also rated “preference” as the comprehensive evaluation with 7 steps numerical scale from 1 (which means bad) to 7 (which means good) under 11 lighting conditions. Subjects in these experiments were 10 university female students in their twenties.

3. RESULTS

In the first experiment, the preference of skin color of the head mannequin was analyzed by Yardstick method. The analyzed values are shown in Figure 2 for each *CCT*. The result in 3000K shows that the preference of the skin color of the human face under all kinds of the LED lamps is better than the halogen lamp and the significant differences are found between the LED lamps and the halogen lamp ($p<0.01$). The result in 4000K shows that the preference under the high *CRI* LED lamps are better than under the high power LED lamp and the significant differences are found between the high *CRI* LED lamps and the high power LED lamp ($p<0.05$). The result in 5000K shows that the preference under all kind of the LED lamps is better than under D_{65} lamp and it also shows that the LED lamps which had high *CRI* value are preferred to the other LED lamps. But, there are no significant differences between 5000K LED lamps.

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In the second experiment, the impressions of the face of the head mannequin were analyzed by multiple regression analysis with "preference" as the dependent variable and other items as the independent variables. The standard partial regression coefficient using all lamps is shown in Table 2. It shows that the preference of the skin color of the human face is determined by "familiarity" primarily, "sophistication" and "health".

Figure 3 shows the frequency distribution and the average of the replies of 10 subjects about "sophistication", "health", "familiarity", and "preference". The results in 3000K shows that the average of each term in halogen lamp is evaluated 4 or less and all kinds of LED lamps are evaluated 4 or more. It also shows that high *CRI*-1 LED lamp is evaluated 4 or more by all subjects. The results in 4000K show that high *CRI*-2 LED lamp is evaluated 4 or more in the average of each term. It also shows that high power lamp is evaluated 4 or less. The results in 5000K show that the average of each term high *CRI*-1 LED lamp is evaluated 4 or more. It also shows that high power lamp and D_{65} lamp is 4 or less.

In addition, the relationship between the evaluation results of the impression ("sophistication", "health", "familiarity", and "preference") and indices of lamps, such as '*CCT*', 'D_{UV}', '*CRI*', and '*PS*'[1] were analyzed. *PS* is an index of preference of facial skin color. Figure 4 shows the relationship between the evaluation results of the "preference" and $CCT/D_{UV}/CRI/PS$. The correlation coefficients between "preference" and $CCT/D_{UV}/CRI/PS$ are 0.6657, 0.2347, 0.6721 and 0.8042, respectively. It also shows that there is a high correlation between '*PS*' and the "preference".

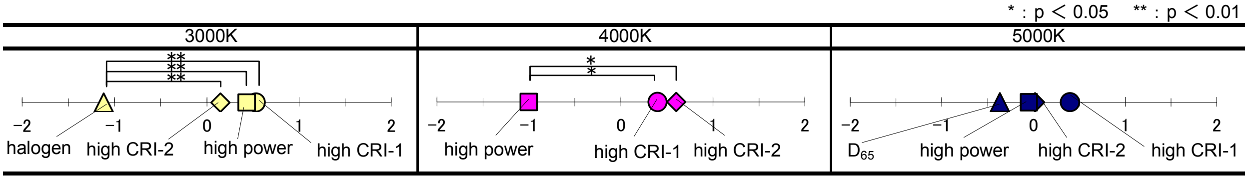

Figure 2 Analyzed value of the preference of the skin color of the human face under each CCT

Table 2 Standard partial regression coefficient using all lamps

explanatory	skin tone	complexion	sophistication	health	activity	familiarity
dependent	-.053	-.033	**.337** ***	**.301** ***	-.151	**.569** ***

*** : p < 0.001

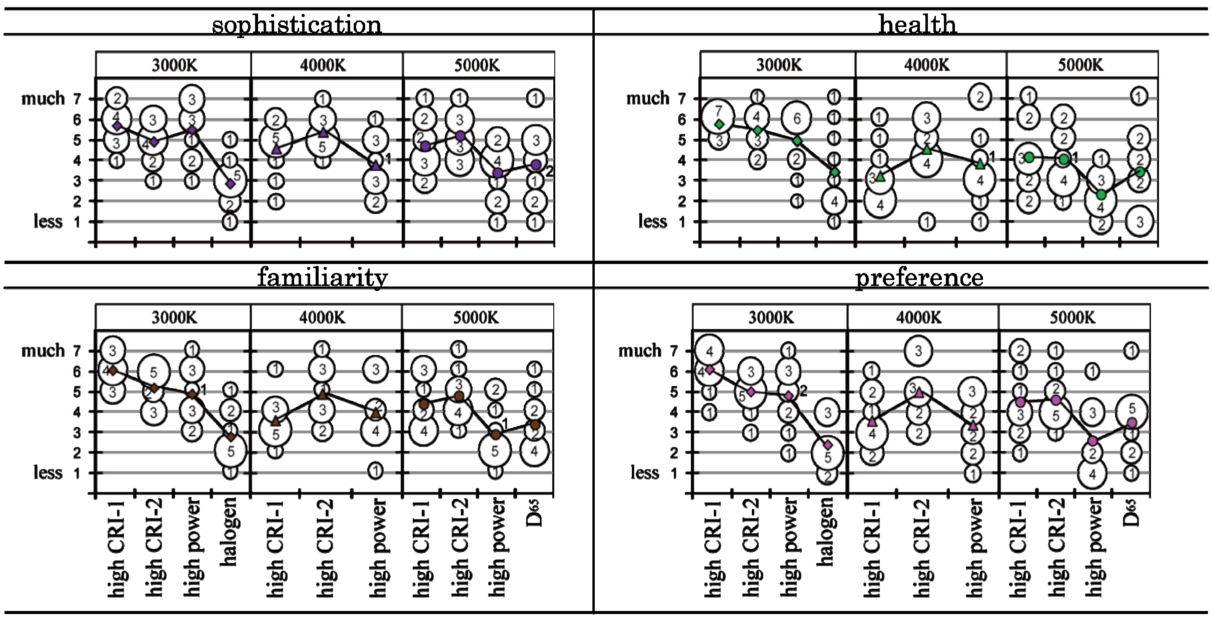

Figure 3 Frequency distribution and the average of the replies of 10 subjects

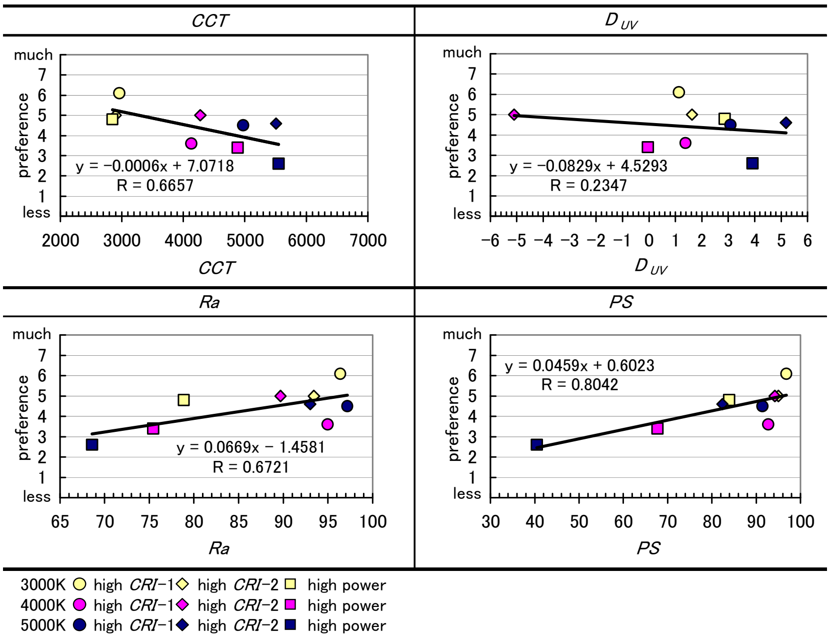

Figure 4 Relationship between the evaluation results of the "preference" and CCT/DUV/CRI/PS

4. CONCLUSION

This study showed that the preference of the skin color of the human face differed by the property of the lamps. The experimental results show that all kinds of the 3000K LED lamps are better than that under the halogen lamps, and that the preference of the skin color of the human face is determined by the "familiarity" primarily, the "sophistication" and the "health". It also shows that, in these terms, the appearance under 3000K LED lamps is better than that under the halogen lamp, the appearance under 4000K high *CRI*-2 LED lamp is better than that under 4000K high *CRI*-1 LED lamp and high power LED lamp, and the appearance under 5000K high *CRI* LED lamps is better than that under 5000K high power LED lamp and D_{65} lamp. It also shows that there is a high correlation between '*PS'* and the "preference".

REFERENCE

(1) T.Yano, K.Hashimoto : Preference for Japanese Complexion Color under Illumination, COLOR research and application, 22-4, pp.269-274 (1997)

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Sensitivity Evaluation based on the Color Distribution of Commercial Building and Media Facade Type

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ABSTRACT

In this study, the types and chromaticity of the media facades of the buildings in downtown are researched and analyzed, according to the location of the constructions and their commercial uses. Through the study on the color distribution changing by the commercial uses and the regional characteristics, the regional cultures and the behavioral patterns of consumption cultures could be considered as the main factors for this study. The methods of study are as follows: First, the characteristics of media facades which had been limited to the area of lighting were examined to be classified into three types. Based on the type classification, 10 regional cases were selected. Second, the cases of media facades were taken by the digital camera and their brightness and chromaticity coordinates were measured and analyzed, using the color brightness photometer CS-100s. The color difference, chromaticity and brightness were measured by the consecutive measurement in the unit of one second, according to the pattern and the change of chromaticity for each case. Third, the measured digital colors quantitatively were extracted and analyzed by the CIE x and y diagram for the chromaticity and the values for the chromaticity. Forth, the analyzed values of the color coordinate changed to CIE regional color diagram to see the arrangement of color distribution according to the sensitivity measurement coordinates.

1. INTRODUCTION

Cities have used the pedestrian passages, signboards of the buildings, banners and so on to convey what they want to deliver. Thanks to the development of digital media together with the ubiquitous technologies, the present communication of information has started to take the shape of media facades. In order to perform the basic function of the building elevation to communicate with the people beyond the simple conveyance of commercial information, the development in this area has been made focusing on the display of the artistic and emotional contents. With the media facades, the regional characteristics and the experience of spaces don't appear seamlessly even in the night. At this stage that the night views of the cities are changing actively by the new applications of media facades, it is necessary to introduce guidelines fitting to the characteristics of the cities. In other words, it is required to suggest some guidelines for the digital colors suitable to the consumption patterns or the types of sensitivity of the residents or the visitors which can be acquired by investigating the characteristics of the city cultures formed based on the commercial consumption cultures. The types and chromaticity of the media facades of the buildings in downtown are researched and analyzed, according to the location of the constructions and their commercial uses. Through the study on the color distribution changing by the commercial uses and the regional characteristics, the regional cultures and the behavioral patterns of consumption cultures could be considered as the main factors for this study.

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2. PURPOSE AND METHODS OF THE STUDY

The methods of study are as follows: First, the characteristics of media facades which had been limited to the area of lighting were examined to be classified into three types. Based on the type classification, 10 regional cases were selected. Second, the cases of media facades were taken by the digital camera and their brightness and chromaticity coordinates were measured and analyzed, using the color brightness photometer CS-100s. The color difference, chromaticity and brightness were measured by the consecutive measurement in the unit of one second, according to the pattern and the change of chromaticity for each case. Third, the measured digital colors quantitatively were extracted and analyzed by the CIE x and y diagram for the chromaticity and the values for the chromaticity. Forth, the analyzed values of the color coordinate changed to CIE regional color diagram to see the arrangement of color distribution according to the sensitivity measurement coordinates. The color coordinate showed the emotional tendencies according to the consumption cultures. The results can be used as the basic investigation in developing the digital sensitivity color schema based on the regional cultures in the future.

Figure 1. View of the Site Measurements

2. MEDIA FAÇADE FOLLWING CONSUMPTION CULTURE

In 2000, Metropolitan Seoul began to plan a project named “Design Seoul”. This project has been changing the night-time atmosphere of Seoul. Outdoor lighting that was used to light buildings during the night is now used as a tool to communicate with pedestrians, taking different forms as a media facade. The role of lighting has changed from lighting up surroundings to arousing emotions from passersby. Media facades of buildings that lead the consumption culture such as department stores, beauty clinics, and the fashion district in Dongdaemun have became very glamorous. Such fancy lighting helps increase awareness of the building. This makes the building a landmark. Increased exposure leads to a boost in sales. Because of the value of this system, many advanced countries include lighting design in architectural plans. In this generation, lighting design is utilized as a business strategy and resource. This study investigates examples of media facades of department stores, hospitals, and the Dongdaemun shopping district, and analyzes their color changes and space. Table 1 shows the color distribution and frequency of each case.

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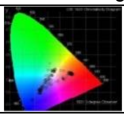
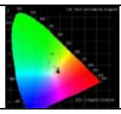
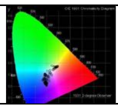
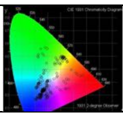
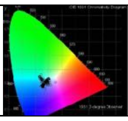
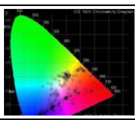
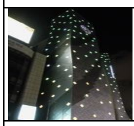
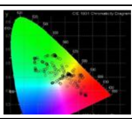
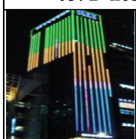
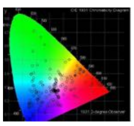
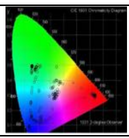
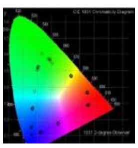
Type	Location	Photo	CIE diagram	White	Blue	Greenish blue	Blue green	Bluish green	Green	Yellowish green	Greenish yellow	Yellow	Yellowish orange	Orange	Reddish orange	Red	Orange pink	Pink	Puplishe red	Puplish pink	Red purple	Reddish purple	Purple	Bluish purple	Purplish blue
Type 01	01. H Department store in Daegu			◉	◉		○		◉		·	○				◉	·	○		·				·	·
	02. G Department store in Cheonan			◉	◉					·		·					○	·		·				○	◉
	03. G Department store in Seoul			○	◉	◉	·	·	·		○	◉	·	·											
	04. L Department store in Seoul			·	◉	·	○	·	·	◉	·	·	·	·	·	·	·	·	·	·	·	·	·	○	
	05. L Department store in Pusan			○	◉	◉	◉																		
Type 02	01. H hospital in Seoul			·	·	◉		·	○		·		○			○		○		◉	·	○	○	◉	
	02. Y hospital in Seoul			○	·	○		·	·	·	○		·	○	○	·			·	·	·	○	·	○	
	03. D hospital in Seoul			○		○			·	○					○	◉		○	○		○		◉	○	
	04. J hospital in Seoul			·	○	·			◉				·		·	○	◉			◉		·	◉	○	
Type 03	01. a mp shopping center in Seoul				◉	·	◉		◉		·	◉		◉	·	◉		·		◉			◉		·

Table 1. Analysis for the cases (◉*Main* ○*Sub* · *little color distribute)*

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4. RESULT OF COLOR ANALYSIS

To study the consumption culture in Korea, the research inquired into department stores, cosmetic surgery hospitals, and shopping malls in Dongdaemun. This study selected 10 buildings and analyzed colors used in the lighting. Frequently-used colors included white, blue, blue-green, bluish-green, greenish-blue, and green. Case 01 under the department store category was a projector-type and used colors like red and pink. Cosmetic surgery hospitals did not use a fixed color pattern; instead, they used lighting mostly for advertising purposes. Buildings in Dongdaemun used all representative colors in the color space, which were quite distracting. Case 02 and 03 under the department store category showed many different colors due to the exterior material of the building; however, the distribution of colors was well-balanced

5. CONCLUSIONS

Lighting design is a process of understanding the concept of the building and giving life to it. Buildings with lighting are more easily recognized at night and attract increased attention. This, in turn, makes the building a landmark. Media facades in Korea give a new role to architecture, and the development of LEDs will reduce energy consumption and have less impact on the ecosystem. As described in the color analysis, media facade design needs to harmonize with the surrounding scenery, so that it will not be seen as light pollution due to excessive brightness or ill-considered use of colors. There needs to be a guideline that will help assign emotional functions to colors in order to touch the city dweller sections to.

ACKNOLWLEDGMENTS

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REFERENCES

Janos, S., 2007, *Colorimetry, Understanding the CIE System,* John Willey & Sons, Inc

Mark, D. F., 2005, *Color Appearance Model*, John Willey & Sons, Inc

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Towards new ambiences of 'light-material-colour' in urban space

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ABSTRACT

Today in designing urban space we are situated on a threshold between traditional and innovative materials. Long-term practices of building with stone and brick seem to be eternally ingrained; however, recent products, such as smart glass, nanocomposites, hybrid materials, etc., that are just being developed are increasingly in competition with established building materials. Some of the new ones, e.g., acrylates, methacrylates, etc. feature colour changes. The challenges architects, urban designers, colour consultants and landscape architects are facing in using these new materials are many and complex, e.g., combining heterogeneous materials with differing durabilities and colour and surface appearances.

1. INTRODUCTION

Subtly our cities are moving from being 'colourful' places to becoming spaces of whiteness, transparency, brightness and glare. Shadow is conspicuously absent and the rough textures of materials have been replaced by a tedious, abstract smoothness where any visual and tactile sense of materials no longer exists. The dazzling light of mirroring façades multiplies neighbouring buildings and fragments urban space. In fact, as a whole architectural forms and the cityscape are meant to glint, shimmer and sparkle twenty-four hours a day. Not only does bright nocturnal lighting of interiors change the appearance of the exterior architectural volumes, but the interior itself is portrayed in an unsteady way by human activities destroying its apparent homogeneity. As well, today projection screens and enormous lit displays in exterior and interior spaces permanently broadcast messages and images of all kinds, mainly advertisements but often also simply projecting the immediate activity of the surrounds. Such nonstop images and messages dissolve the actual presence of the real public and private spaces of everyday life and reduce the appearance of colour to something virtual and ephemeral. The predominance of continual lighting and commercial advertising in urban space was recently vividly evident by its absence. After the earthquake of March 11th, 2011, in Japan many of the modern cityscapes of the affected areas were without electricity. Rendered inoperable the lack of the dynamic digital-technology-driven lighting made the real underlying dullness and lifelessness of the urban space apparent.

In short, as understood and applied in a traditional way, colour is no longer considered as a vital, physical element of urban space. While this loss and the accompanying effects are to be mourned and criticised, as suggested above, other potentially advantageous features are developing. Especially promising is the replacement of traditional pigments and authentic materials with flexible, interactive products. Smart and intelligent materials can adapt their light-transmitting properties and chromatic appearances in response to human sight and touch, as well as to temperature changes and sound. Hybrid electrochromic devices and materials make it possible to create different effects, which can be, e.g. transparent, translucent, mirror-like or coloured. The poignant visual effects of smart glass, methacrylates and other sophisticated materials under development can be easily adapted to individual needs and desires creating exclusive atmospheres and artificial colour-and-sound ambiences. Structural colour caused by interference effects is a main property of contemporary materials, e.g., iridescence permanently changes the chromatic appearance of materials, objects and buildings according to dynamic light and controlled environmental conditions. Such applications require the establishment of new colour codes as well as new colour vocabularies and new colour practices. As a result new colour cultures can also be expected to emerge.

This paper deals with the current threshold between traditional and innovative materials in urban design. Long-term practices of building with stone and brick seem to be eternally ingrained and are considered to have reached a high level of perfection; however, recent products, such as smart glass, nanocomposites, hybrid materials, etc., that are just being developed are increasingly in competition with established building materials. Some of the new ones, e.g., acrylates, methacrylates, etc. feature colour changes. The challenges architects, urban designers, colour consultants and landscape architects are facing in using these new materials are many and complex, e.g., combining heterogeneous materials with differing durabilities and colour and surface appearances.

2. ON MATERIALS

Local regions provide raw or natural materials in situ which not only have particular colour qualities and surface textures, but also distinguishing physical and mechanical properties related to construction principles. In addition to being part of the natural surrounds and already thereby imbedded within the memories of the inhabitants, the visual appearances of such raw materials also have an immediate and significant impact on the built environment in which they are applied. Over the years any respective application lends continuity to the architectural substance and this in turn leads to the development of a specific cultural and architectural heritage of a region. Earlier an important part of such a tradition of regional architecture was the emergence of prevalence of a so-called natural colour palette. However, during the 19th century new materials were developed as a result of inventions and innovations in technology, chemistry and other fields, e.g., concrete, a composite construction material that profoundly changed building procedures as well as architectural and chromatic appearances. During the 20th and at the beginning of the 21st centuries new materials were especially invented for façades. Treated like skins such as cladding is achieved using materials whose surfaces vary in colour or are treated chemically. The colour appearance of these trendy materials, such as aluminium, steel, glass, acrylates, methacrylates, as well as skin-like architectural fabrics, depends on the personal choice of the trendsetters rather than nature. For example, being lighter than steel, the chromatic appearance of architectural aluminium cladding expresses lightness and luminosity, while colour palettes for steel are more dense and saturated.

However, the application of innovative materials, as mentioned above, cannot be based upon the longstanding tradition of the natural colour chart. A complementary colour range will have to be established collectively, not only in order to be coherent with features of the site, but also in accord with local urban policy representing the aims of political and administrative authorities and also accommodating the choices of property developments and the local inhabitants. Each of these colour charts are adapted to different functions and spatial scales (Schindler 2012, 2012a). During the last decade we have observed that there is often a dramatic break or no relationship between architectural traditions and newly emerging innovative materials. Negotiating the threshold between traditional and new understandings and practices requires time for adapting and assimilating different materials, colour applications and surface appearance into a 'new tradition' (Quinton, 2011).

3. ON SHADOW AND LIGHT

Shadow and light are the two most important means of volumetric articulation to consider in the application of natural and contemporary architectural materials (Cler, 2011). Varying according to geographical location, natural light, this flat and sombre material is generally not taken into account in contemporary architectural projects resulting in a lack of making use of cast shadows. Not only defining architectural forms in a cyclical or rhythmic way with periodic and incidental animating effects that change over time, but cast shadows can also change the colour appearance of façades and volumes with its colour ranges of chromatic greys or achromatic tones. Both subtly and forcefully shadow can be intentionally employed to provide architectural forms with a sense of firmness. Shadow can also be used to emphasize inherent qualities of materiality. Any transparency or smoothness of a façade counters surface texture, which enhances the appearance of shadow nuances. The same is true of fine matt coatings, which reflect little or no light and therefore hardly convey any trace of shadow. On the other hand, coatings with rough textures and metal cladding with trapezoidal, sinusoidal or half round profiles enhance the appearance of shadow, e.g., by creating lively micro-reliefs or vertical and horizontal patterns.

Colour changing and deep shimmering qualities of new materials composed of effect pigments are completely dependent on the intensity and incidence of light (Cler et al, 2011). Therefore it is senseless to use them in dark spaces.

Newly developed methacrylates utilise chromatic aspects that vary with the changing light and position of the viewer. Buildings with such materials animate and create both themselves and their surroundings in a performative way with their fluctuating chromatic ambiences. Will inhabitants living in small villages accept them? Won't they be frightened by the absence of any reference to traditional and perennial colour ranges? Will such exterior spaces be experienced as rich and diversified or is their 'success' rather due to short-lived curiosity about the new and trendy?

4. ON AMBIENCES AND URBAN SPACES

In effect the colour texture of a building defines and articulates both architectural volume as well as detail. Today we can observe that some architectural projects use materials and their chromatic appearances as small colour surfaces scattered over the whole building without taking into account the context of urban space. Any excess of colour on a building can be disturbing when viewed within a short distance; however, from farther away the colour impression of the same building becomes grey and uniform. The objective of chromatic studies is to study such effects and determine suggestions for the best use of colour materials at different scales considering well-balanced colour-material combinations in distinct environments (Cler et al, 2011a).

New material products, however, are not the only significant elements affecting the ambiences of contemporary urban spaces (Schindler, 2010, 2010a, 2010b, 2011). Often present naturally in the surrounds, vegetal – and water surfaces – play an important part in defining chromatic ambiance. Today more and more 'living systems' or 'murs végétaux' are even being used to envelope building façades. Such micro-biotopic vertical gardens not only ensure a constant 'green' with their changing foliage accommodating seasonal changes, but they are sometimes even planned according to the emitted scents.

As well, another important new element affecting the ambiences of contemporary urban spaces is the employment of photovoltaic panels, not only on roofs but also completely covering façades oriented to the sun.

Finally, as urban space has become more dense and diverse, the chromatic ambience also strongly depends on a complex interaction of factors not only including those described above, but also human activities related to work, leisure, habitat, etc. as well as local and seasonal natural light conditions, cultural and historical background including the memories of colour and the historical context (Singier, 2011) Utmost importance, however, is to be given to what the 'user' or inhabitant thinks, wants and dreams of.

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REFERENCES

Schindler, V. M. 2010. Ohh… Green! Come 'l'Architettura Verde' influisce sulla cromaticita del nostro ambiente edificato. In *COLORE Quaderni di Cultura e Progetto del Colore* (Milan) 66: 20-25.

Schindler, V. M. 2010a. Vert, vert, vert… In *Habiter demain, de l'utopie a la réalité*, edited by Véronique Willemin, Paris: Editions Alternatives, Collection Anarchitecture, 101.

Schindler, V. M. 2010b. Jean Nouvel: Context and the Concept of the Vegetal. In *World Architecture 'Marking Place and the Times: The Epochal Architecture of Jean Nouvel'* (Beijing) 239: 31-35. Editor in Europe: Verena M. Schindler.

Schindler, V. M. 2011. Le vert en ville, architecture et nature? In *Les Cahiers de l'IAU* (Paris) 158: 165-167.

Cler, M., F. Cler and V. M. Schindler. 2011. Colour and Light in Urban Planning: Policy, Palettes and the Sense of Place, Mood and Movement. In *Proceedings of AIC 2011, Midterm Meeting of the AIC, 7-10 June 2011, Zurich, Switzerland*, edited by Verena M. Schindler and Stephan Cuber, Zurich: pro/colore, 348-351.

Nicole Singier (ed.). 2011. *Couleurs, lumières, matières. Ambiances et cadres de vie*. Bourg-en-Bresse: CAUE de l'Ain et M&G Editions.

Cler, M. 2011. Colour Appearance in Urban Chromatic Studies. In *New Directions in Colour Studies*, edited by C. P. Biggam, C. A. Hough, C. J. Kay and D. R. Simmons, University of Glasgow, Amsterdam: John Benjamins, 181-189.

Cler, M., F. Cler and V. M. Schindler. 2011a. Segmentation, canalisation de la ville, simulacres et prothèses pour les ambiances desertées. In *Faire une ambiance, actes du colloque international, Grenoble, 10-12 septembre 2008*, edited by Jean-François Augoyard, Bernin: Editions la Croisée, 140-144.

Quinton, M. 2011, Interview de France et Michel Cler. *AMC* 206: 106-107.

Schindler, V. M. 2012, 'Environnement polychromes' au Centre Pompidou, exposition présentant notamment des oeuvres de France et Michel Cler. In *Primaires 'Couleurs sensibles'* 173: 40-43. Edited by Annie Mollard-Desfour and Laurence Pauliac, Paris: Centre Français de la Couleur,

Schindler, V. M. 2012a. 'Polychrome Environments' at the Centre Pompidou in Paris: The Work of France and Michel Cler, Architect–Colour Consultants. In *Proceedings of the International Interdisciplinary Conference on Colour and Pattern Harmony, Óbuda University, Budapest, Hungary, June 11-13, 2012,* CD, Budapest: Hungarian National Colour Committee.

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Examination of a Suitable Lighting for a Nap in a Resting Room of an Office

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ABSTRACT

The purpose of this study was to investigate the chromaticity and the illuminance of a suitable lighting for a nap in a resting room of an office psychologically. We tested eight kinds of light; two achromatic light and six coloured light. We measured subjective sleepiness under each light condition by a visual analogue scale (VAS) and the Roken Arousal Scale (RAS). In addition, we evaluated subjective impressions for them. The results showed that the red light and the blue light inhibited subjective sleepiness. Moreover, the impression evaluation for the red lighting was very low. On the other hand, the orange light and the incandescent light not only promoted subjective sleepiness but also provided a good emotional evaluation. We conclude that the orange light or the incandescent light is psychologically suitable for a nap in the room that cannot be darkened.

1. INTRODUCTION

In recent studies, sleep at daytime, that is the "nap," begins to attract social attention. It has effects of the recovery from fatigue, stress reduction, and improvement of performance in a work (e.g. Milner and Cote, 2009). However, the optimal environment for a nap has not been examined. Especially, a lighting environment is important for sleep, because it is known that the exposure to bright light in the evening raises arousal level and disturbs deep sleep (e.g. Czeisler et al., 1986). In addition, a blue light inhibits melatonin secretion by the pathway which mediates activities of melanopsin retinal ganglion cells (Brainard et al., 2001). In this study, we investigated the chromaticity and the illuminance of a suitable lighting for a nap in a resting room of an office, because the room generally cannot be completely darkened.

2. METHODS

2.1 Participants

Nine undergraduate or graduate students ranging in age from 22 to 25 years (means = 23.3 yrs, SD = 0.9 yrs, 5 males and 4 females), participated in the experiment. They had normal colour vision and no sleep complaint. We instructed the participants to abstain from alcohol and caffeine and to keep a regular sleep-wake schedule and a regular time for lunch. The experimental procedures were explained to them before beginning the experiment. Written and oral informed consent was obtained from all participants.

2.2 Lighting conditions

We tested eight kinds of lighting; incandescent lamps, broadband white LEDs, a white lighting made by RGB LEDs, yellow LEDs, blue LEDs, green LEDs, orange LEDs, and red LEDs. The CIE xy chromaticities and the spectral distribution of these lights are shown in Figure 1.

There were three illuminance conditions for the broadband white lighting; 50, 100, and 200 lx. The illuminances of the other lightings were fixed at 100 lx, which is a recommended illuminance for a resting room by the Japanese Industrial Standards (JISZ9110, 2011). In the blue, green, orange, and red LED conditions, supplemental fluorescent lights filtered by the same colour as the LED lights were added to the LED lights in order to obtain the illuminance of 100 lx.

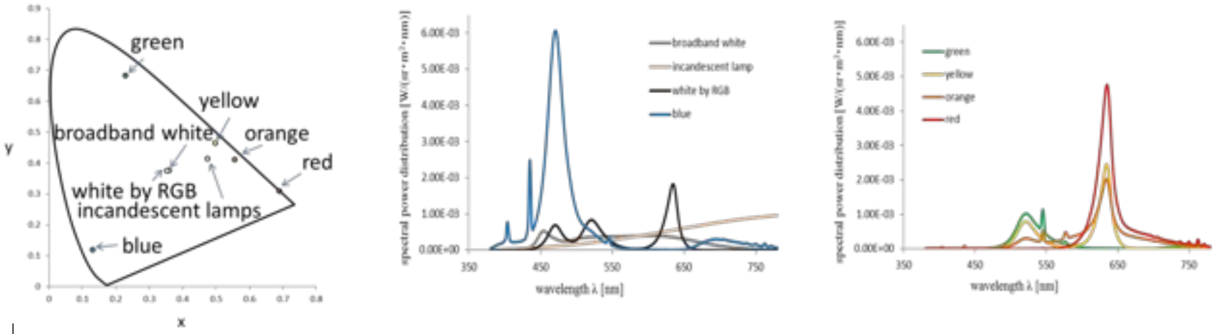

Figure 1. The CIE xy chromaticities and spectral distributions of eight kinds of lighting tested in the experiment.

2.3 Evaluation indexes

We measured subjective sleepiness under each lighting condition by a visual analogue scale (VAS) and the Roken Arousal Scale (RAS, Takahashi et al., 1996). In the VAS, the participants evaluated subjective sleepiness by putting a mark on a horizontal line (100 mm in length) anchored by a pair of words with not-sleepy (0 mm) and sleepy (100 mm), at each end. The RAS can evaluate six factors (*sleepiness*, *general activity*, *relaxation*, *strain*, *difficulty of concentration*, and *hypobulia*) by answering 12 subjective feelings listed in Table 1. All subjective feelings listed in Table 1 were evaluated by a 7-grade scale. In addition, sixteen kinds of subjective impressions (*beautiful*, *light*, *cosy*, *bright*, *calm*, *favorite*, *natural*, *refined*, *comfortable*, *secure*, *glaring*, *fresh*, *sophisticated*, *clean*, *lively*, and *pleasant*) for each lighting condition were measured with a 7-grade scale.

Table 1. Six factors and subjective feelings evaluated by the RAS

factors	evaluation words
sleepiness	"feel that eyelids are heavy," "sleepy"
general activity	"filled with vitality," "active feeling"
relaxation	"unbended feeling," "calm feeling"
strain	"nervous," "thrilled"
difficulty of concentration	"blunted feeling," "concentration is hard"
hypobulia	"have no motivaiton," "be not keen to do"

2.4 Procedure

First, the participant answered subjective sleepiness by the VAS and the RAS before an exposure of the experimental lighting. And then, the participant moved to a bed in an experimental room and lay on his/her back. The wall colour of the experimental room was grey corresponding to N7. The participant observed the lighting through an achromatic diffuser for 7 minutes. During the observation, the participant was instructed to open his/her eyes and not to fall asleep. After the observation, the participant answered subjective sleepiness by the VAS and the RAS again, and evaluated sixteen subjective impressions for the lighting. The experiment was carried out between 12:30 pm and 15:30 pm in October and November.

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3. RESULTS AND DISCUSSION

The results of the VAS and the RAS for each light were obtained by subtracting the subjective rating score before the exposure from that after the exposure. That is, the lighting that provides a higher score can facilitate sleepiness. On the contrary, the lighting that provides a negative score inhibits sleepiness. Figures 2 and 3 show the results of subjective sleepiness for each light evaluated by the VAS and the sleepiness factor of the RAS, respectively. The horizontal axis denotes kinds of light. The vertical axis denotes the subjective sleepiness score. The VAS score and the RAS score depended on the colour and illuminance of lighting. The scores of the blue LED light and the red LED light were negative or very low. That is, the colour of the lighting affected the subjective sleepiness in daytime. The influence of illumination was also observed in Figures 2 and 3. As the illuminance of the broadband white light was higher, subjective sleepiness was less facilitated.

We applied a one-way repeated measures analysis of variance to these results. In comparison of the VAS score, the incandescent lamp condition, the broadband white LED conditions of 50 lx and 100 lx, and the orange LED condition were significantly higher than the blue LED condition ($p<0.01$). In comparison of sleepiness factor of the RAS, the incandescent lamp condition and the orange LED condition were significantly higher than the blue LED condition ($p<0.05$). In addition, the broadband white LED condition of 50 lx, the orange LED condition, and the green LED condition were significantly higher than the red LED condition ($p<0.05$). The orange LED condition was significantly higher than the broadband white LED condition of 200 lx ($p<0.05$). These results suggest that the blue and the red lights are not suitable for a nap, and that the orange light, the incandescent lamp, and the white light with the low illuminance are suitable.

Figure 4 shows examples (*favorite* and *calm*) of the results of subjective impressions for each light. The red LED condition was relatively lower evaluation than the other light conditions. The subjective rating scores of the red condition were generally low for the other impressions as well. This result is consistent with the report by Inoue and Tomari (2007) that measured impressions for various coloured lights. For the blue light condition, the number of high evaluation was larger than that of low evaluation. The orange light and the incandescent light provided good subjective rating scores for emotional evaluation as well as the facilitation of subjective sleepiness.

We compared the broadband white light with the white light made by RGB LEDs in order to examine only the effect of spectral components excluding the effect of colour. As a result, the

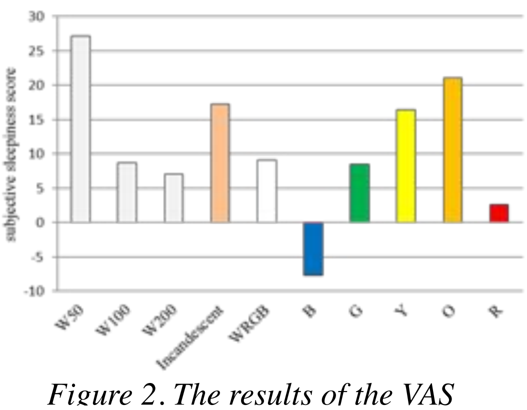

Figure 2. The results of the VAS

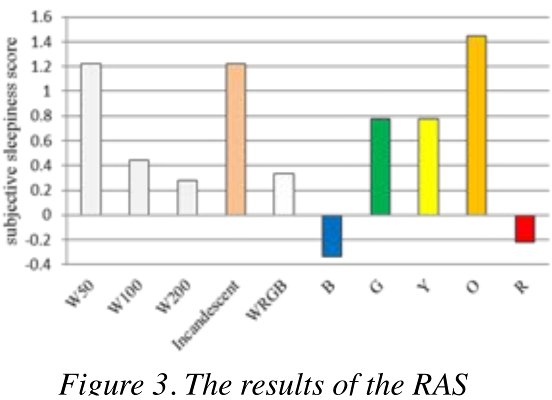

Figure 3. The results of the RAS

significant difference between them was not found in subjective sleepiness and the emotional evaluation (see Figures 2, 3, and 4). This may be because the wall of the experimental room was uniformly grey. If a room is colorful, we may be able to examine an influence by a difference in the color rendering.

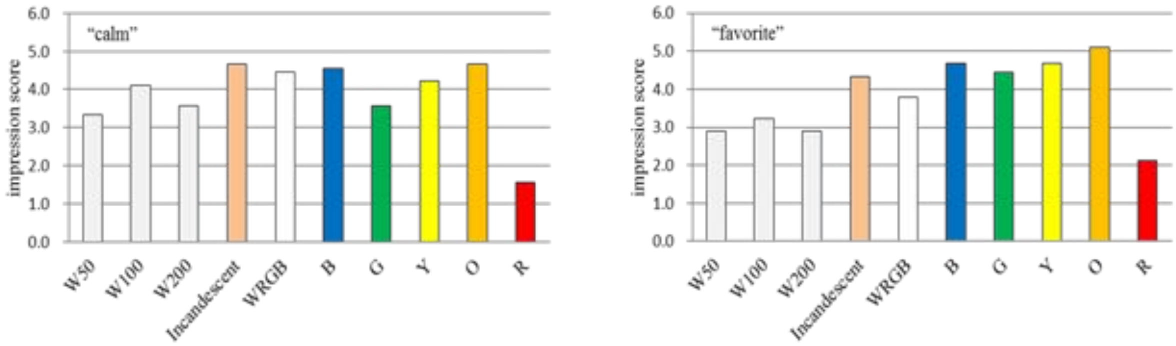

Figure 4.The results of the subjective impression

4. CONCLUSION

In this study, we investigated the chromaticity and the illuminance of a suitable lighting for a nap. We found that the chromaticity and the illuminance of the lighting affect on subjective sleepiness in daytime. Our results indicate that a blue and a red lights are not suitable and that a orange light or a incandescent light are psychologically suitable for a nap in a room that cannot be completely darkened such as a resting room of an office. It is necessary to confirm these suggestions by physiological evidence in a further work.

REFERRENCES

Brainard, G. C., J. P. Hanifin, J. M. Greeson, B. Byrne, G. Glickman, E. Gerner, and M.D. Rollag. 2001. Action spectral for melatonin regulation in humans : evidence for a novel circadian photoreceptor. *The Journal of Neuroscience* 21: 6405-6412

Czeisler, C. A., J. S. Allan, S. H. Strogatz, J. M. Ronda, R. Sanchez, C. D. Rios, W. O. Freitag, G. S. Richardson, and R. E. Kronauer. 1986. Bright light resets the human circadian pacemaker independent of the timing of the sleep-wake cycle. *Science* 233: 667-671

Inoue, Y. and M. Tomari. 2007. The influence of the chromatic light on visibility, psychophysiological and psychophysical responses. *Architectural Institute of Japan* 47: 73-76

Japanese Industrial Standards. 2011. JISZ9110: General rules of recommended lighting levels

Milner, C. E., and K. A. Cote. 2009. Benefits of napping in healthy adults: impact of nap length, timeof day, age, and experience with napping. *Journal of Sleep Research* 18: 272-281.

Takahashi, M., H. Kitazima, and Y. Honjoh. 1996. Analysis of the relationship between sleepiness and relaxation using a newly developed mental work strain checklist. *The Journal of Science of Labor* 72: 89-100

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Colorful World, Wonderful Life
--- Application Research on Color of Residence Landscape

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ABSTRACT

In the modern society, people pay more attention to living environment and search harder for harmony between people and nature. With their requirement for residential space and quality getting increasingly higher, they are looking forward to returning to the nature and spiritual care. Color is one of the most legible visual elements. Color design of residential communities, which should embody both history of a culture and modernism, should respect but also break tradition. More attention should be paid to building new residence landscapes on the basis of harmony of landscape colors, and residence landscapes could be colorful on the basis of visual harmony. This writing focuses on application of color in residence landscapes, starting with explaining definition of residence landscape and significance of color in such landscape, following it with introducing current status of color application in residence landscapes both at home and abroad, and then elaborating specific color application from the perspectives of residential buildings, hard pavement, landscape sketch, plants and lighting.

1. ABOUT RESIDENCE LANDSCAPE

1.1 Definition of residence landscape, its position in landscape and current status

Landscape refers to the beautified spacial vision closely related to people's work, study and living life. Integrating the artistic beauty and cultural beauty, residence landscape should represent two types of attitudes: attitude towards relationship between nature and city and attitude towards relationship between public domain and private domain. Changes are being experienced in these two attitudes from closeness to openness.

1.2 Significance and value of color in residence landscape

Color plays a wide variety of roles in landscape, such as physical and mental influence, color recovery, identification, cultural signal and aesthetic effect. Being capable of producing visually aesthetic views is one of the most important roles that color plays in landscape. Through reasonably arranging elements such as ground, water, plants, sketches and buildings in respect of color, balance between visual contrast and coordination is achieved, successfully shaping landscapes of various styles and presenting admirable views.

2. COLOR STATUS OF INTERNATIONAL RESIDENCE LANDSCAPE

Color of a city can improve quality of people's living environment and enhance charm of the city. As introduced by Cui (2006), according to Norway National College of Art and Design professor Great Smerdia, if color can lift living quality, people should let color into the depth of their lives. Color can improve our taste for beauty, for sure, and enhance functionality. On the other hand, as proved by the experience of city color building in the west, color is also significant in promoting individualized city images, become a distinct and unique mark of some regions. Successfully color building can also endow residents with a sense of recognition and belonging.

3. COLOR STATUS OF CHINESE RESIDENCE LANDSCAPE

With urban areas rapidly expanding in China, lack of color planning and management mechanisms leads to chaos and disorder in city color environment, which is both unsystematic and excessively bright in color applications. In the current stage of grand construction, many housing projects are rushed to finish, partially resulting in designers' neglect over individuality, culture and color design.

4. APPLICATION OF RESIDENCE LANDSCAPE COLOR

Based on nature of color carriers, color can be classified into natural color, semi-natural color and artificial color. Natural color is the color exhibited by natural substances. Semi-natural color refers to color that has been processed by man, without altering nature of natural substances, such as color of various natural stones, wood and metal that have been processed. Artificial color is color that is generated through artificial techniques, such as color of glass and paint.

4.1. Color of residential buildings

Application of color and materials affects the expressive force of buildings to a large extent. Therefore, color design should be regarded as a major part of planning and be considered at the very beginning of design.

The core of color planning is to satisfy the requirements of unifying the style, being plain and building comfortable atmosphere. In modern cities of high population density, crowded buildings and high pressure, people long for an elegant and peaceful color environment, and therefore the tone of grey becomes the major color of modern city buildings. Given that buildings in the same residential community are mostly unified in terms of materials and color, the highlight of color control for the community is not only color coordination and integrity among buildings within the community, but also influence of a color over the district landscape after it's widely applied in the community. Therefore, selection of a major color for a residential community should be prudent, and attention need be paid to coordinating communities developed later in line with existing communities.

The function of color in residential buildings is to satisfy people's physical and mental requirements. Visually speaking, color of buildings need shape a comfortable and healthy view for residents and protect them from disturbance of bizarre and bewildering color and light. Emotionally speaking, as a signal of identification and local culture, color of buildings should promote in residents the sense of recognition and belonging.

4.2. Color of hard pavement

"Color geography" was first raised by French colorist Lenclos (2004), who believed that color of buildings in a region could be widely different from those of various geographic locations, because it is shaped by both physical geography and local culture, while a unique color becomes an integral part of local culture of a region in return. It's essential for designers to investigate local geographic environment at the beginning of design in pursuit of the color of the region, but unfortunately, this process is widely lacking in both city planning and community building now in China.

Hard pavement is an important indicator for quality of residence landscape, using mostly semi-natural color and artificial color. With technology advancing, artificial materials have much more available varieties than natural ones, giving people more choices. In building of color landscape, if planning and design are not prudent in neglect of environment, such strength will easily undermine the landscape. Therefore, color design for residence buildings should follow the principles of using similar colors, using colors of similar hues despite different brightness, and using similar tones despite various hues.

4.3. Color of landscape sketch

Landscape sketch refers to facilities providing services or intended for appreciation, and is categorized into indicative sketch and functional sketch in residential communities.

Color design for indicative sketch need be coordinated with surroundings and easily identifiable. Its application in China now is disorderly, requiring systematic design in the future. Design of functional sketch should highlight visual effect, entertainment and participation, creating a complete view together with surroundings and injecting into the landscape vitality.

4.4. Plants

Plants are one of the most dynamic color elements in residential communities. In China where color environment design has just started, more attention is paid to color planning of artificial environment, while design for plant color is not satisfying.

Plant color is coordinated in line with four seasons to considering long-term effect. Since plants display different color expressions in different seasons, and therefore serve as the optimal choice for creating dynamic color effect.

Plant color is coordinated in one season to highlight short-term effect. Plants are a color, a shape and a style themselves, and if properly applied, can shape an admirable natural view.

Color coordination of plants need follow several principles. Plants always appear together with other landscape elements either in a supporting position or as an independent appreciation target, and design should focus on the overall color effect. Plants are green with nuances in brightness and hues, which is attempering, and therefore when plants are widely used, green should be the anchor color. Visual staying phenomenon makes our eyes tired when a single color prevails, but not so when colors are supplemental. In the case of plant landscape, since green is the anchor color, red tone must be applied properly to meet visual requirement.

4.5. Lighting

Color of lighting, controllable by people, is categorized into warm-colored light and cold-colored light. Lighting of various artificial colors should be fully explored to create desired night landscape.

Lighting of different locations, brightness and colors in exterior areas should be made an organic body, and functionality should be considered when colors of lighting are selected for exterior areas.

REFERENCES

Cui Wei. 2006. *City Environment Color Planning and Design*. Beijing: China Architecture & Building Press.

Lenclos, J. P., and D. Lenclos. 2004. *Colors of the World: A Geography of Color*. New York: W. W. Norton & Company, Inc.

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How Does Street Light Affect our Psychological Impression?

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ABSTRACT

The aim of this study was to clarify how the characteristics of lighting environment at night would influence our psychological impressions and to identify the relationships among our psychological impressions. We carried out an experiment in which subjects observed pictures of outdoor lighting environments at night and evaluated their psychological impressions; "Clarity", "Activity", "Brightness", "Glaring", "Safety", "Comfort", and "Preference". It was found that "Brightness" closely correlated with other impressions. Moreover, it was found that darker areas on the ground strongly affected "Brightness". We extracted those areas based on the baseline-luminance determined by the luminance distribution of the ground. Our finding suggested that "Brightness" was primarily important for the evaluation of the outdoor space at night. The baseline-luminance on the ground may give a useful index to evaluate the outdoor environment at night.

1. INTRODUCTION

Outdoor space, having a variety of elements, is a complex environment. Lighting of the outdoor space at night significantly influence on human psychological responses. Many studies related to the influence of outdoor lights on psychological or physiological responses have been conducted (Rea et al., 2011, Boyce et al., 2000). Those studies mainly focused on improving visibility or safety using lighting. In outdoor spaces at night, we may have more subjective psychological impressions such as "Activity", "Comfort" or "Preference". Little is known, however, about the nature of those psychological impressions in complex visual lighting environments at night. As to at the interior room, many studies were conducted on the relationship between lighting and our psychological impressions such as "Brightness", "Activity" or "Comfort" (Ishida and Ogiuchi, 2002, Ogiuchi and Ishida, 2003, Yamaji and Ishida, 2007). However, it has not been known that these models could be applied to outdoor spaces. It is necessary to examine quantitatively our psychological impressions to complex lighting environment at night.

The aim of this study was to investigate the influence of the lighting environment at night on our psychological impressions and the relationships among our psychological impressions.

2. METHODS

Subjective assessments were carried out using images of street scenes at night. Subjects evaluated 62 images presented by a LCD projector on a screen in random order. Subjects were 3 male and 6 female students and one male academic staff at the department of Architecture. They gave scores for 7 evaluation items, "Clarity", "Activity", "Brightness", "Glaring", "Safety", "Comfort", and "Preference" with 6 steps on a categorical scale.

3. RESULT

3.1 Evaluation of psychological impressions

Figure 1 shows the results of "Brightness". All the images were sorted in ascending order according to their brightness scores from bottom to top and right to left. We can see from this figure that overall brightness of the whole scene affected on "Brightness" of the outdoor spaces. It seems that the outdoor spaces were perceived to be bright when the road surfaces and the walls were illuminated uniformly, and high luminance and large area of signboards or building windows were included. Table 1 presents the coefficient of correlation matrix of the evaluation items. The result shows that "Brightness" correlated highly with "Activity", "Clarity", and "Safety". "Comfort" correlated highly with "Safety" and "Preference". Figure 2 presents the relationship between "Brightness" and "Comfort". The result shows that "Comfort" and "Brightness" correlated positively. It is suggested that "Brightness" is a primary factor determining our psychological impressions to outdoor spaces at night.

Tab. 1 Coefficient Correlation of the evaluation items

	Brightness	Activity	Clarity	Glaring	Safety	Comfort	Like
Brightness	1.00						
Activity	0.79	1.00					
Clarity	0.79	0.70	1.00				
Glaring	0.49	0.48	0.35	1.00			
Safety	0.75	0.66	0.73	0.27	1.00		
Comfort	0.42	0.33	0.48	-0.07	0.68	1.00	
Like	0.43	0.35	0.51	-0.06	0.71	0.88	1.00

Fig.1 Result of Brightness

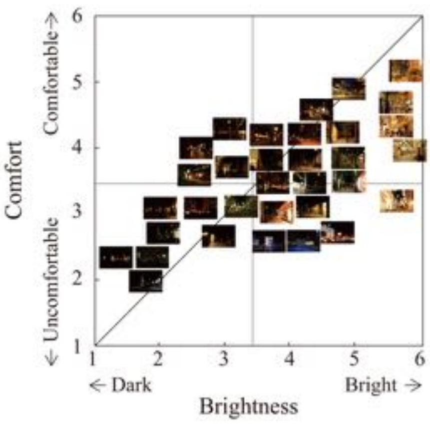

Fig. 2 Relationship between Brightness and Comfort

3.2 Effect of the characteristics of outdoor lighting on Brightness

In order to clarify quantitatively what characteristics of lighting affect "Brightness", we investigated relationships between "Brightness" and basic statistics of outdoor lighting environment at night; the average luminance of whole scene, the variation of luminance and the number of lighting elements. Figure 3 shows the relationship between "Brightness" and each of the three lighting statistics. It was shown that the basic statistics of outdoor lighting had no clear correlations to "Brightness". Returning to Figure 1, we can see that the brightness of the ground surface may affect "Brightness". Studies (Ishida and Ogiuchi, 2002, Ogiuchi and Ishida, 2003) on the environmental brightness of an interior space have suggested that the apparent brightness of the space was primarily determined by the perceived amount of light filled in the space, corresponding to the base of luminance distribution. If this

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notion can be applied to the outdoor space, it is worth considering the relationship between "Brightness" and the base of luminance distribution covering a wide range of the ground

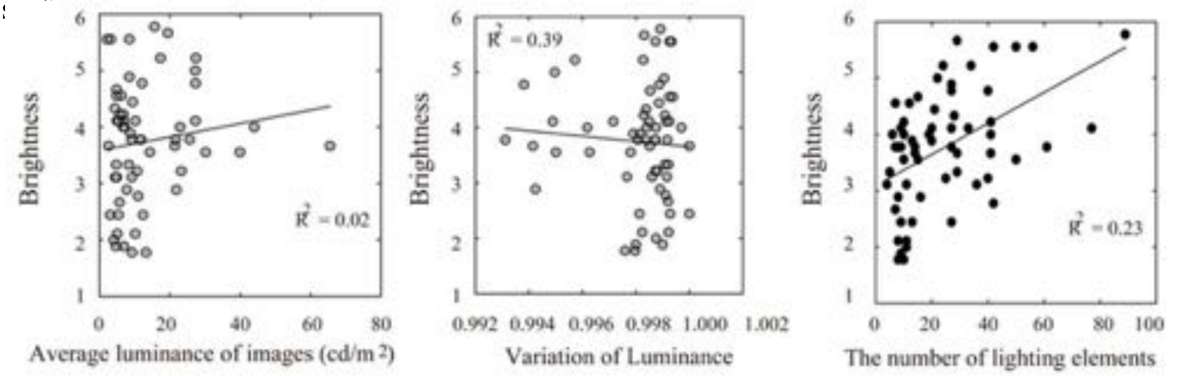

Fig.3 Relationship between the characteristics of outdoor lighting and "Brightness"

3.3 Effect of luminance distribution of ground surface on Brightness

In order to determine the base of luminance distribution**,** the baseline-luminance of ground surfaces, we obtained the luminance of ground surfaces of the images as follows. Figure 4 shows an example of the images used in this experiment. First, two dimensional luminance distribution of images was measured with a color luminance meter(KONICA MINOLTA CA-2000). Next, we decided the area of ground surfaces by visual inspection, and the image was divided into 32 x 50 grids whose size was set to 1 deg of the visual angle. The average luminance of each grid was calculated and colored with the percentile value of the luminance distribution as shown Figure 5. Figure 6 indicates the minimum luminance of each of vertical lines in the ground area.

Fig. 4 Image of outdoor at night

Figure 7 shows relationships between "Brightness" evaluation and three percentile values of the luminance distribution on the ground. It was shown that 25 and 50 percentile of luminance closely correlated with "Brightness". 80 percentile of luminance and "Brightness" revealed positive correlation, but weaker than other percentiles. It was found that darker areas, that is, the baseline-luminance on ground surfaces closely correlated with "Brightness". The results indicate that the brightness on the ground,

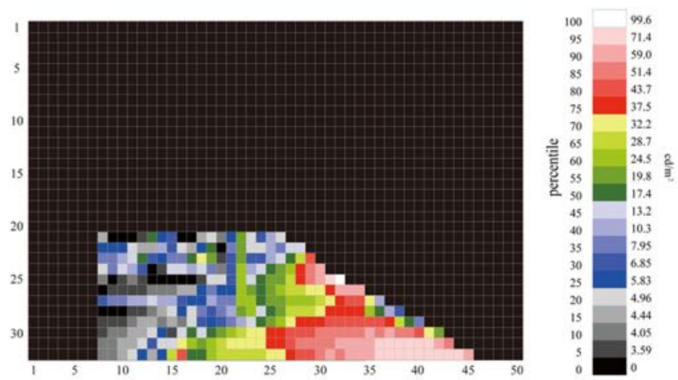

Fig. 5 Image each grid colored with percentile value of the luminance ground surface

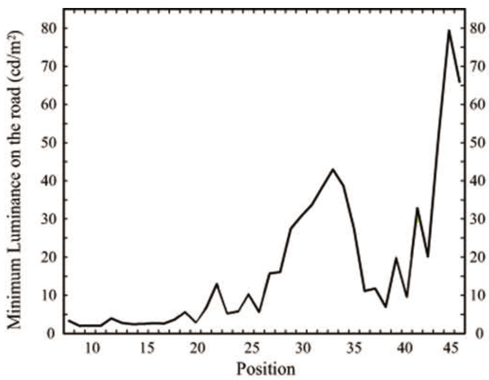

Fig. 6 The minimum luminance of each line of the grid of ground

not on the whole scene, may play significant roles in determining our visual impressions of outdoor spaces at night.

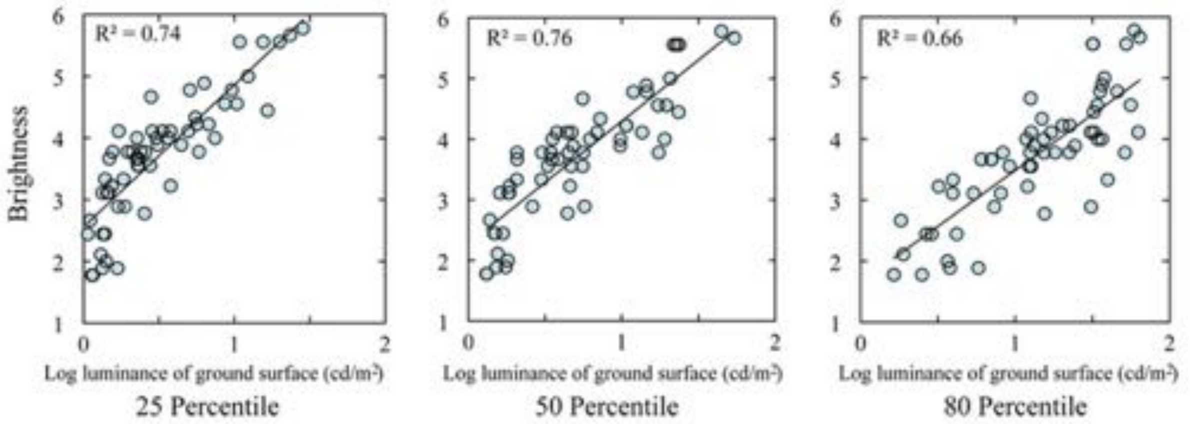

Fig.7 Relationship between "Brightness" and each percentile luminance of ground

5. CONCLUSION

It was shown that "Brightness" highly correlated with other visual impressions. Thus, it is worth clarifying the effecting factor on "Brightness" for the evaluation of outdoor space at night. In this study, we found that the darker area on the ground surface, 25 percentile of the luminance distribution, affected "Brightness". The topics of our further study are to clarify the additional effects of "Brightness" and to investigate the relationship between characteristics of lighting in the outdoor space and other psychological impressions.

REFERENCES

Boyce, P.R., N.H. Eklund, B.J. Hamilton, and L.D. Bruno: Perceptions of safety at night in different lighting conditions, Lighting Research and Technology, pp.79-91, 2000

Ishida, T and Y. Ogiuchi: Psychological determinants of brightness of a space - Perceived strength of light source and amount of light in the space, Journal of Light & Visual Environment, Vol.26, No.2, pp.29-35, 2002

Ogiuchi, Y and T. Ishida: Environmental Brightness Estimation for Full-Scale Spaces by the Virtual Luminance Distribution Method, Proceedings of the 25thCIE Session, pp. D1-30-33, 2003

Rea, M.S., L.C. Radetsky, J.D. Bullough: Toward a model of outdoor lighting scene brightness. Lighting Research and Technology, pp.7-30, 2011

Yamaji, H. and T. Ishida: Investigation of the applicability of the index NxLC for estimating active-calm impression of light environment, Journal of Environmental Engineering, AIJ, No.619, pp.1-8, 2007, in Japanese

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Color Tones of Cityscape based on a Comparison of Seoul Regional Cultures

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ABSTRACT

Now the sceneries in Seoul worthy of the name gave become tangled like nets with historic settings such as the palaces and the Korean-style house roads that have been formed for a long time, the main streets encompassing up-to-date IT technologies, or the re-designed streets with the arranged signage. This study is to investigate the color harmony schemes of two areas in Seoul which are recommended as the streets for tour courses. In this study, the color scheme was limited to five kinds of colors after analyzing the distribution of pixels. And the colors of the sky and the natural landscapes without the buildings were excluded in analyzing the color schemes based on the frequency of color distribution. The derived representative color scheme was expressed in NCS color coordinates and the RGB colors and analyzed by the tones based on the NCS nuance and the distribution of color system. As a result of this study, it can be said that the characteristics of the areas come from the landscapes and the contrast in color schemes of the two areas may be used for the analysis of the regional cultures, lives, and even the tendencies of the people in the business district.

1. INTRODUCTION

Seoul City has successfully emphasized the value of city brand enough to attract the attention of the world; with the result that Seoul was selected as the 3rd best city for the world's people to visit in 2010. Seoul deserves to become a place with variegated landscape capturing public attention thanks to its history, location and environmental characteristics. Now the sceneries in Seoul worthy of the name gave become tangled like nets with historic settings such as the palaces and the Korean-style house roads that have been formed for a long time, the main streets encompassing up-to-date IT technologies, or the re-designed streets with the arranged signage. If the sections showing the strong contrasts are placed in a parallel row, we may be able to see the dramatic varieties that do not seem to come from a city. This study is to investigate the color harmony schemes of two areas in Seoul which are recommended as the streets for tour courses. The first one is the Gahoedong street of the northern village where the high-ranking officials and the royal families used to reside in the old days. And the second one is the Gangnam broad street from the Gangnam subway station to the Kyobo Tower intersection.

2. PURPOSE AND METHODS OF THE STUDY

Social, historic and cultural features of the areas in the study show contrasts. The study focuses on whether an urban landscape naturally formed and culturally expanded shows contrast. For the purposes of this study, the surrounding sceneries of the two selected streets were photographed first. A digital camera (Canon G10 30.5mm) was used for the photographing from 10 a.m. to 3 p.m., when the surrounding buildings are in harmony with the environment on the basis of the townscape color. Secondly, the photos mainly taken for the places where the color harmony schemes of the areas are well characterized and properly taken in the aspect of colors seen with the naked eye and in the visual colorimetric analysis were classified by area and by location. This classification is usually made by the researcher's analysis because the cityscapes are naturally accepted and recognized by the naked eye. Thirdly, the color harmony scheme was analyzed using the NCS color coordinates after the color frequency of the classified photos was investigated using the Pixelate of Color System. In this study, the color scheme was limited to five kinds of colors after analyzing the distribution of pixels. And the colors of the sky and the natural landscapes without the buildings were excluded in analyzing the color schemes based on the frequency of color distribution.

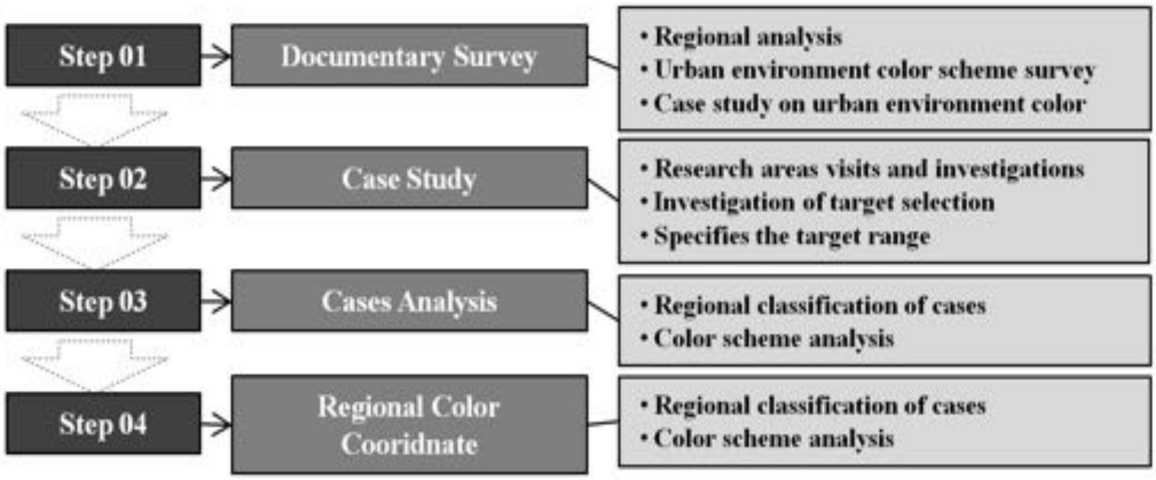


Figure 1. Process of the Research Method

3. LOCAL FEATURES DEPANDING ON CULTURAL CONTRAST

Seoul shows dynamic cultures even a single city. The study selects Gangnamdaero and Bukchon (Gahoi-dong) expected to show contrast in the color analysis and the cultural comparison of the 2 areas are as follows. Gangnamdaero is located from Sinsa-dong, Gangnam-gu to Yangjae-dong, Seocho-gu with 6.9km length and 50m width for 10 lanes and borders between Gangnam-gu and Seocho-gu. It is a information and design area and hub for cutting-edge consumption culture and pursues the concept of future, removing or replacing the past history with cutting-edge IT culture. From the viewpoint of the history, the Seoul City government named the street as Yeongdong-1no when it gave names to 59 streets on the occasion of 578th anniversary of Hanyangcheondo (moving the capital of Joseon Dynasty to Seoul) in November 26, 1972 and the name changed to the current one in June 26, 1976. The area has been fully developed since the Seoul Olympic Games in 1988. There are 4 subway lines and has excellent proximity due to opening the extension line of Sinbundang, an outskirt residential area of Seoul and most of the area is flat. It is an economic hub for consumption including plastic surgery hospitals, wedding shops and luxury shops. Meanwhile, Bukchon consists of Jaedong, Gahoi-dong and Samcheong-dong in Jongno-gu, is a historic center and has allies with rest and close to the nature. The example includes naturally-developed street design. The landscape is related to each element compared to the cultural aspect. Historically, it is from 'a town on the north of Cheonggyecheon and Jonggak' and consists of Bukchon for high-ranking officials and royal families and Namchon, located on the south of Jonggak with low-profile officials and merchants. During the Japanese occupation, the 2 villages were naturally developed for Koreans in Bukchon and Japanese in Namchon. As the administrative boundary of Seoul expanded in 1930s, the areas changed into Hanok (traditional Korean house) cluster in the city center and became a modern urban space with modified Hanoks to absorb population coming to Seoul. Currently, the Korean government supports the area as a part of nurturing Hanok project. Seoul, even a single city, has various historic, cultural and geographic features and the study selects 2 areas with contrast to analyze the landscape features. Color Arrangement and Code depending on Area.

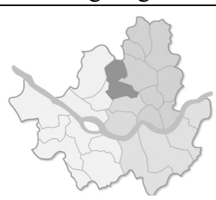
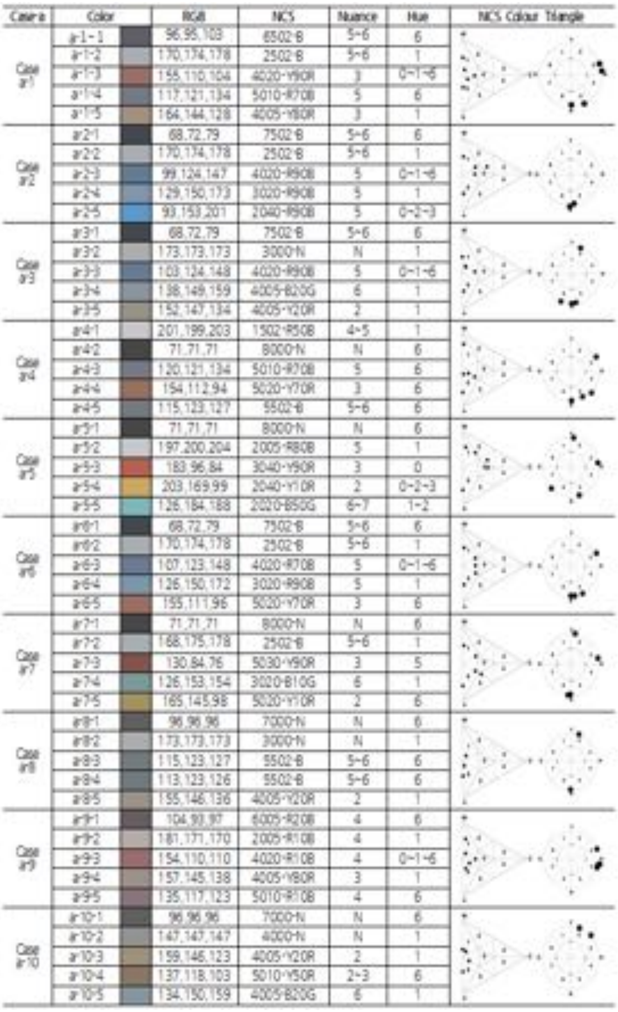
case	Location		Photo
Case A	Gangnam-gu	Gangnamdaero	 
			
Case B	Jongno-gu	Gahoedong street	 
			

Table 1. Cases for the Research

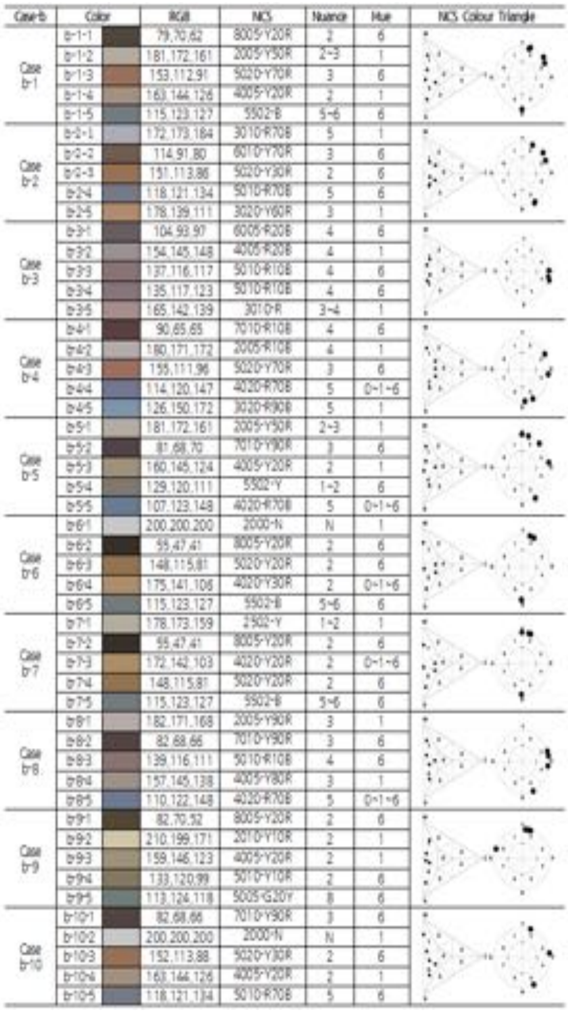
4. COLOR COORDINATION AND CODE FOR CASES

Considering the environment color plan, the urban landscape color arrange is analyzed using the tone specification of the NCS color coordinates called the natural color system developed based on the relative concept on changing environment or phenomenology. Figure 2 and 3 select representing images of the urban landscape and analyze color distribution rates to examine 5 color arranged identification by NCS color coordinates and RGB color and analyze distribution of tone and colors depending on the NCS nuance. Bukchon and Gangnamdaero show tone 1 and 6 in the NCS nuance and the colorimeters Bukchon and Gangnamdaero are YR and RB, respectively, showing contrast. The dominant color of Bukchon shows achromatic color, however, YR accounts for 30% and plays as an assistant color. The hue of YR in Bukchon ranges 10 to 20 on average. However, some images show high rates of over 90. Gangnamdaero shows high RB of 90 on average. Considering the architectural features of the 2 areas, it is expected as a color comparison of traditional Korean houses and modern commercial buildings with concrete.



Case-a	Color	RGB	NCS	Nuance	Hue	NCS Colour Triangle
Case a-1	a-1-1	96,95,103	6502-B	5~6	6	
	a-1-2	170,174,178	2502-B	5~6	1	
	a-1-3	155,110,104	4020-Y90R	3	0~1~6	
	a-1-4	117,121,134	5010-R70B	5	6	
	a-1-5	164,144,128	4005-Y80R	3	1	
Case a-2	a-2-1	68,72,79	7502-B	5~6	6	
	a-2-2	170,174,178	2502-B	5~6	1	
	a-2-3	99,124,147	4020-R90B	5	0~1~6	
	a-2-4	129,150,173	3020-R90B	5	1	
	a-2-5	93,153,201	2040-R90B	5	0~2~3	
Case a-3	a-3-1	68,72,79	7502-B	5~6	6	
	a-3-2	173,173,173	3000-N	N	1	
	a-3-3	103,124,148	4020-R90B	5	0~1~6	
	a-3-4	138,149,159	4005-B20G	6	1	
	a-3-5	152,147,134	4005-Y20R	2	1	
Case a-4	a-4-1	201,199,203	1502-R50B	4~5	1	
	a-4-2	71,71,71	8000-N	N	6	
	a-4-3	120,121,134	5010-R70B	5	6	
	a-4-4	154,112,94	5020-Y70R	3	6	
	a-4-5	115,123,127	5502-B	5~6	6	
Case a-5	a-5-1	71,71,71	8000-N	N	6	
	a-5-2	197,200,204	2005-R80B	5	1	
	a-5-3	183,96,84	3040-Y90R	3	0	
	a-5-4	203,169,99	2040-Y10R	2	0~2~3	
	a-5-5	126,184,188	2020-B50G	6~7	1~2	
Case a-6	a-6-1	68,72,79	7502-B	5~6	6	
	a-6-2	170,174,178	2502-B	5~6	1	
	a-6-3	107,123,148	4020-R70B	5	0~1~6	
	a-6-4	126,150,172	3020-R90B	5	1	
	a-6-5	155,111,96	5020-Y70R	3	6	
Case a-7	a-7-1	71,71,71	8000-N	N	6	
	a-7-2	168,175,178	2502-B	5~6	1	
	a-7-3	130,84,76	5030-Y90R	3	5	
	a-7-4	126,153,154	3020-B10G	6	1	
	a-7-5	165,145,98	5020-Y10R	2	6	
Case a-8	a-8-1	96,96,96	7000-N	N	6	
	a-8-2	173,173,173	3000-N	N	1	
	a-8-3	115,123,127	5502-B	5~6	6	
	a-8-4	113,123,126	5502-B	5~6	6	
	a-8-5	155,146,136	4005-Y20R	2	1	
Case a-9	a-9-1	104,93,97	6005-R20B	4	6	
	a-9-2	181,171,170	2005-R10B	4	1	
	a-9-3	154,110,110	4020-R10B	4	0~1~6	
	a-9-4	157,145,138	4005-Y80R	3	1	
	a-9-5	135,117,123	5010-R10B	4	6	
Case a-10	a-10-1	96,96,96	7000-N	N	6	
	a-10-2	147,147,147	4000-N	N	1	
	a-10-3	159,146,123	4005-Y20R	2	1	
	a-10-4	137,118,103	5010-Y50R	2~3	6	
	a-10-5	134,150,159	4005-B20G	6	1	

Figure 2. NCS Color Tone of Gangnamdero



Case-b	Color	RGB	NCS	Nuance	Hue	NCS Colour Triangle
Case b-1	b-1-1	79,70,62	8005-Y20R	2	6	
	b-1-2	181,172,161	2005-Y50R	2~3	1	
	b-1-3	153,112,91	5020-Y70R	3	6	
	b-1-4	163,144,126	4005-Y20R	2	1	
	b-1-5	115,123,127	5502-B	5~6	6	
Case b-2	b-2-1	172,173,184	3010-R70B	5	1	
	b-2-2	114,91,80	6010-Y70R	3	6	
	b-2-3	151,113,86	5020-Y30R	2	6	
	b-2-4	118,121,134	5010-R70B	5	6	
	b-2-5	178,139,111	3020-Y60R	3	1	
Case b-3	b-3-1	104,93,97	6005-R20B	4	6	
	b-3-2	154,145,148	4005-R20B	4	1	
	b-3-3	137,116,117	5010-R10B	4	6	
	b-3-4	135,117,123	5010-R10B	4	6	
	b-3-5	165,142,139	3010-R	3~4	1	
Case b-4	b-4-1	90,65,65	7010-R10B	4	6	
	b-4-2	180,171,172	2005-R10B	4	1	
	b-4-3	155,111,96	5020-Y70R	3	6	
	b-4-4	114,120,147	4020-R70B	5	0~1~6	
	b-4-5	126,150,172	3020-R90B	5	1	
Case b-5	b-5-1	181,172,161	2005-Y50R	2~3	1	
	b-5-2	81,68,70	7010-Y90R	3	6	
	b-5-3	160,145,124	4005-Y20R	2	1	
	b-5-4	129,120,111	5502-Y	1~2	6	
	b-5-5	107,123,148	4020-R70B	5	0~1~6	
Case b-6	b-6-1	200,200,200	2000-N	N	1	
	b-6-2	55,47,41	8005-Y20R	2	6	
	b-6-3	148,115,81	5020-Y20R	2	6	
	b-6-4	175,141,106	4020-Y30R	2	0~1~6	
	b-6-5	115,123,127	5502-B	5~6	6	
Case b-7	b-7-1	178,173,159	2502-Y	1~2	1	
	b-7-2	55,47,41	8005-Y20R	2	6	
	b-7-3	172,142,103	4020-Y20R	2	0~1~6	
	b-7-4	148,115,81	5020-Y20R	2	6	
	b-7-5	115,123,127	5502-B	5~6	6	
Case b-8	b-8-1	182,171,168	2005-Y90R	3	1	
	b-8-2	82,68,66	7010-Y90R	3	6	
	b-8-3	139,116,111	5010-R10B	4	6	
	b-8-4	157,145,138	4005-Y80R	3	1	
	b-8-5	110,122,148	4020-R70B	5	0~1~6	
Case b-9	b-9-1	82,70,52	8005-Y20R	2	6	
	b-9-2	210,199,171	2010-Y10R	2	1	
	b-9-3	159,146,123	4005-Y20R	2	1	
	b-9-4	133,120,99	5010-Y10R	2	6	
	b-9-5	113,124,118	5005-G20Y	8	6	
Case b-10	b-10-1	82,68,66	7010-Y90R	3	6	
	b-10-2	200,200,200	2000-N	N	1	
	b-10-3	152,113,88	5020-Y30R	2	6	
	b-10-4	163,144,126	4005-Y20R	2	1	
	b-10-5	118,121,134	5010-R70B	5	6	

Figure 3. NCS Color Tone of Bukchon

5. CONCLUSION

This study might be identified contrast in the landscape color among areas with cultural contrast. It also emphasizes proposals for local identity understanding cultural aspects in the guideline for landscape color. The study also surveys and analyzes the scope of the landscape color with cultural contrast forecast but it analyzes landscape color to predict and expand cultural features.

REFERENCES

Juyeon, Kim., 2011, Relation with Cultural Keywords depending on Features of Landscape Colors in Urban Area, *Journal of the Design Knowledge,* 22: 191-202

Haim Levkowitz, 1997, Color Theory and Modeling for Computer Graphics, Visualization, and Multimedia Applications, Springer, 99-150

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Exploring the Influence of the Landmark Public Art on the Neighborhood Environment-

Take an Example of the Public Art on the Exterior Wall in Shuiyuan Market

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Preface

Public arts contribute to the improvement of municiple space and increase the opportunities of exposing citizens to the arts. In recent years, the government has beeninviting skilled artists to work on the old buildings and gave them new looks by themeans of public arts. Since 2006, Taipei Municiple Government has carried out the program of Taipei Beautiful, planning urban renewal and establishing urban features. One example is that the internationally renowned artist Yaacov Agam (1928~) was invited to renovate the exterior wall of Shuiyuan market with his unique innovative style, reshaping the landmark buildings in Gongguan business center.
As a landmark building of the public art in Gongguan business center, Shuiyuan Market has attracted the attention because of the interaction between the artworks and the angles of viewing, the images change as the viewing angles change, furthermore, the bright tones and the contrast between the large-area color and the surrounding environment gave rise to discussion, which also gradually led to the color change of the surrounding environment.

1. Early Color and Image of Architecture in Gongguang Area

Early Taiwan architecture adopted Eclecticism[1] due to the influence from Japanese Ruling period, emphasizing on linearity and symmetry. The choice of exterior colors of building was under the influence of proposal of color stages for Taiwan architecture by the President of Taiwan Architects Association, Ide Kaoru (1879-1944) [2], which appealed with the "national defense color" for air defense needs[3]. The choice of colors taken into consideration includes red, brown, dark green and light green. The most representative architecture at the time comprised National Taiwan University and National Taiwan Normal University.


Figure 1　Architecture Style on NTU Campus

The image shows that the fast settlement of stores and slow building conversion has helped the building to preserve its early appearance while covered by the large advertising signs and external wall posters from the stores.

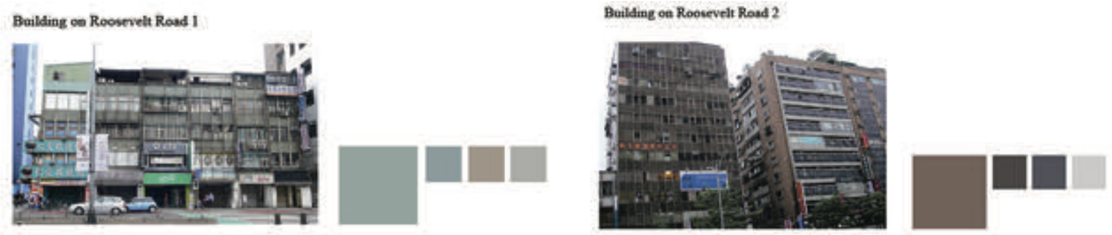

Figure 2　Architecture in Gongguang Business District

Apart from elevated floor heights due to the steel structure, the exterior design of new building is added with the feature of glass curtain since the 20th century. The buildings still preserve the national defense colors from early architecture for choice of colors. This shows that the part of the architecture colors in Gongguang Area consist of the colors in response to air defense needs in early days and the foundation in national defense colors.

2. Color contrast of　Shuiyuan Market between the Past and Present

The overall color of early Shuiyuan Market consists of brown colors due to the materials chosen for building the alterations to the General Administration Building, the predecessor of Shuiyuan Market. When the exterior wall was altered in 2010, artists covered the exterior wall of the building using a colors symbolizing water and incorporated with rainbow painted on the exterior wall as the theme. At this time, the colors of Shuiyuan differ from the early day, exhibiting the exceptional color added by artists to the locality.

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1. Eclecticism: An architecture style popular in Taiwan from 1920-1930. Subject to the influence from modernism, buildings at this time mostly pursued linearity and symmetrical façade with the center as the slightly protruding hills. The colors are mostly heavy without much deviation from red-brick color. It was a traditional period for architecture.
2. Ide Kaoru (1879-1944) is one of the most representative architects of Taiwan in the 1930s.
3. This color was mainly prevalent before and after the WWII due to its protective colors for buildings to escape from air raid during the war time; and hence the name “national defense color.”

Figure 3 Current condition of Heart of Shuiyuan, prepared by the study

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3. Color changes in stores surrounding Shuiyuan Market

The Gongguang area is a residential and commercial mixed district, whereas most buildings preserve the exterior design of early development. New buildings mostly follow the early benchmark design of colors. Hence, the public exterior wall of Shuiyuan Market has been decorated with art works, the stores surrounding the market also respond to the visual effects such as colors from the buildings after renovation.

3.1 Color changes for stores on Roosevelt Road

The cement walls of the building located on the front right of Shuiyuan Market is used for advertising rentals. The walls mostly used cold and rigid colors from the early days while using the emotional warm colors to segment from the heavy colors, thereby to highlight the advertisement. After the exterior walls of Shuiyuan Market have been completed, the advertising colors in this area gradually associate with the colors on the exterior walls of Shuiyuan Market, transforming from the previously rigid cold colors to the refreshing blue colors similar to that of Shuiyuan Market. The size of advertisement differs from the prior approaches of covering the entire wall but to expose the original colors of the exterior wall.

3.2 Color changes for Stores on Dingzhou Road

The stores on the back of Shuiyuan Market consist of stores having operated for a longer period of time, The stores use branding colors as its image representation and find it more difficult to change in response to the color changes in the exterior wall of Shuiyuan Market.

After the Shuiyuan Market renovated its exterior wall, its bright colors not only can highlight the volume weight of the building but also draw attention from the passersby with the change of colors. Most buildings surrounding Shuiyuan Market used gray colors for their advertisement in the early days, and although gray colors can coordinate with the surrounding environment, the advertising effect are weakened in comparison with the bright colors on the exterior wall of Shuiyuan Market.

4. Conclusion

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Taipei City Government altered the exterior wall of Shuiyuan Market through public arts, which not only renovated the old market but also created a local new landmark. Although the colors after alteration have successfully highlighted the building itself, they also brought impacts and tests for the surrounding stores.

4.1 Repackaging for buildings under annual budget

The exterior walls of Shuiyuan Market are repackaged using the annual public art planning budget from Taiwan government, which is used as local landmark building with considerably contrasting effects to the decoration. Nonetheless the lack of understanding the history and humanistic customs of surrounding environment from the artist have weakened the overall effects with quick changes and lack of local communication despite of the swift demonstration of project results.

4.2 Color changes for surrounding environment after the art decoration

Most stores affected by the colors of public arts in Shuiyuan Market are the surrounding stores. Although the stores choose colors to match the exterior wall colors of Shuiyuan Market, the unfamiliarity to materials have reduced the results of anticipation.

4.3 Public participation and education

The general public is not aware of alteration to Shuiyuan Market as a public art project. Although they are satisfied with the results after alteration, they do not completely know the project content and process. For the local residents, Shuiyuan Market includes many fragments of life and early memories. Hence although they recognize the changes to the surrounding environment after alteration to the exterior wall, they also express their incomprehension to the alteration process of Shuiyuan Market and feeling lost after the change.

REFERENCES

[1]J.P.Lenclos(1990)《Couleurs de la France》Moniteur，Paris

[2]Kobayashi, Shigenobu(1999) 《Colorist：A Practical Handbook for Personal and Professional Use》Kodansha Amer Inc

[3] Chang Hwei-an（2011）《The Floating Color Codes in Treasure Hill》，Taipei：Department of Cultural Affairs

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An Analysis of Urazaishiki (Reverse Coloring) used in Japanese Paintings by Itō Jakuchū applying Gonio-Photometric Spectral Imaging

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ABSTRACT

In the Japanese painting *Kōyō Shōkin-zu* by Itō Jakuchū, most of the autumn colored maple leaves were painted by reverse coloring technique, *Urazaishiki*. In this study, we measured *Urazaishiki* and non-*Urazaishiki* sample paintings of maple leaves by a gonio-photometric spectral imaging system and analyzed the corresponding visual effects. It was found that *Urazaishiki* shows various gonio-apparent visual effects (depending on optical conditions of illumination and observation), whereas non-*Urazaishiki* shows rather simple visual effects. The results of this study were introduced in a TV program on Itō Jakuchū, broadcasted by NHK in January 2012.

1. INTRODUCTION

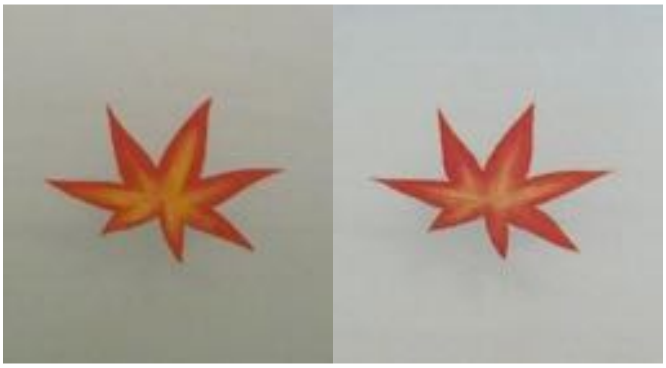
Itō Jakuchū (1716-1800) is a Japanese painter, well known for his works titled *Dōshoku Sai-e* (E. Colorful Realm of Living Beings; c.1757-1766), a set of 30 hanging scrolls, which is one of Japanese cultural treasures. In 2011, NHK (Japan Broadcasting Corporation), made a project to record high-definition images of the 30 scrolls and examined the painting techniques used by Jakuchū. We were requested by NHK to apply scientific analysis of *Urazaishiki* (reverse coloring or verso coloration), one of the coloration techniques used in *Dōshoku Sai-e*. *Urazaishiki* is a technique in which color is painted from the reverse side of the silk cloth. Because of the translucent characteristic of silk, a combination of reverse and front side painting generates various optical effects. In *Kōyō Shōkin-zu* (E. Birds and autumn maples; c.1766 see Figure 1.), one of the scrolls, *Urazaishiki* is applied to most of the autumn colored maple leaves, which presents different grades of opacity and transparency. In this study, we measured *Urazaishiki* and non-*Urazaisiki* sample paintings by a gonio-photometric spectral imaging system and analyzed the corresponding visual effects.

Figure 1. Kōyō Shōkin-zu (E. Birds and autumn maples; c.1766)

2. SAMPLES AND MEASUREMENT

2.1 Samples

In order to measure the effect of *Urazaishiki*, two sample paintings of an autumn maple leaf, with and without application of *Urazaishiki*, were produced (Figure 2). Base material was *Nichōhi Eginu* (Silk fabric) and coated by *Myōban* ($AlK(SO_4)_2 \cdot 12H_2O$). Pigments were *Odo* (yellow ocher, $Fe_2O_3 \cdot nH_2O$), *Shinsha* (cinnabar, HgS), and each pigment was mixed with *Nikawa* (gelatin) binder. These pigments were detected by X-ray fluorescence analysis of the original *Kōyō Shōkin-zu*. For both maple leaves, their center parts were colored with yellow and their peripherals with red. For the *Urazaishiki* sample, yellow pigment was painted on the reverse side of the silk cloth, while for the non-*Urazaishiki* sample, the yellow pigment was painted on the front side.



Left: non-Urazaishiki sample Right: Urazaishiki sample
Figure 2. Sample paintings of maple leaves.

2.2 Measurement

Nowadays, several spectral imaging methods can be used to measure and analyse artistic samples. To combine the spectral and the goniometric approach we used a liquid crystalline tunable filter-based instrument. *Urazaishiki* and non-*Utazaishiki* samples were measured by a gonio-photometric spectral imaging system composed of a white LED illuminant, a liquid crystalline tunable filter, and a CCD of monochrome imaging device with Peltier cooler. The CCD device has 772 by 580 pixels, 16 bit range, and anti-blooming function. An accurate data of spectral reflectance factor at each pixel of the image can be obtained by the system. Each sample was illuminated from the direction of 45° and 75° with respect to the sample normal and the reflected light flux was detected in the direction of the sample normal (Figure 3). Before measuring spectral reflectance factors of the samples, the instrument was calibrated for both illuminations using a reference panel showing a diffuse reflecting surface. For each wavelength the exposure times were optimized to keep high dynamic range.

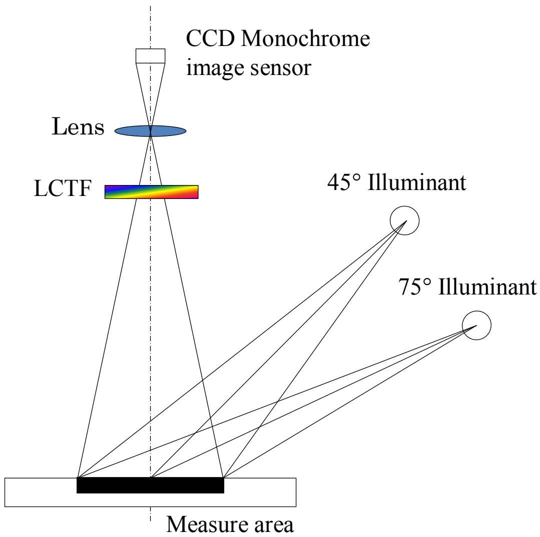
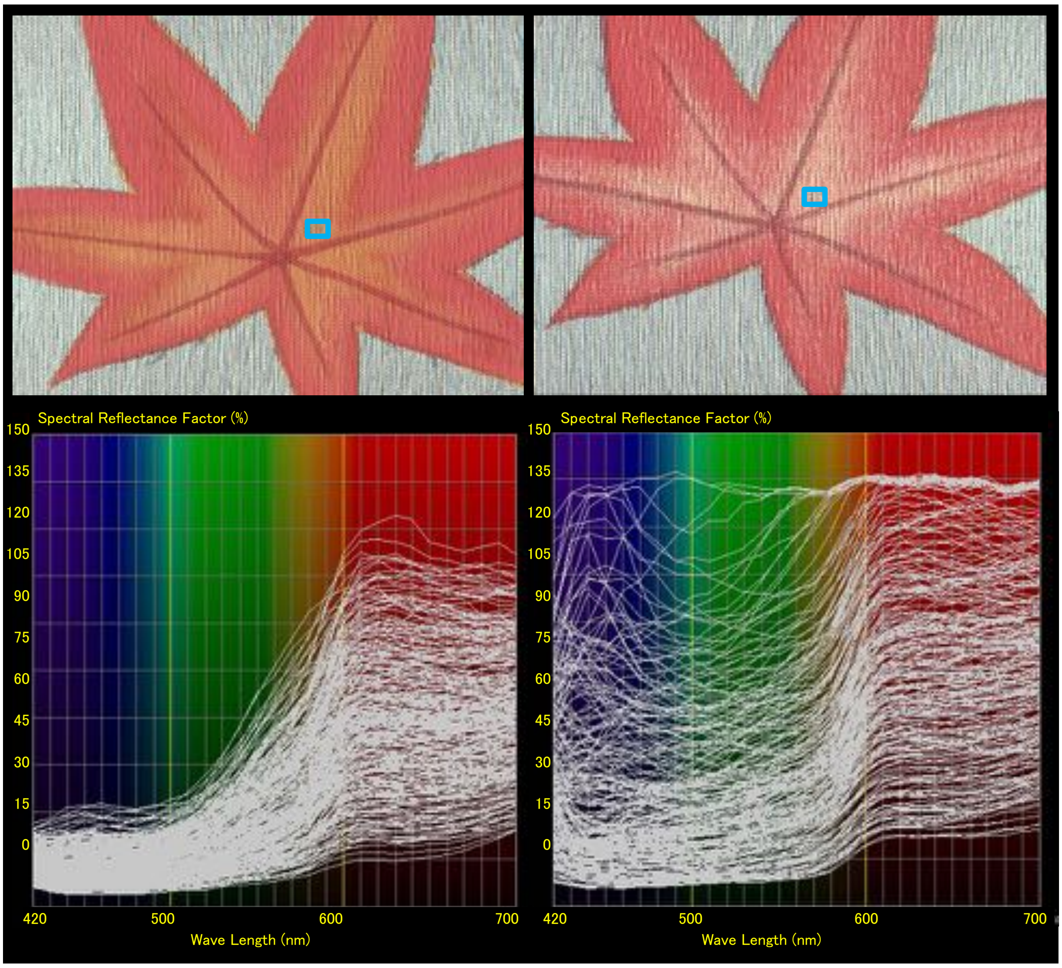


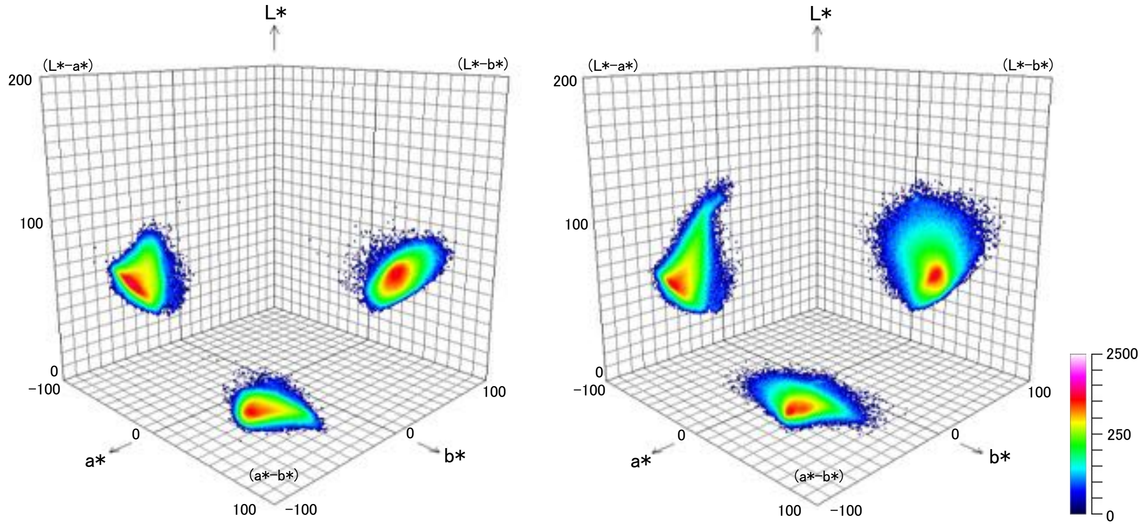
Figure 3. Gonio-photometric spectral imaging system.

3. RESULT AND DISCUSSION

The *Urazaishiki* sample exhibits higher reflectance factors compared to the non-*Urazaishiki* sample for all illumination geometries, which is shown in Figure 4 (75° illumination). The upper images were taken by the spectral color measurement device. The lower images show the spectral reflectance factors of the central part of the autumn maple leaves, which are indicated by blue line squares in the upper images. The graph of the *Urazaishiki* sample between 420nm and 600nm shows many variations of spectral reflectance factor compared to the non-*Urazaishiki* sample. Figure 5 demonstrates color distributions of the maple leaves illuminated by 75° illumination in CIELAB color space, and the color distributions are projected to L^*-a^*, L^*-b^*, and a^*-b^* plane. The color scale in Figure 5 indicates pixel density in CIELAB color space. The lightness L^* of the *Urazaishiki* sample shows a wider and higher in L^*-a^* and L^*-b^* plane, and a wider area in a^*-b^* plane compared to the non-*Urazaishiki* sample. The reason for such a behavior seems to be the following. For the *Urazaishiki* sample, the spectral response at each pixel in the center part of the leaf is generated by a superposition of unique gloss pattern due to the silk substrate and the specific spectral profile due to the absorption of light by the pigment. Summarizing the results, it was found that *Urazaishiki* shows various gonio-apparent visual effects (depending on optical conditions of illumination and observation), whereas non-*Urazaishiki* shows rather simple visual effects.



Left: non-Urazaishiki sample *Right: Urazaishiki sample*
Figure 4. 75° illuminated spectral reflectance factor of maple leaves.



Left: non-Urazaishiki Sample *Right: Urazaishiki Sample*

Figure 5. 75° illuminated color distribution of maple leaves in CIELAB color space.

4. CONCLUSION

It was found that *Urazaishiki* shows various gonio-apparent visual effects depending on optical conditions of illumination and observation, whereas non-*Urazaishiki* shows rather simple visual effects. The spectral imaging way is one of the powerful methods to measure and analyze a work of art. Especially, gonio-photometric measurement is quite useful to analyze characteristics of paintings. Measurement of local spectral reflectivity at different illumination conditions can be used for a better understanding of the internal paint layer structures and its visual appearance of the painting.

ACKNOWLEDGEMENTS

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REFERENCES

The Museum of the Imperial Collections (eds.). 2008. *Itō Jakuchū Dōshoku sai-e shūri jigyō hōkoku-sho* (in Japanese). The Imperial Household Agency.

Zhi-Xue Li et al. 2011. *Research on LC-based spectral imaging system for visible band*. GIS Applications II. Vol.8181.

Japan Broadcasting Corporation 2012. *Jakuchū's Miracle World --- Kyōi no hikari no gaka* (a Japanese TV program by NHK BS Premium).

Yumi Awano, Masayuki Osumi, 2011. *Development of Multi-angle Spectral Imaging System using LED Illuminant - LCTF Device and Analysis of Japanese Silk Textiles*. AIC 2011.

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Textile Ri-Design (Auth Code:224802)

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Abstract:

This work intends to present the work done by the young designers students of the "Digital Textile Design" course at AFOL Milan with Afol Moda, which reinterpreted the Russians textiles of 1920-1930, also known as *Agitational Textiles*.

1. THE YEAR OF ITALIAN LANGUAGE IN RUSSIA AND OF RUSSIAN LANGUAGE IN ITALY

The year 2011 has been declared "Year of Culture: and The Year of Italian Language in Russia and of Russian Language in Italy". The "Italian Minister of Cultural Heritage" and the "Minister of Culture of the Russian Federation" have reached an agreement to promote initiatives that facilitate cultural exchange between the two countries.

The young designers of the Digital Textile Design course have been invited to reconsider in a contemporary key some of the most important fabrics of the *Agitational textiles*, derived from the different textile collections held in Russian Museums. As a result, this interpretation resulted in a small textile collection that represents not only a simple pattern repeated texture or quotation, but also a real and modern reinterpretation aiming to a rich commercial application, related to the market of textile, fashion and interior design.

The issue that immediately raised was how such famous and well-known decorative patterns could be given a contemporary feel.

First, we analysed the most significant aspects of Italian contemporary design, which has been marked by a markedly international dimension over the last decades as designers from all over the world collaborate with Italian companies and their projects are conceived and implemented in Italy. However, Italian design still retains a unique imprinting with peculiar and distinct features such as its quest for harmony, its rich contents and its sober complexity. Italian design is also recognisable by its variety in product styles, collections and textile themes.

We then followed this approach in order to retain these features also in *Agitational Textiles* reinterpreting projects.

Secondly, we schematised the project stages of *Printing Textile Design* as it had to visually express concepts and emotions by using few elements:

- Subject: *Agitational textiles* designs stylised abstract or figurative subjects;
- Dimensions: dimensions were reduced;
- A repeat pattern layout: the layout was mainly based on two-dimensional graphical patterns.
- *Palette* colours: colours were mainly bight, contrasting and saturated and they were inspired by popular production and by country craftsmanship.
- Pictorial technique: the pictorial technique of the most revolutionary period was flat and two-dimensional.

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2. THE SOVIET AGITATIONAL TEXTILES

Thirdly, we analysed 48 historical artefacts belonging to the Russian textile museum collections of the State Hermitage Museum and Ivanovo State Museum of Applied Arts. We then divided them according to the major themes of political propaganda of Agitational textiles:

- New Soviet ideology
- Industrialization
- Electrification
- Village collectivisation
- Red Army

Fourthly, we made a visual research on the abstract art production derived from *Constructivist* and *Supremacist.* We also expended our research on the study of graphics, propaganda posters and lettering dating back to the same period.

3. THE COLOUR PALETTE CONSTRUCTION

Fifthly, we took part in the collective construction of a *colour palette* that summed up both the chromatic imaginary Russian identity colours and the real colours used in the historical period being considered.
- We tried to create a colour palette that was consistent with the chromatic spirit of the textiles in question. The palette consisted in a reduced quantity of colours vis-à-vis the excessive quantity of colours that emerged from the analysis of the production of the two decades and great attention was paid to maintain the significance of the revolutionary chromatic climate.
- Basic colours proved to belong to the white, red and black families, followed by yellow, blue and brown. Their different lightness and intensity versions (blue, pink, grey, beige and other hues) were considered as “accompanying colours” because they did not play a major role in the Soviet aesthetics of the period being considered in the stereotyped image of Russian identity.
- We divided the colours into three groups: neutral, cool and warm colours.
- We then made some luminosity changes both within the same group and between the lightest and the darkest colour of the whole palette in order to entail a general harmony.
- All the colours were selected from the *Atlante Cromatico Zanichelli* pages, corresponding to Adobe Photoshop and Adobe Illustrator CMYK colour sector.

- In the *neutral colour* group the shades range from light beige 9-11-21-0 to dark brown 50-68-77-62.
- In the *cool colour group* the shades range from yellow-green 39-31-64-3 to indigo 87-84-33-21.
- In the *warm colour group* the shades range from light pink 5-18-23-0 to red plum 33-100-72-44.

- On the whole we created around 24 degrees that condensed and represented the extremely rich palette of the *Agitational Textiles*.

- Sixthly, we distributed the 24 colours in 4 groups, articulated in a more communicative way than 3 leaving groups.

- The first group consisted of 6 gradations that could be placed borderline between the concepts of neutral[1] colours to bright colours. It started with light beige and included: 9-11-21-0, 5-18-23-0, 14-24-66-0, 13-31-49-0, 30-44-45-2, 39-31-64-3.

- The second group consisted of 6 gradations that could be placed borderline between the concept of cold tones with a prevalence of green, the concept of neutral tones and of the medium-dark tones. It started with medium grey and included: 43-39-44-4, 79-0-100-0, 56-26-77-6, 61-45-87-34, 48-53-79-31, 50-68-77-62
- The third group consisted of 6 gradations that could be placed borderline between the concept of hot tones and medium-dark tones. It included: 10-30-99-0, 16-77-100-5, 15-48-99-0, 9-72-99-1, 10-100-100-2, 33-100-72-44.
- The fourth group consisted of 6 gradations that could be placed borderline between the concept of cold colours with a prevalence of blue, the concept of medium-dark, and the concept of *fashion* colours.[2] It included: 12-51-32-0, 62-21-20-0, 58-38-21-1, 64-84-33-22, 78-69-28-10, 87-84-33-21.

- Hues in the first colour palette were translated into the appropriate dyes by the company "Clerici Tessuto S.p.A.", which printed them on cotton for Interior.
- Colours in the second colour palette were compared with the results of the printing process on cotton and then translated in the corresponding hues for jersey (72% polyamide + 28% elastane) by the company "Eurojersey". These were selected based on the colour tests of acid dye recipes for ink jet printing.
- This method ensured palette uniformity throughout the first and the second collection.

4. THE FIRST INTERPRETATION

The first collection of textiles design, created by the students of 2010-2011 Digital Textile Design course, has followed the most known and typical stereotype image of the Russian colours, with a predominance of red, blue and white, followed by orange and yellow, green, with very few neutral tones.

5. THE SECOND INTERPRETATION

The second collection of textiles design, created by the students of 2011-2012 Digital Textile Design course, has instead used combinations more in line with the contemporary market of the textile industry, in a fusion between past and present, historical re-interpretation and present more creative development, with a predominance of secondary tones, consistent with the fashion trends.

6. THE EXHIBITIONS

The result of the students has led to tree exhibitions proposed by Renata Pompas, the Director of Digital Textile Design course by AFOL Milano-Moda:

[1] In the fashion industry, this very flexible definition, based on the context, includes beige, cream,
[2] This definition includes seasonally less usual colours, like pink and violet.

- TEXTILE RE-DESIGN exhibition, **Kaunas** (**Latvia**) 2011, part of the textiles events that took place in Latvia in September: "The 16th ETN Conference" (European Textile Network), the "Texere General Meeting" (Textiles Education and Research in Europe). The students have exhibited 12 fabrics, printed by the company “Clerici Tessuto”, at the Museum of Kaunas, where they will remain from September until December.

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- TEXTILE RE-DESIGN exhibition, **Milan** (**Italy**) December 2011, in collaboration with the “Associazione Italia Russia”. This important event was sponsored by “Clerici Tessuti”, an Italian textile Industry leader. “Tre&TrePiù”, an Italian furniture Industry leader and supported by “Illumiluce”, an Italian lighting company and “Casa di Minea”, an Italian jewellery and accessories brand.

- TEXTILE RE-DESIGN exhibition, **Maniago** (**Italy**) 2012, in collaboration with the “Associazione Italia Russia” and the “Associazioni Tessile Valcellina”, which were part of the textiles events that took place in April: “The International Contemporary Textile/Fiber Art award - Mixing Cultures”.

- At this moment we are working together with “Associazione Italia Russia” and “Associazione Russia Italia” to transfer the TEXTILE RE-DESIGN exhibition in **St. Petersburg** (**Russia**) in June 2013.

VISUAL AND THEORETICAL REFERENCES

_ 48 images from the State Hermitage Museum and Ivanovo Museum of Applied Arts (Russia) textiles collections.
_ Yasinskaya, *Soviet Textile Design of the Revolutionary Period*. Thames&Hudson, 1983.
_ Pamela Jill Kachurin, *Soviet Textiles: Designing the Modern Utopia*, MFA Publications, 2006 .
_ Tat'jana Strižènova, *Moda e Rivoluzione*. Gruppo Editoriale Electa, Milano, 1979.
_ Marina Blumin, *Agit-fabric: an experience of the Russian avant-garde*; on catalogue exhibition: Giuseppe Barbieri, Silvia Burini (a cura di), *Avanguardia russa esperienze di un mondo nuovo* - Milano, Silvana Editore, 2011.
_ Giovanni Carandente (a cura di), *Arte russa e sovietica 1870 – 1930,* catalogue exhibition, Milano, Fabbri Editori, 1989.
_ Piero Boragina, Giuseppe Marcenaro, *Russia & Urss - arte, letteratura, teatro 1905 - 1940* - on catalogue exhibition, Milano, Skira, 2006.
_ I. Jasinskaja, *I tessili della rivoluzione russa*, Milano, Idea Books Edizioni, 1983.

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An evaluation on the emotion and sensibility on effects of LED colors applied to daily clothes

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Abstract

Smart photonic clothing, a type of the smart clothing, is based on light-emitting technology in which LEDs and optical fiber are combined in clothing. Controlling the colors of clothing provides an image of the sensibility of the wearers of such clothes(Cho, 2010). In smart clothing, LEDs not only enable the realization of various colors but also generate unexpected effects through the changes in the colors, light suffusion rates and degrees of brightness. This occurs because the LED lights penetrate into diverse materials due to its strong brightness and forward progression characteristics. However previous LED clothes are mostly for performance, studies are rarely to be done for daily clothes.

This study seeks to examine the differences of the emotion and sensibility according to the effects of colors of light source and the number of layers.

1. Instruction

As IT-based digital lifestyles become a common and ubiquitous trend in keeping with social changes, designs that use high technology to express functionality and creativity are emerging in many sectors. This trend is also active in fashion design, as modern society values consumption that emphasizes sensibility. A case in point is smart clothing, which combines high-tech, textile, and clothing.

LED has strong brightness and forward progression characteristics. These characteristics of LED are believed to be appropriate for demonstrating potential as a high-value-added fashion product that expresses creativity and originality in the ubiquitous age and as a sensibility-oriented fashion trend. However, there are few proper standards thus far. Moreover, few previous studies have focused on emotion and sensibility evaluations on LED-applied photonic clothing or LED-applied photonic clothing as daily clothes.

Emotion and sensibility evaluations of various expression methods using LED lights will be utilized as the basic source in LED-applied photonic clothing for everyday life. It can also be used in many different design fields adopting LED as a design component.

2. LED-Applied Photonic Clothing

LED(light-emitting diodes) is a semi-conductive light source. Conventional LEDs are made from a variety of inorganic semiconductor materials, and show full range of colors. LEDs present many advantages included lightness, smaller size, lower energy consumption and longer lifetime**.** Because of these characteristics, LEDs can be used as a sort of color expression in clothing.

Previous works of the LED-applied clothing:

There are two methods of applying LEDs to photonic clothing, using LEDs as a light source itself and LEDs as a light source linked with POF(*i.e.*,Plastic Optical Fiber).

Luminex developed the photonic clothing weaved POF and conventional yarn together and used LEDs as a light source(2005). This photonic clothing is flexible, light weight and also available for cutting and washing. Yonsei University(2009) studied the smart photonic clothing combined with LED and POF, which react to vibration, sound and environment.

Developed by Philips Lumalive, a LED-applied t-shirts(2006) integrates a flexible array of multicolor LEDs into a piece of cloth, which allows the cloth to display graphics, text, and animation. The company is poised to go fully commercial with a range of Lumalive textile LED products. *The Galaxy Dress* by cute-circuit company uses the smallest 24,000 full-color LEDs(2009). To diffuse the light there are 4 layers of silk chiffon. Hussein Chalayan's collection in 2008, he designed a series of *laser LED dresses* in collaboration with Swarovski. Texture, color, and print of *laser LED dresses* are changed through LEDs. AiQ, global fabric and apparel company, presents washable textile LED applications in ISPO 2011 which are utilized in fitness, sports, outdoor activities and healthcare.

Although many works of the LED-applied clothing have been done, however there have been few studies of emotion and sensibility influenced from LED lights. In consequence, studies on the emotional effect from the LED lights appear to be necessary in the relevant fields.

Limitation of the LED-applied clothing:

If people stare at LEDs directly for a long time, it could damage eye sight, because of its exceeding luminance. So it's needed to pay a special attention when using for clothing. During the LED is covered with layers of fabric in a garment, high luminance of LEDs could be weakened as associated with the colors of LEDs and colors, types of fabrics. Therefore those are important factors not only LEDs but also fabrics to be considered when developing the LED-applied clothing. .

3. Research Method

Test Protocol:

A total of thirty participants(*i.e.*, 12 men and 18 women aged between 25 and 39) were sampled for the experiment in this study. Experiments were conducted to evaluate the emotion and sensibility according to LEDs color and the number of fabric layers. First, participants were asked to stare at LED itself for 10 seconds, then answered the questionnaire. In the second step, the participants were asked to stare the four colors of LED covered by fabric layers for ten seconds, and to answer the questionnaire with interval of 30 seconds. The fabric layers covering the light source were manipulated to be three levels including one layer, three layers and five layers.

LEDs and Battery

The colors of light sources were red, green, blue, and white(lamp-typed LEDs, Ø5mm, 3V, 20mA) powered by a battery, R6(AAM,1.5V, 800mA).

Control of intervening variables

To evaluate the exact emotion and sensibility of the LED light experiments were conducted in a dark room(0.02 cd/m^2). Because this experiment is for daily clothes, the distance between the samples and the subjects were defined as 1m according to Edward T. Hall of Proxemics Personal Distance(46cm ~ 122cm). To remove the order effect, orders of stimulus were

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randomized.

Stimulus

An identical size(12"x12"), fabrication(100% polyester, 110g), color(black) of fabrics were applied to the whole procedure of the experiment in order to control the side-effects from fabric size, fabrication, color.

Questionnaire

A set of adjective descriptors was given to the participants in the form of five-point semantic differential scale consisting of 15 one-directional adjectives(see Table 1). The adjective descriptors used in the evaluation were selected based on previous researches(Lee et al.2009, Lee et al.2011).

Table 1. 15 adjectives for evaluation on emotion and sensibility

descriptor				
1. bright	2. luxurious	3. comfortable	4. splendid	5. warm
6. simple	7. multifarious	8. soft	9. preferred	10. futuristic
11. natural	12. strong	13. pleasant	14. active	15. cheerful

Data Analysis

One-way ANOVA using SPSS 18 was applied to analyze the difference according to the color of light source and the number of the layers. A Duncan's test was applied to the ANOVA results as the post analysis.

4. Results

We performed one-way ANOVA and Duncan's test to analyze the effect of the LED colors and the number of fabric layers on emotion and sensibility. On the basis of the analysis results, all of the effects from the three ways of fabric layers on the light sources are presented in Table 2, in the form of shadowed squares.

Table 2. result of emotion and sensibility evaluation

descriptor \ layer	0L	1L	3L	5L	0L	1L	3L	5L	0L	1L	3L	5L	0L	1L	3L	5L
bright	strongly agree	agree	middle	not agree	strongly agree	agree	middle	not agree	strongly agree	agree	middle	not agree	strongly agree	agree	middle	not agree
comfortable	middle	agree	agree	agree	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s
splendid	agree	agree	middle	not agree	agree	agree	middle	middle	agree	agree	middle	not agree	agree	agree	middle	not agree
warm	agree	agree	△	middle	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s
simple	n.s	n.s	n.s	n.s	strongly agree	agree	agree	agree	agree	agree	agree	middle	n.s	n.s	n.s	n.s
multifarious	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	middle	agree	agree	middle	middle	middle	agree	middle
futuristic	middle	middle	middle	not agree	agree	agree	middle	middle	agree	agree	agree	middle	middle	agree	middle	middle
strong	strongly agree	agree	middle	not agree	agree	agree	middle	not agree	agree	agree	middle	not agree	agree	middle	middle	not agree
pleasant	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	agree	agree	agree	middle	agree	△	middle	middle
active	agree	agree	middle	middle	n.s	n.s	n.s	n.s	agree	agree	middle	middle	agree	△	middle	not agree
cheerful	agree	agree	middle	not agree	agree	△	△	middle	agree	agree	middle	middle	agree	agree	middle	not agree
LED color	Red				White				Blue				Green			

(■ = strongly agree, ■ = agree, ■ = middle, ■ = not agree, △ = overlapped, p< .01)

As presented in Table 2, only five descriptors among the 15 adjectives in the questionnaire, appear to have significant influence from all the types of LED color.

Analyzing the effect by LED colors, red light source showed the significant differences in 'bright', 'comfortable', 'splendid', 'warm', 'futuristic', 'strong', 'active', and 'cheerful'. Among the eight descriptors above, two adjectives, 'comfortable' and 'warm' showed the significant influence only in the case of red color of light source. It indicates that the effect of red color of light source is more dominant than other colors of light source regarding 'comfortable' and 'warm'.

White light source showed the significant differences in 'bright', 'splendid', 'simple', 'futuristic', 'strong', and 'cheerful'. 'Bright' and 'strong' showed the significant influence.

Blue light source showed the significant differences in 'bright', 'splendid', 'simple', 'multifarious', 'futuristic', 'strong', 'pleasant', 'active', and 'cheerful'. Among nine descriptors above, three adjective, 'bright', 'splendid', and 'strong' showed the significant influence. In terms of color types of LED, blue appears to have the most influential effect on the various emotion and sensibility.

Green light source showed the significant differences in 'bright', 'splendid', 'multifarious', 'futuristic', 'strong', 'pleasant', 'active', and 'cheerful'. Among the eight descriptors above, four adjectives, 'bright', 'splendid',' active', and 'cheerful' showed the significant influence.

It indicates the similar tendency in emotion and sensibility regarding 'bright', 'splendid' and 'cheerful' for all light source colors. In other words, this homogenous tendency of effects from the color types of LED, implicates that the effects of number of fabric layers are more dominant than those of LED colors in the cases of 'bright', 'splendid' and 'cheerful'.

It showed that the heterogenous tendency of emotion and sensibility regarding 'futuristic' for all light source colors. It implicates that the effect of LED colors is more dominant than that of fabric layers.

5. Conclusion

This study was to investigate the emotion and sensibility influenced from the color of light source and to the number of layers. In summary, layers and colors effected on the emotion and sensibility. It showed differences of the emotion and sensibility by the light source colors. Even it's the same color of the light sources, it showed the different emotion and sensibility depending on the number of layers.

This study was conducted by restricted fabric type and color. For daily clothes, it is needed to diversify the fabric types and colors in a further study.

References

Cho, Gilsoo, 2010, *Smart Clothing: Technology and Applications*, FL : Taylor&Francis Group

Lee, Jin-Sook, Won-do Kim, So-Yeon Kim, 2009, Sensibility Evaluation of LED Lighting and Fluorescent Lamp based on Color Temperature, Architectural Institute of Korea

LEE, Jinsook, NAM Shin, Kim Soyeon, 2011, A study on the range of optimum lightness and the evaluation of emotional image by LED lighting color for automobile interior indirect illumination, Journal of Korea Society of Color Studies

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Studying Art Paintings through a Multispectral Imaging System Composed of Light-Emitting Diodes Covering the Spectral Range from 370 to 1600 nm

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ABSTRACT

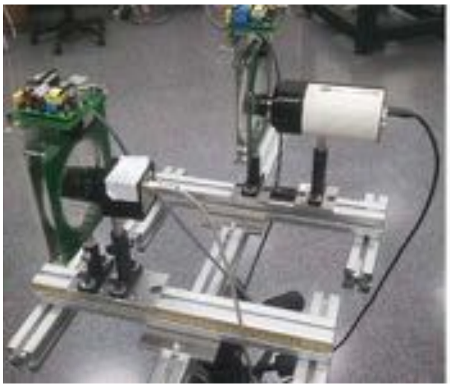
Multispectral systems are implemented in many ways and are intended for different purposes. Some of them have been used for the study of art work but they have been mostly based on filters. In this work we assess the feasibility of a multispectral system based on Light-Emitting Diodes (LED) for the study of art work paintings. This system is comprised of two cameras and two sets of LEDs with different peak wavelengths of emission. Images from the 23 channels of the system give access to pixel-wise information of color and spectrum in the range of 370nm to 1600nm. The spectrum for each pixel is calculated via two methods: the pseudo-inverse estimation method using a training set of samples and the interpolation method using splines. The performance of the system in terms of color and spectral reconstruction is evaluated using three different metrics. The results obtained in spectral estimation shows a good performance of the system. In addition, some of the possibilities that the system offers are shown with images and spectra estimation of pixels for real wall paintings.

1. INTRODUCTION

Multispectral imaging is a field with application to a wide range of problems because it offers spectral information with high spatial resolution; these features are useful in the pharmaceutical industry, biology, arts and many others scenarios, Sheth et al. (2009); Vilaseca et al. (2008). In the art conservation area, some approaches of multispectral systems have been implemented in order to get access to a better color measurement and reproduction, to spectral information or the possibility of digital archiving of art work, Fischer and Kakuolli (2006). The recent development and accessibility to LED technology has become an attractive alternative to be used in multispectral systems, Brydegaard et al. (2009); Martinez et al. (2011), including those used in art work studies. LED elements have narrow-spectral emission and are available in several wavelengths over the different spectral ranges of ultraviolet (UV), visible (VIS) and near-infrared (NIR). Therefore, they allow lighting the sample with a large number of specific wavelengths or customized combinations of them in a fast way and in synchrony with the imaging sensors used. Following this idea, this work shows the evaluation of the performance of an LED based system and its use in the study of art work paintings in a museum. The system is evaluated in terms of color and spectral reproduction through three metrics and two methods of spectral estimation. These metrics show a good performance of the system and the high proximity of the results for the two methods of reconstruction supports the system accuracy, and therefore its suitability to study real wall paintings.

2. METHODS AND MATERIALS

The multispectral system has two modules. The first module comprises a monochrome CCD camera with 12 bit depth and 1392x1040 pixels, and a set of 16 groups of LEDs for illumination, each group with a specific peak wavelength of emission. The spectral response of this camera and the emissions of the LEDs in this module cover the spectral range from 370 to 950 nm. Likewise, the second module has an InGaAs camera with 14 bit depth and 320x256 pixels, and a set of 7 different groups of LEDs. This module covers the range of wavelengths of 900 to 1600 nm. Figure 1a shows the experimental setup with its two modules.



a) *b)*

Figure 1. a) Experimental setup. b) Part of the palette of colors used as training set of samples.

Images of wall paintings were captured using this system. The paintings are located in Saint Michel's cell at the Royal Monastery of Pedralbes (Barcelona) and are attributed to the painter Ferrer Bassa. They are an exceptional masterpiece of the Catalan Gothic painting scene dating from 14th century. Here, two methods for the spectral estimation from the digital values given by the system have been used: the pseudo-inverse estimation method (PSE) and the interpolation method based on splines (Interp), both of them widely described elsewhere, Vilaseca et al. 2006, Abed et al. (2009). In order to estimate the reflectances of these images using the pseudo-inverse method, a training process of the system must be carried out. For this purpose, a set of colored patches was generated (Figure 1b). These patches were painted with colors commonly encountered in Bassa's palette and emulating the fresco technique used by him.

Finally, to compare and evaluate the results of spectral estimation three different metrics were employed. The root mean square error (RMSE) and the goodness-of fit Coefficient (GFC), Hernández-Andrés et al. (2001), that account for spectral accuracy and the color difference formula DE2000 (DE00) that accounts for color evaluation, Sharma et al. (2005).

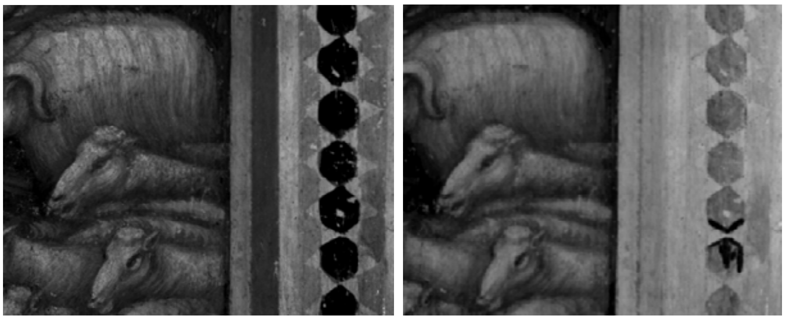
3. RESULTS AND DISCUSSION

Results in Table 1 are obtained when measurements over the training set are carried out. They show a general good performance of the system, but with some differences depending on module and estimation method. The pseudo-inverse method yields better results for both modules than the interpolation method, although both methods have poorer performance in the second module where the minor quantity of channels, that is to say, number of LEDs, makes the values of the RMSE increase. Even so, these values are near to 2% that is still a low value. The GFC results also confirmed the same, where 0.999 values represent good spectral matches. In terms of color differences the pseudo-inverse method has again a better performance, but it is worth noticing that no training process is necessary for the interpolation method, fact that depending on the situation may compensate its higher, but still good, mean value in DE00 and RMSE.

Table 1. Results of evaluation metrics in spectral estimation for the training set of samples.

Mean Values	*Module 1*			*Module 2*	
	DE00	RMSE x100	GFC	RMSE x100	GFC
PSE	0.988	1.094	0.999	1.970	0.999
Interp	2.193	1.830	0.999	2.351	0.998

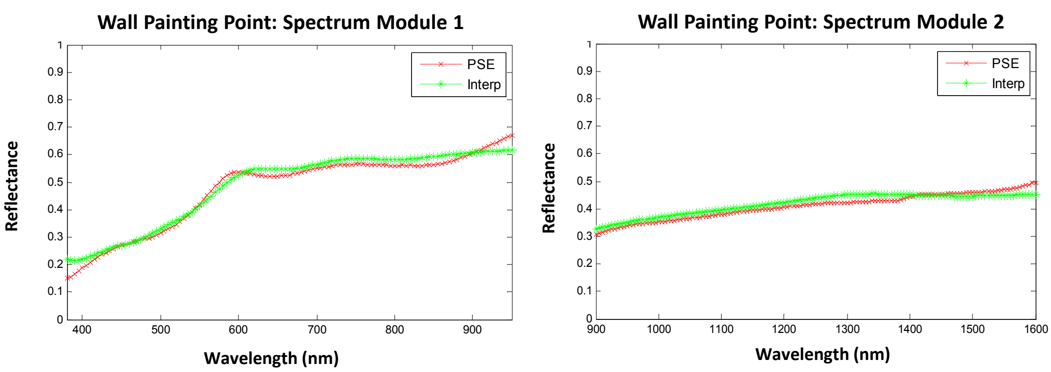
Figures 2a and 2b show monochromatic images of Bassa's wall paintings at the spectral channels of 630nm and 1200nm. These two images are examples of images in the visible range and the infrared range, respectively. Just observing the images some differences can be noticed, this is a key point for people in the restoration field, as it allows assessing the art works over different portions of the spectrum.



a) b)

Figure 2. Images of Ferrer Bassa's wall painting. a) Image at 630nm b) Image at 1200nm.

Figure 3 shows the result of spectral estimation using pseudo-inverse and interpolation methods, for two pixels in the images in Figure 2. The metrics between these spectra give values of RMSE(%) = 2.266 and GFC = 0.999 in the first module and RMSE(%) = 2.285 and GFC = 0.999 for the second module, meaning that these spectra have a good matching. We claim that the resemblance between these estimated spectra are a proof of their proximity to the real spectra of those pixels. This is because the interpolation method should at least follow roughly the shape of the real spectrum and it gives a clue about whether the pseudo-inverse method is also yielding a correct result.



a) b)

Figure 3. Spectral estimation of two points over the wall painting in Figure 2. Comparison between the pseudo-inverse and interpolation methods, a) for module 1, and b) for module 2.

4. CONCLUSIONS

The implementation of a multispectral system based on LEDs for art work studies has been shown. The performance of the system in spectral reconstruction for a training set of samples has been evaluated through three different metrics. These three metrics show that the pseudo-inverse estimation method has slightly better accuracy than the interpolation method in the two different modules that comprises the system. Even with this difference in the results, the two methods have considerably good performance (DE00 near 2, RMSE near 2%, GFC of 0.999). The images of spectral channels of real art work and the comparison of reconstruction of pixel spectra in this real sample underlines the possibilities that this system can offer to people involved in the field of art study and conservation.

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REFERENCES

Abed, F. M., Amirshahi, S. H., & Abed, M. R. (2009). Reconstruction of reflectance data using an interpolation technique. *Journal of the Optical Society of America A*, 26, 613-24.

Brydegaard, M., Z. Guan and S. Svanberg. 2009. Broad-band multispectral microscope for imaging transmission spectroscopy employing an array of light-emitting diodes. *American Journal of Physics* 77: 104-10.

Fischer, C., & Kakoulli, I. (2006). Multispectral and hyperspectral imaging technologies in conservation: current research and potential applications. *Reviews in conservation*, 7, 3–16.

Hernández-Andrés, J., J. Romero and R. Lee Jr. 2001. Colorimetric and spectroradiometric characteristics of narrowfield-of-view clear skylight in granada, spain. *Journal of the Optical Society of America A* 18: 412-20.

Martínez, Ó., Vilaseca, M., Arjona, M., Pizarro, C., et al. (2011). Use of Light-Emitting Diodes in Multispectral Systems Design: Variability of Spectral Power Distribution According to Angle and Time of Usage. *J. Imaging Sci. Technol.*, 55, 050501-1 050501-8.

Sharma, G., W. Wu and E.N. Dalal. 2005. The ciede2000 color-difference formula: Implementation notes, supplementary test data, and mathematical observations. *Color Research & Application* 30: 21-30.

Sheth, S.A., N. Prakash, M. Guiou and A.W. Toga. 2009. Validation and visualization of two-dimensional optical spectroscopic imaging of cerebral hemodynamics. *NeuroImage* 47 Suppl 2: T36-43.

Vilaseca, M., R. Mercadal, J. Pujol, M. Arjona, M. De Lasarte, R. Huertas, M. Melgosa and F.H. Imai. 2008. Characterization of the human iris spectral reflectance with a multispectral imaging system. *Applied Optics* 47:5622-30.

Vilaseca, M., J. Pujol, M. Arjona and M. De Lasarte. 2006. Multispectral system for reflectance reconstruction in the near-infrared region. *Applied Optics* 45: 4241-53.

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Color Characteristics of the American Casual Fashion Design with Inherent Symbolic Features of Black Music and Paintings

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ABSTRACT

The purpose of this study is to elaborate on black cultural specificities by exploring the distinct American black culture in division of symbolic interpretation of music and drawings and to analyze color characteristics in black casual fashion design in America.

This research included a literature review clarifying the symbolic interpretation of black painting as a visual expression of language and black music as a linguistic expression systemized through the time. In order to analyze the color characteristics of casual fashion design, cases were extracted for analytic purposes from the websites of casual wear brands reflecting the current American blackness. The scope of this research covered 137 brands for males and 33 brands for females. 1,719 fashion images were collected from these websites over the period from September 2010 to July 2011 to analyze colors. The colors were divided into those used in backgrounds and others used in graphics. Each color of the design was converted to Munsell's H V/C codes based on the Munsell Conversion Software 2011 Version. Also, the representative colors and tones were extracted from the analysis of those presented in the background and graphic colors.

This study is significant as it can establish to design development in application of black cultural specificities by identifying symbolic characteristics of black drawings and music, deriving representative colors and color arrangement palettes presented in black casual fashion of the America, and clarifying correlation of color characteristics present in the cultural specificities and fashion.

1. INTRODUCTION

Costumes express national characteristics and culture of each era and these cultural features have been expressed in various forms of art. As for black people, one of ethnic minorities in the American migrated to cities after abolition of slavery. They formed their own cultures and presented cultural specificities in their paintings, music, and fashion.

The approach of the related previous studies is that the concept of resistance in sub-culture is re-created despite of changes of time. There are also case studies analyzing the impact of sub-culture styles persistent in the 2000s on fashion trends and the overall currents. However, there is no study specifically analyzing color characteristics present in graphics. The subject has become a new and wider popular culture through music and various types of media rather than just a subculture.

This study elaborated black cultural specificities through symbolic interpretation of music and drawings and analyzed color characteristics in black casual fashion design of the America.

2. METHOD OF RESEARCH

As for methods of research, in order to identify black cultural specificities, a literature review was in place, clarifying symbolic interpretation of black painting as a visual expression of language as well as black music as linguistic expression systemized in the flow of time. In order to analyze characteristics of black casual fashion based on the results, websites presenting the brands of black casual wear in the America were explored, through which 1,719 images of men's and women's wear were collected and saved as JPEGs over a period between June 2010 and August 2011. Colors were divided into those used in the backgrounds and others used in graphics. Each color of the design saved was converted to Munsell's H V/C codes based on the Munsell Conversion Software 2011 Version. Color characteristics were analyzed in division between 10 and 40 hues of Munsell while tone characteristics were analyzed through 12 tones of P.C.C.S. Achromatic colors with chroma levels, 0.5 or below were divided into W (white), Gy (Gray), and Bk (black) according to brightness. Also, the representative colors and tones were extracted based on the results from an analysis of colors and tones presented in the background and graphic colors. With an aim to analyze the characteristics of color arrangement in casual fashion design, models were constructed according to areas of background and graphic colors.

Table 1. Background color samplings

Number	H	V	C	Tone	Hue	40colors
logo5	5.9GY	2.2	2.6	Dkg	GY	5GY
logo6	9.4RP	5.9	16.0	B	RP	10RP
logo7	.2RP	3.9	1.6	G	P	10P

Figure 1. Color arrangement samplings of Graphics

3. CONCLUSION

The results from this study revealed correlations between symbolic characteristics of black music and drawings and color characteristics of their casual fashion design. The symbolic characteristics of black music and drawings, identified through a literature review, were divided into the ten types covering defiance, resistance, aggressiveness, extemporaneousness, playfulness, dependency, sarcasm, aboriginality, humor, and abstractness.

Table 2. The Distinct Characteristics of Black Culture Inherent in Painting

Periods	Blackness	Elements of Painting
B.C.~ 19C (Perspective of Others)	Positive	Symbol of wealth and power (B.C.)
	Differentiated Exotic	Pagan, otherness, exotic, subject of exclusion, suffering, evil, death, darkness, meaning expressed in something pagan or strange as well as colors and tones of brightness
	Dependency	Master-slave structure
	Aboriginality	State of nature
	Strong	Resistance against the dominant culture
20C (Perspective of Black People)	Sarcasm	Expression of social repression and aspiration for freedom
	Playfulness	Wit and humor. Efforts to elevate human grief playfully. Aspiration for freedom
	Humor	Aspect to express negative sides with a light and innocent smile

Table 3. The Distinct Characteristics of Black Culture Inherent in Music

Blackness	Elements of Music	Meaning
Defiance, resistance	Core themes, strong raps, use of slangs, and shouting	Expression of complaint against hard life and repression, spirit of resistance
Aggressiveness	Lyrics (labor-related songs), shrieks, and swearing	Praise violence on back streets and express aggression toward the government and police
Sarcasm	Hollering, blues language, and forms of repeated tunes	Expression of images containing derision of the mainstream society
Playfulness, hopefulness	Dancing, singing, lead singing and singing together, motown sound, stax sound	Express aspiration for freedom with joy and hope
Aboriginality	Voice element	Return to Africa
Extemporaneousness	Voice element, syncopation-applied, improvised singing and playing (hollering)	Improvised playing without certain forms and rules
Abstractness	Emotional expressions such as screaming or sobbing	Expression of emotions of black people and inherent concepts in symbolic terms

The following is the summarization of color characteristics of the US black casual fashion. As for the characteristics of background colors of women's wear, vivid or strong tones of colors, R, PB, P, and RP were applied in general. On the other hand, as for the characteristics of background colors of men's wear, the color, R was applied mainly and there were tones of vivid and dark grayish. The color commonly applied to both wear was vivid tone of R as well as achromatic colors such as white and black. As for the comparison of overall graphic colors of men's and women's wear, colors were almost the same while tones were similar. As for color characteristics of women's wear, there were tones of light, pale, and bright in colors such as Y, PB, and B while in colors such as R and RP, there was a trend of using tones such as vivid, strong, and dark grayish. In graphic colors of men's wear, tones of vivid and strong were high in the color, R , while in the color, Y ,tones of vivid and bright were prominent. There was a major distribution of primary colors excluding GY, G, and BG. As for achromatic colors, the same representative color was selected except for light grayish found with men's wear.

In conclusion, the difference in graphic colors of men's and women's wear was insignificant. Overall, there was a strong contrast of colors and tones. As for color characteristics in terms of graphic forms of men's and women's wear, colors presenting playfulness were prominent in women's wear while those related to aggressiveness were found with men's wear. As for the common feature, the colors expressing extemporaneousness and abstractedness were identified. The characteristics of these colors were mostly clear and strong. As for the characteristics of color arrangement in terms of graphic forms, colors with a large difference in brightness and tones were applied to letter patterns in order to express extemporaneousness and abstractedness. Aggressiveness prominent in distribution with men's wear was related to dark colors and those with a prominent difference between brightness and chromaticness while playfulness found with women's wear related to complementary color arrangement with high chromaticness as well as application of similar colors in addition to the characteristics of being bright and colorful.

This study is meaningful as it can contribute to design development in application of black cultural specificities by identifying symbolic characteristics of black drawings and music, deriving representative colors and color arrangement palettes presented in black casual fashion of the America, and clarifying correlation of color characteristics present in the cultural specificities and fashion.

REFERENCES

Addison Gayle, JR. 1971. *The Black Aesthetic*. Garden City.

Allen, W. Francis, Ware, Charles P. Garrison, Lucy Mckim. 1867. *Slave songs Of the United States.* New York: A. Simpson and Co.

Brown, Sterling. 1958. *"Negro Folk Expression" in A.Meier and E. Rudwick*. The Making of Black America.

Jones,Leroi. 1968. *Black Music.* New York: William Morrow & Co.

Jones,Leroi. 1963. *Blues People*. New York: William Morrow & Co

Tagg,J. 1989. *Black Music, Afro- American music and european music*. Popular Music.

Trieste firma cultura. 1999. *Basquiat.* Charta

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A study of automatic color scheme method for personal website design

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ABSTRACT

In this study, we proposed a systematic method to automatically suggest some color combinations based on the basic concepts of chromatics with the color inference rules during the website design. The method we proposed is divided into three phases, including dominant color selecting, color fine-tuning, and webpage assigning. That is, a harmonic color was selected from a natural photo specified based on the Median-Cut of color quantization in the first phase. Secondly, we developed a new color scheming method, which is integrated by the triadic and complementary ones, to fine tune basic color and to determine others required for webpage design. In the third phase, these new color schemes were assigned to the simple web page layout. A prototype system was developed to evaluate the performance of our method. The preliminary result shows that this automatic system proposed can help no design experience users to greatly shorten the learning time and reduce their working load to obtain a webpage with acceptable quality. More detail evaluation is need for future research.

Keywords: Color Scheme, Color Harmony, Webpage Design

1. INTRODUCTION

The Internet has been growing fast in recent years. Many people use it to make personal websites to market themselves and also show their unique characteristics. For personal websites, not only are the webpage designs and contents different but also the appearance and choice of color are important. But people who has no experience in design, color scheming is difficult for them. Although there are a lot of textbooks based on color schemes or samples of color patterns, the readers still cannot master these concepts. Therefore, the purpose of this study is to develop an automatic color scheme method to solve the problem of coordinating color schemes.

According to many literature reviews of webpage area、a sense of beauty and database of pictures, for instance, Huang(2010) the webpage designers need to notice that webpage is not only a ratio of ration to area but also pictures in webpage which will be affected by color harmony. Tsai(2008) thought the sense of beauty in personal blogs are affected by user's lifestyle、background and environment. There are hardly researches for people who have no experience in design. Yoshida, Watanabe, Nishida(2006) developed a system of design for webpage designer. Therefore, this study will combine color area with the concept of color harmony to develop an automatic color system method. [5]

This automatic color system method's procedures as follows: firstly, to collect Dominant Color Selecting, Color Fine Tuning, Webpage Assigning of pictures. Secondly, to use Triad Color Scheme as its main color method to adjusted the legibility of text. Finally, the result will display on the webpage.

The remainder of this paper is divided into three sections. The second section of article is our method in full details of procedure and algorithm. This is followed by experimental results in Section 3, with a thorough description of procedures, instruments, results, and evaluations. Finally, the conclusions and future works are drawn in Section 4.

2. AUTOMATIC COLOR SCHEME

The procedures of the automatic color scheme method is as follows:(a) Input Photo (b) Select Dominant Color (c) Select Auxiliary color and ornamented color (d) Adjust Value and Saturation (e) Adjust the legibility of text (f) Assigning to Webpage.

Figure 1. Automatic Color Scheme Method Procedure

2.1 Dominant Color Selecting

In our research, median-cut algorithm was proposed to select dominant color from a nature photo. Median-cut algorithm is not only fast to implement but also good in quality. This method used the smallest cuboid bounding box at the 3D RGB space to enclose all the colors occurring in original image, then repeatedly subdivided color space into smaller and smaller rectangular boxes until the original color space was divided into 256 regions. Dominant color of the nature photo was selected by the sum of the median of per pixel.

Because the dominant color of photo selected by using Median-cut method was described in RGB color space, we need to convert RGB values to HSV values for choosing color from color wheel. After color space transformation, the hue was expressed in HSV color system. In order to be consistent with Itten's color wheel, the angle of HSV need to be changed. Figure 2 illustrates the relationship between HSV and Itten's color wheel.

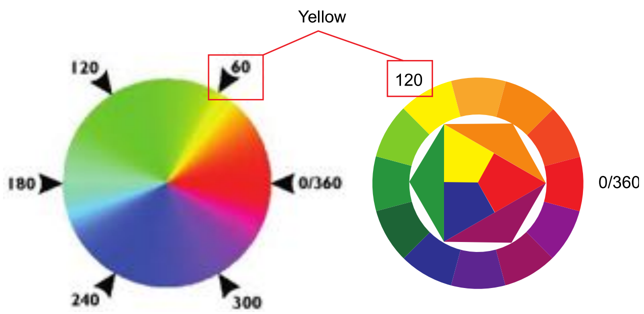

Figure 2. Corresponding HSV with Itten Color Wheel

2.2 Color Fine Tuning

There are at least three regions need to be done color matching in every single webpage. Web designers usually avoid using solo color when establishing a website color scheme. Basically, most of designers do not choose more than three colors for a webpage. Therefore, we used triadic color scheme for selecting auxiliary color, and put ornamental color determined by using complementary color scheme into the smallest region in web page layout.

Since ten's color harmony theory is based on the relative positions of the hues on the color wheel and lacks of consideration of value and saturation, we have to adjust the value and saturation of auxiliary color and ornamental color, and modify the legibility of text according to background color. In our method, we chose black and white as text color, and divided the value of background color into ten levels. The lower level in value, the brighter in text color. [2][3]

2.3 Webpage Assigning

Based on the connection with golden ratio of color design, dominant color, auxiliary color and ornamental color, the one is used as the primary is called dominant color, another that compliments is called auxiliary color. When it needs an accent, it called ornamental color. Each one was separately added to a proper area of webpage used this automatic color scheme method. [1][4]

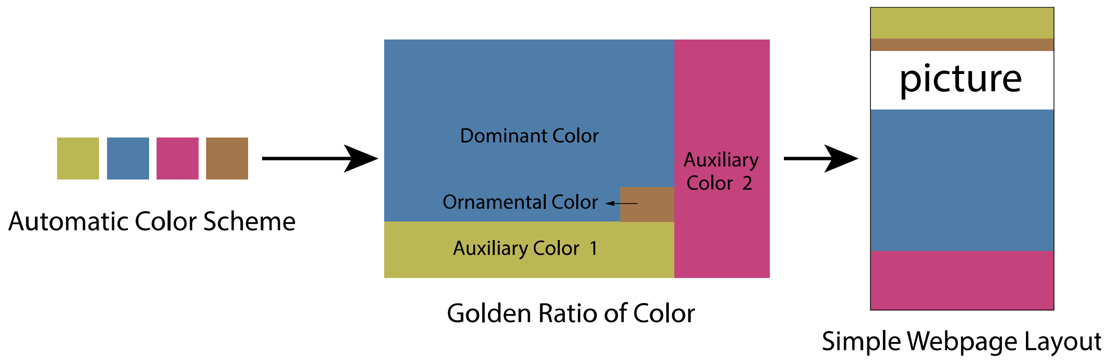

Figure 3. Webpage Assigning Procedure

3. EXPERIMENT AND RESULTS

A prototype system was developed to evaluate the method proposed. We created the automatic color scheme, and design a simple webpage layout to show the result of automatic color scheme by Dreamweaver CS5 in JavaScript. Figure 4 illustrates some results of this system. According to the result, Median-Cut Algorithms can grab correct color from a natural photo. We acquired a harmony color combination from mixed Triadic Color Scheme with Complementary Color Scheme. Besides, we adjusted the color of text based on the value of background color to get the good visual effects.

Figure 4. The Result of Automatic Color Scheme

4. CONCLUSIONS AND FUTURE WORKS

In this paper, we will combine the concept of color area with color harmony and develop automatic color scheme method. It can simplify the processes of color design work to people who has no experience in design. We choose dominant color from photo, and the method can make the dominant color consistent with theme of photo. Although the study just use natural photo to create the color scheme, we looking forward to the future studies will provide more themes color scheme to improve the automatic color scheme method.

REFERENCES

[1] Beaird, J. 2010. *The Principles of Beautiful Web Design*. Canada: SitePoint.

[2] Birren, F. 1900. *The elements of color: a treatise on the color system of Johannes Itten, based on his book The art of color*. New York: Van Nostrand Reinhold.

[3] Burchett, K. E. 1911. Color Harmony Attributes. *Color Research and Application* 16(4): 275-178.

[4] Schaik, P. V., and J. Ling. 2001. The effects of frame layout and differential background contrastion visual search performance in Web pages. *Interacting with Computers* 13(5):513-525.

[5] Ueki, H., and M. Azuma. 2003. Background color coordination support system for web page design. In *The Second IEEE ICCI 2003, Proceedings*, ed. by D. Patel, S. Patel, and Y. Wang. London: IEEE CS Press, 207-213.

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poster

Application of Camouflage Patterns to Background for Design Works

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ABSTRACT

Although military camouflage patterns have excellent designs and color harmonies that symbolize natural scenes, they have negative images because they are often used on the battlefield.

We utilize military camouflage patterns for the background of non-military design works. It makes simple simulations and does not specify the displaying place. The colored and patterned background helps especially the practical decision of color scheme.

It can also be utilized for presentation of existing art works simulating the surroundings that displayed. We designed a new camouflage pattern for the work of ceramic art actuality presented at outdoor natural scene. The pattern was printed on the paper base and succeeded to reproduce of the surroundings at indoor.

1. INTRODUCTION

Military camouflage patterns have negative images because they are often used on the battlefield. Though, they have excellent designs and color harmonies that symbolize natural scenes, and some modern artists utilize them for a motif of their works as shown in Figure 1: Newman and Blechman (2004).

We utilize the patterns for the background of non-military design works in expectation of that it makes simple simulations and does not specify the displaying place. The colored and patterned background will helps especially the practical choice of color and the decision of color scheme.

The merits of the utilization are:

- many patterns already exist,
- they simulate country or area and season,
- they simulate the natural scene without specific form, and so on.

It can also be expected to use for the presentation of existing art works simulating the surroundings that displayed.

Figure 1. "Camouflage Self-Portrait" by Andy Warhol. (1986)

2. METHODS AND RESULTS

2.1. Camouflage patterns used

The pattern data of the military camouflages had been obtained from a Web page: Meisai Zukan (2011), and Figure 2 shows the patterns used, namely, the U. S. Marine Corps pattern; CF1, the U. S. Army pattern; CF2, and the Japanese Self-Defense Force pattern II, CF3. The pattern of CF2 is called M81 Woodland derived from ERDL (Engineer Research and Development Labor) pattern. The *RGB* values of the color used for the camouflages are given in Tables 1 - 3.

Figure 2. Camouflage patterns used

2.2. Application to background for color design

Figure 3 shows the color samples on pure white and on the camouflage patterns. It shows that the chroma of colors is emphasized and the light colors are conspicuous on the camouflage by the contrast effect.

As an example of the practice, the lanterns for an art festival ("Soul of Asuka 2011" held at Kogenji, the oldest temple in Japan) are designed on the background (Figure 4). The festival was an event connected with Asuka art project 2011. Asuka was the one of the Imperial capitals of Japan during the Asuka period (538 – 710 AD), and according to one theory, Buddhism was introduced into Japan by Koreans at there.

Following the historical event, a traditional Korean lantern called Cheongsachorong (靑紗燈籠, 청사초롱) was adopted as the design source of the lantern. The lantern is typically made by joining red and blue silk shades and hanging a candle inside the body. The color was modified by using color of Japanese national flag to symbolize the friendship between our countries.

The effect of color scheme was simulated by using the three camouflage patterns as shown in figure 5. The camouflage patterns helped to confirm the usage of white color was quite effective in the natural scene.

After the design work, the Nylon fabrics were dyed by acid dyes to obtain the decided color. A hundred of the lanterns were made and were exhibited for the festival. The usefulness of the camouflage background for design work was demonstrated.

Table 1. Color used for CF1 *(RGB value).*

	light	← lightness →		dark
	CF1-1	CF1-2	CF1-3	CF1-4
R	186	119	50	50
G	178	115	98	48
B	142	68	73	41

Table 2. Color used for CF2 *(RGB value).*

	light	← lightness →		dark
	CF2-1	CF2-2	CF2-3	CF2-4
R	222	120	122	82
G	206	134	94	74
B	162	101	70	75

Table 3. Color used for CF3 *(RGB value).*

	light	← lightness →		dark
	CF3-1	CF3-2	CF3-3	CF3-4
R	167	82	107	28
G	172	132	75	32
B	122	54	28	34

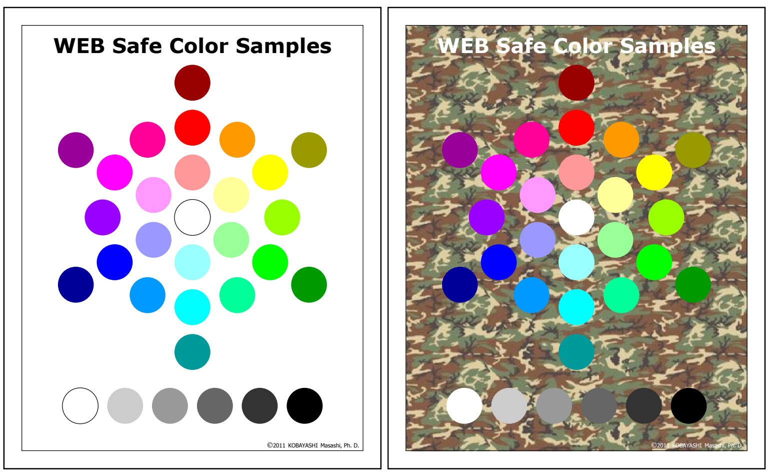

Figure 3. Color samples on pure white and camouflage pattern.

Figure 4. Design process of color scheme on camouflage pattern.

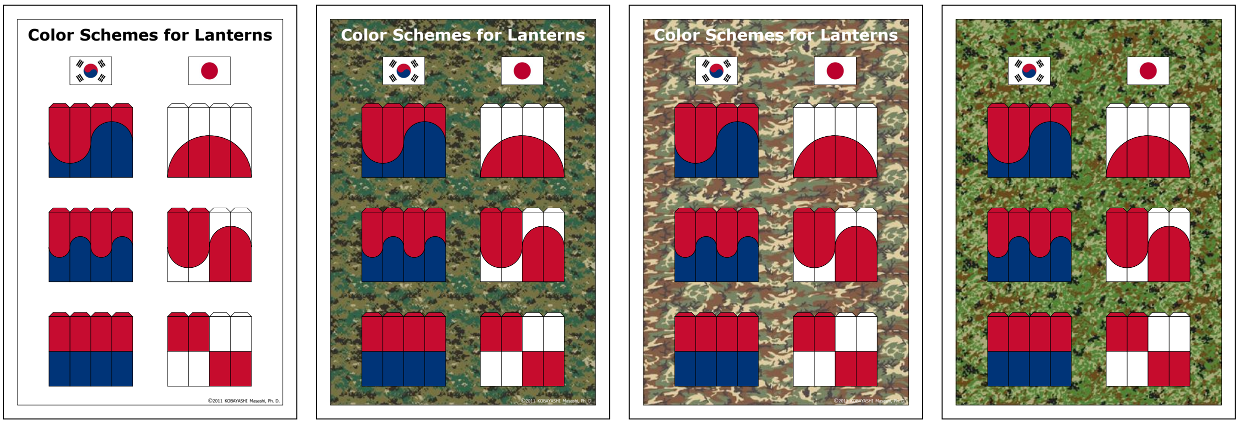

Figure 5. Color schemes on camouflage patterns.

2.3. Application to background for presentation

At the art festival, an ceramic work named "*Koto* [Ancient Capital]" was exhibited in the precincts of Kogenji temple (Figure 6). As shown in Figure 7, the autumnal ginkgo leaves came down on it. The aim of the artists is the embodiment of fusion of the artificial work and nature.

The camouflage patterned background can also be utilized for presentation of existing art works simulating the surroundings that displayed.

We designed a new camouflage pattern "*Autumnal Ginkgo Leaves*" as shown in Figure 8 for the work of ceramic art actuality presented at outdoor natural scene.

Figure 6. Art work construction by artists.

Figure 7. "Koto [Ancient Capital]"(part) by Dong-Ki Park and Takashi Kikuchi as the Forest Beyond. (2011)

The pattern was printed on the paper base and succeeded to reproduce of the surroundings at indoor as shown in Figure 9.

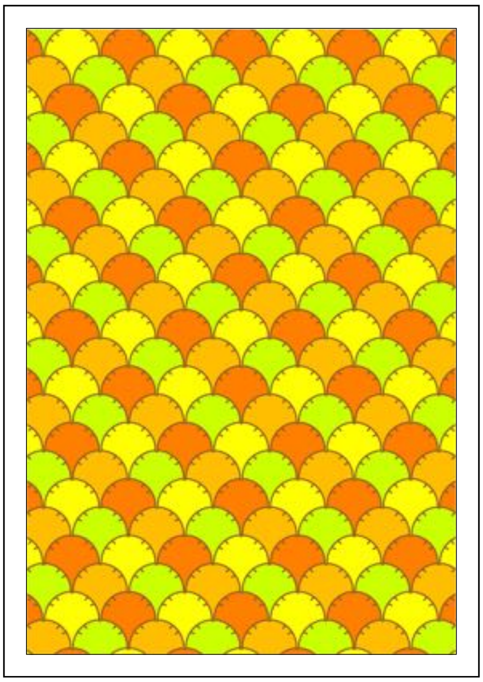

Figure 8. New pattern "Autumnal Ginkgo Leaves" designed by Masashi Kobayashi, et al. (2011)

3. CONCLUSION

We utilize military camouflage patterns for the background of non-military design works. It makes simple simulations and does not specify the displaying place. The colored and patterned background helps especially the practical choice of color and the decision of color scheme.

It can also be utilized for presentation of existing art works simulating the surroundings that displayed. We designed a new camouflage pattern for the work of ceramic art actuality presented at outdoor natural scene. The pattern was printed on the paper base and succeeded to reproduce of the surroundings at indoor.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the invaluable assistance of the students of Osaka Shoin Women's University who made the lanterns for the festival. The graphic report of the activity is presented in the internet Web page: Osaka Shoin Univ. (2011)

Figure 9. Effect of camouflage patterned background on exhibition of art work.

REFERENCES

Newman, A., and H. Blechman. 2004. *DPM Disruptive Pattern Material: An Encyclopedia Of Camouflage: Nature, Military, and Culture.* London: DPM (BVI) Ltd.

Nezu. Update 2011. Meisai Zukan (The Illustrated Book of Camouflage, in Japanese). Available online, http://meisaizukan.web.fc2.com/.

Osaka Shoin University. 2011. http://www.osaka-shoin.ac.jp/univ/whatsnew/whatsnew/2402/whatsnew_detail.html

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Difference between Stereoscopic and Monocular Vision for Gonio-apparent Surfaces

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ABSTRACT

This study investigated which appearance properties of gonio-apparent materials are influenced by stereoscopic and monocular vision. In a psychophysical experiment, various surfaces were assessed according different attributes. The results revealed that observers found it relatively more difficult to judge certain appearance properties regardless of mode of viewing. It was also found that texture and coarseness intensity were easier to assess.

1. INTRODUCTION

Stereoscopic vision and monocular vision involve observation using either two eyes or one eye respectively. It has been suggested that stereoscopic vision has advantages over monocular vision for certain tasks (Blake and Sekuler 2005, Holliman 2005). For example, it provides a wide viewing field and facilitates depth perception. Various gonio-apparent (angle-dependant) surface features such as texture, metallic pigments or pearlescence are related to depth. The majority of earlier research has focused on only single or a few properties rather than the overall appearance (Ershov et al. 2001, Kaiser 2006, Maloney and Yang 2003, Nadal 2003). Furthermore, relatively few studies looked at the differences between stereoscopic and monocular modes of vision (Obein 2004). The aim of this study is to investigate which properties are influenced by viewing mode using a psychophysical approach.

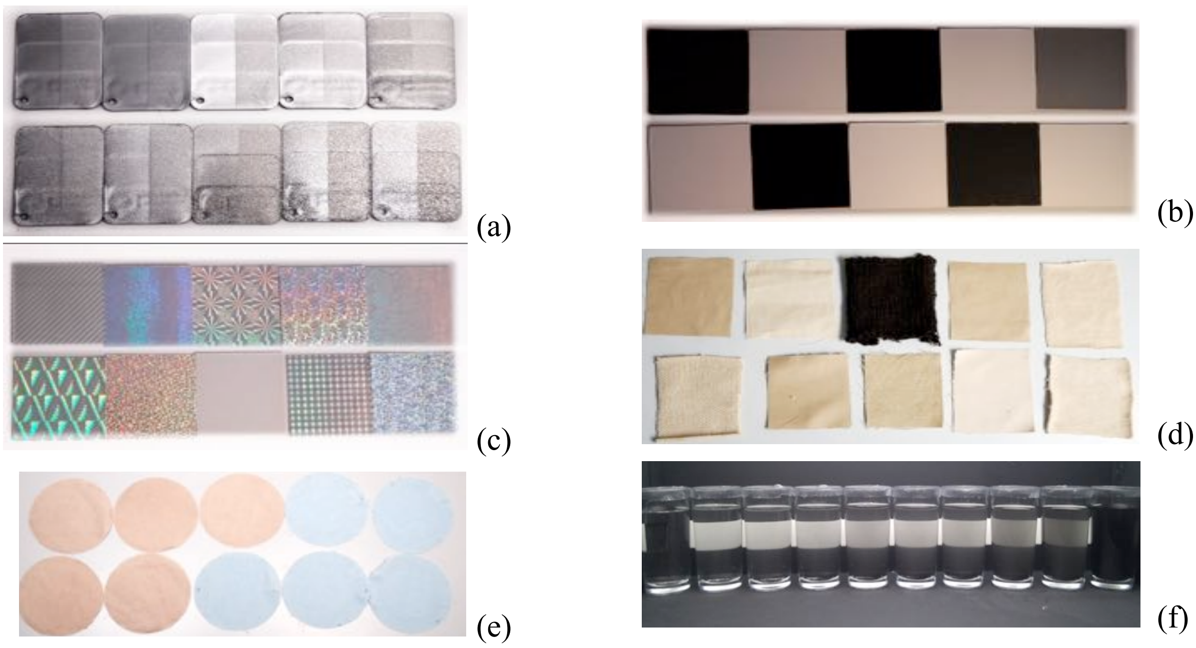

Figure 1: gonio-apparent samples – (a) metallic, (b) gloss, (c) pearlescence, (d) texture, (e) pilling and (f) haze.

2. SAMPLE PREPARATION

Six types of materials (Figure 1) were used in the study: (a) plastic metallic-effect panels, (b) uniform variable-gloss grey cards, (c) pearlescent cards, (d) knitted fabrics, (e) plain-weave fabrics and (f) water. Each type consisted of ten samples, each having a different level of a gonio-apparent property. The properties studied here are: coarseness (intensity, density and size), glint (intensity, density and size), gloss, pearlescence, texture, pilling and haze.

3. PSYCHOPYSICAL EXPERIMENT

A total of 220 samples were assessed by a panel of 10 observers with normal (or corrected-to-normal) visual acuity and normal colour vision. The panel consisted of seven females and three males (three of which are European, the rest Asian) aged between 24 and 33. During the experiment, observers assigned a category on a nine-point scale for each sample through comparison with a reference sample. Each observer judged the samples twice using both stereoscopic and monocular vision. In total, 8800 observations (220 samples × 2 viewing modes × 2 repeats × 10 observers) were made in the experiment.

An object's overall appearance is comprised of a combination of various attributes, but one attribute might seem stronger than the others under certain circumstances. The experiment therefore fixed the light source and the angle between light source and observer. Coarseness and glint were judged under a spot light; gloss, pearlescence and haze under diffuse light; and texture and pilling under directional light. To control the angle, coarseness, glint, gloss and pearlescence samples were placed on a tilting table at a specific angle which exhibits specular reflection. Texture and pilling used an industrial pilling-assessment viewer having directional, low angle of incidence light (< 15º).

4. RESULTS AND DISCUSSION

The results from the two viewing modes are compared in Figure 2, where the x-axis indicates the samples used and the y-axis the median category given by the observers. Results for stereoscopic and monocular vision are shown in diamonds and squares respectively. Most of the properties that were assessed using stereoscopic vision have category points higher than, or equal to, those for monocular vision with the exception of coarseness density and glint density. It should be noted that the density category has an opposite (downwards) trend compared to the others. This finding indicates that stereoscopic vision aids the perception of gonio-apparent surfaces over monocular vision. The most significant difference between the two viewing modes was for coarseness-intensity. In addition, the error bars are generally relatively small. Those for both texture and haze manifest the smallest standard error; while glint intensity, glint density and pearlescence have relatively larger error bars. These error tendencies were independent of viewing mode. It can also be seen in all of the subplots that the median values for the two viewing modes of samples 1 and 10 have either the same value or a half grade difference between each other. This means that samples at either extreme are judged identically using either one or two eyes and further suggests that stereo vision is most helpful for materials exhibiting more subtle angular variation.

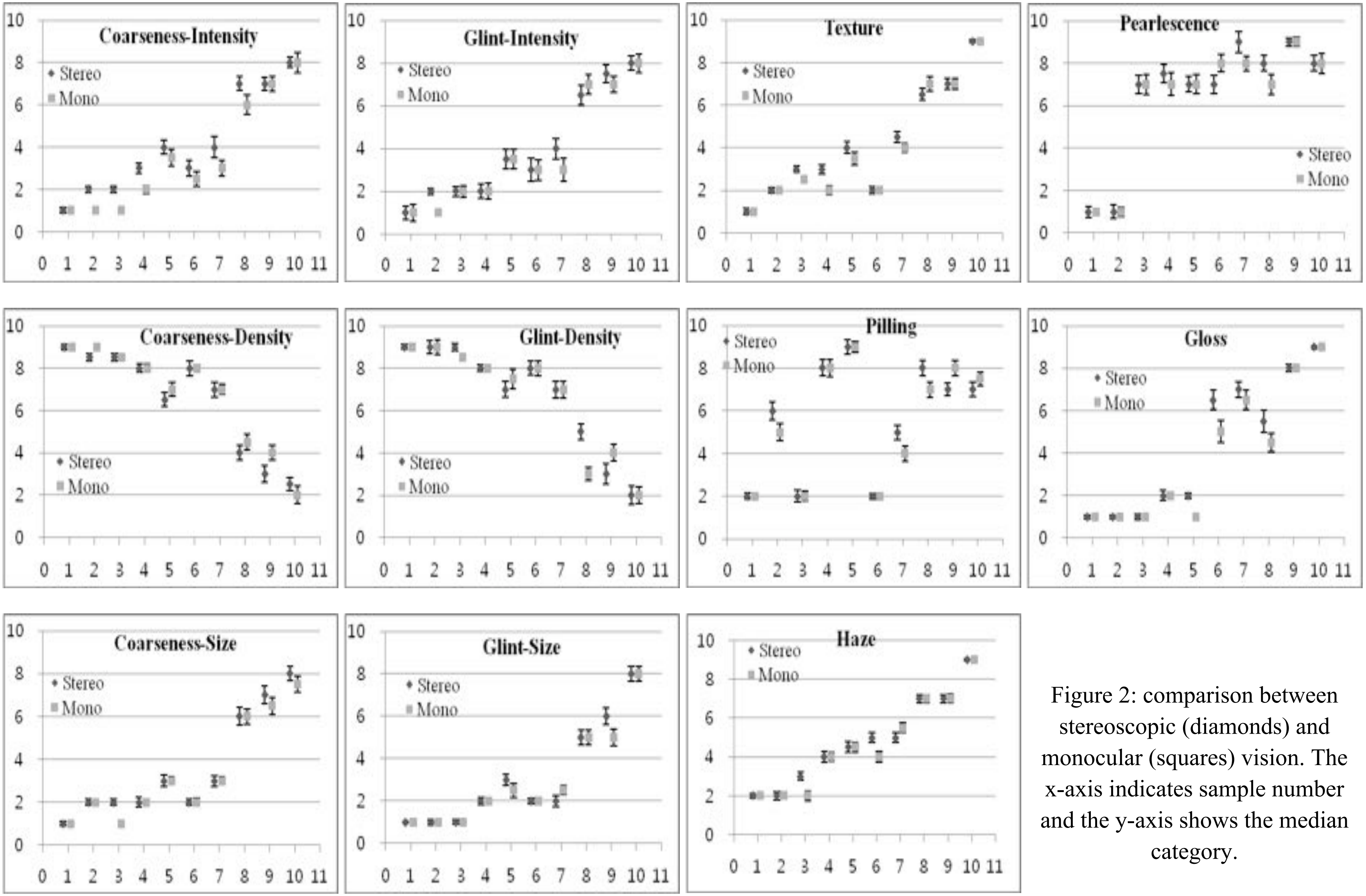

Figure 2: comparison between stereoscopic (diamonds) and monocular (squares) vision. The x-axis indicates sample number and the y-axis shows the median category.

5. CONCLUSIONS

The results from the psychophysical experiment indicate that appearance properties of gonio-apparent surfaces are significantly influenced by the use of either stereoscopic or monocular vision. Textured samples tended to both produce smaller inter-observer variation and exhibit greater differences between viewing modes. This implies that observers found it easier to judge texture, and this property in particular can lead to significant perceptual differences between the two viewing modes. In conclusion, texture is an effective type of property for the verification of differences between stereoscopic and monocular vision. This has important industrial implications where fabric is depicted using two-dimensional displays or printers. To a lesser extent, coarseness intensity also seems to be stereo-sensitive and this also needs to be taken into account in, for example, the quality assurance of products having a metallic finish. As a next step, these findings will be applied to stereoscopic imaging systems, with an overall aim of enhancing the realism in the reproduction of object appearance.

REFERENCES

Blake, R., and R. Sekuler. 2005. *Perception*. Boston: McGraw Hill.

Ershov, S. V., B. A. Khodulev, and K. V. Kolchin. 2001. Simulation of sparkles in metallic paints. *International Conference Graphicon 1999*, 121-128.

Kaiser, E., G. J. Van den Kieboom, L. Njo, R. Super, and R. Gottenbos. 2006. Observation of visual texture of metallic and pearlescent materials. *Color Research and Application*, **32** (4): 256-266.

Lgnell, S., U. Kleist, and M. Rigdahl. 2009. On the relations between color, gloss, and surface Texture in injection-Molded Plastics. *Color Research and Application*, **34** (4): 291-298.

Maloney, L.T., and J. Yang. 2003. Maximum likelihood difference scaling. *Journal of Vision*, **3** (8): 573-585.

Nadal, M. E., and E. A. Early. 2003. Color measurements for pearlescent coatings, *Color Research and Application*, **29** (1): 38-42.

Holliman, N. 2005. 3D display systems. http://www.dur.ac.uk/n.s.holliman/index.html. Last accessed: 10 June 2011.

Obein, G., K. Knoblauch, and F. Viénot. 2004. Difference scaling of gloss: Nonlinearity, binocularity, and constancy. *Journal of Vision*, **4** (9):711-720.

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Color design of luminescent interface display of climate control device

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ABSTRACT

The study demonstrates a design process of the color of luminescent surface facilitated by RGB LEDs and shows that both exploratory and confirmatory approaches were synergized to result in a design solution. Focusing on the relationship between color and in-door climate of automobiles, the study consists of three parts: In Part I, a workshop of ten designers was run in which ideas about were exploited to find scenarios. The quality of scenarios was evaluated in terms of interesting, informative, and inspiring aspects to conclusively derive the scenario of "Eco & Healthy Driving"; In Part II, a user test was carried out in order to investigate the relationship between the attributes of luminescent color—hue, brightness, and purity- and a indoor climate condition. In the user test (n= 36), subjects were instructed to match a luminescent color to a given in-car climate condition. It was revealed that the hue category of luminescent surface is related to the temperature while brightness of luminescent color is correlated with the blow level; In Part III, a new design scenario, "Eco & Healthy Driving" was projected for further development and application by employing the results of user test.

1. INTRODUCTION

Advancements in Lighting Emitting Diodes (LED) have made it possible to go beyond replacing Liquid Crystal Display (LCD) and Back Light Unit (BLU) with White LEDs, to dynamically displaying colorful shades of light by employing RBG LEDs. Such progress highlights the fact that the color of products does not only concern reflected light of surface of object, but also highlights the direct light, especially when the direct light is observed by users. Accordingly, the luminescent color of interface display should be recognized as an element of product design.

In this study, strategies and case studies of expressing color on the interface display of in-car climate control devices are investigated. Particularly, this study focuses on designing the background color of interface display on in-car climate control devices to ultimately increase the competitiveness of interface displays as a product of car design and to increase user satisfaction.

2. PLAN FOR STUDY

This study firstly, explored the intuitive information expressed in interface displays of climate control devices and setting up a color design strategy. It was also a part of the goal to design a user test that would allow for specific proposals of color contents that can be used to implement the strategy mentioned above; Secondly, user tests were executed to identify the scenario of color contents of surface light that would allow the implementation of color design strategy to be reliable at a satisfactory level. Lastly, an implementation was tried proposing on a complete surface light design that can be built into in-car climate control device interface displays by using the empirical results.

3. PART I

Part I attempts to exploit and find a scenario of color presentation on the interface display. In order to generate color scenarios of display of climate control device, firstly, various instances detectable by climate control devices from inside and outside the car were collected. Secondly, color attributes of interface display emitted by RGB LED are identified through the three characteristics, dominant wavelength (nm), luminance (cd/m2 or nit), and purity (%). In order to make the overall concept more equitable to the participants' background knowledge on color, luminosity and purity were combined and expressed as "intensity". Consequently, the workshop participants were acquainted with the intensity through the explanation that an increase in intensity of luminescent color would leads to an increase in both luminance and purity.

Participants were first asked to generate various matching combinations of input and output colors, and then to extract combinations that exhibited an intuitive correlation. Each combination was then evaluated through the evaluation criteria were set that concerns 1) intuitive satisfaction, 2) comfortability of continuously using a certain scenario, and 3) how impressive each scenario concept ultimately is. These three dimensional aspects of the evaluation criteria are related to levels of emotion as suggested by Norman (2003).

The concept of **"Eco & Healthy Driving"** was advocated since it concerned with how the messages "it is hot" and "it is cold" can be transmitted to users, depending on whether the in-car temperature is higher or lower than the overall domain temperature of 23 °C, a temperature that Koreans find most pleasant. For instance, during the summer when the in-car temperature is higher than 23 °C, climate control devices can make the interpretation that users will feel more comfortable with the air-conditioner turned on, whereas in the winter, it might communicate the information that turning the heater is unnecessary.

4. PART II

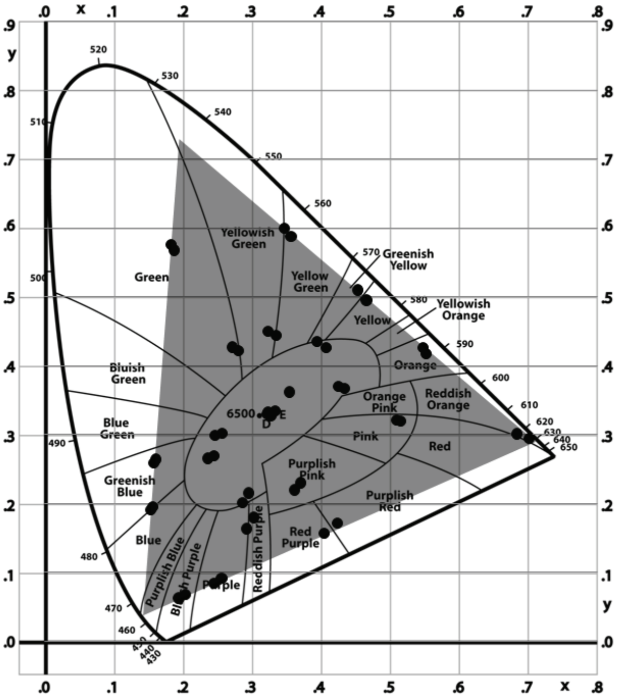
In Part II, a User Test was conducted in order to investigate the relationship between the attributes of color displayed in the interface of climate control device and the perceived quality of the in-car climate condition. As participants were searching for the appropriate display color while directly experiencing the in-car climate, the effects the display colors would have in actual circumstances and similar environment were tested as well.

3.1 Method

Sixteen male and 20 female students were recruited for a total of 36 participants. The average age of the subject population was 22.33 with a standard deviation of 2.95 years.

Stimuli: Collection of 45 color stimuli

In order to create a collection of display colors for the evaluation process during the user tests, the aspects of hue category, lumination and purity were considered as follows. Firstly, ten variations of hue categories — red, orange, yellow, yellowish green, green, greenish blue, blue, bluish purple, purple, and purplish red – were set. The shaded region in Figure 1 represents the color gamut emitted by the RGB LED of the climate control device. Then, it was the luminance, related to the intensity of a lighting surface and measured through Candela per square meter (cd/m2) or called as "nit". Since it is more concerned about visual perception rather than physical properties (DiLaura et al., 2011, p.5.22), the brightness is taken. This brightness of luminescent surfaces was divided into two levels; strong and weak. The strong one was the strongest level of luminescence that the RGB LED could generate, and the weak one was the half. Then the purity, which indicates the vividness of luminescent surface, was considered. As a color is closer to the boarder line (i.e. purity 100%), it becomes more vivid. In this way, each hue category had four variations: two levels of brightness and two levels of purity and thus, 40 chromatic color stimuli were collected respectively. Secondly, four whites were added that had four brightness levels. Lastly, a dark olive was included since it appeared when the display was not connected to power.



(Left) Figure 1. The 45 color stimuli plotted in CIE Chromaticity Diagram: the shaded area is the color gamut of RGB LED of the climate control device. Because the Chromaticity Diagram does not show the Z-axis that corresponds to luminescence level, two dots seem to overlap at one point.

Stimuli: Twelve types of in-car climate

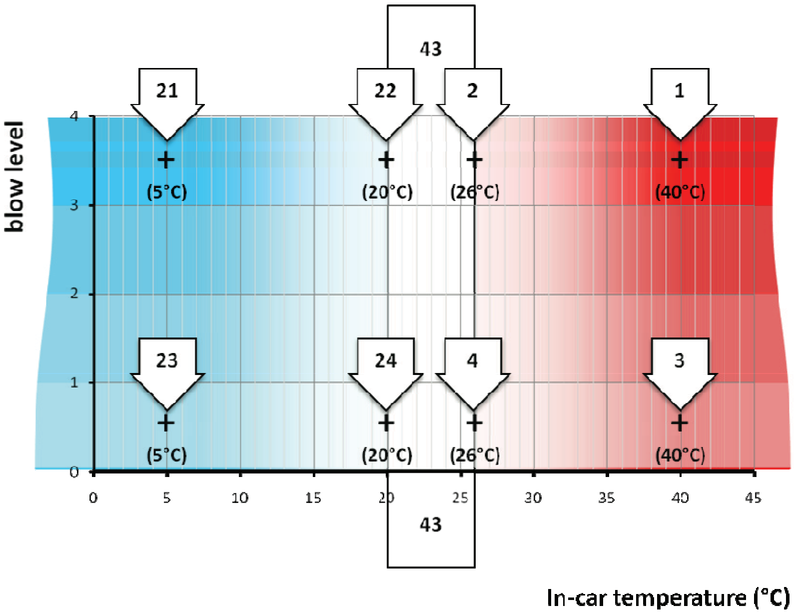
The climate control device used in user study had eight different stages of blow level with the temperature range of 5 °C to 40 °C. The four out of the eight different blow levels were implemented, and three in-car temperature situations were set: the standard of 23 °C that Koreans find most pleasant, 30°C for the heating condition and 10 °C for the cooling condition. In each temperature level allowed the participants to experience four blow levels, and hence, a total of 12 different in-car climate situations were prepared. Each participant was exposed to the twelve in-car climate types in random order, and asked to find the interface display color from the palette of 45 color stimuli that best expressed the given in-car climate type. Because the climate control device used in the experiment was a product that was mounted on the H Motor "i30" model, the user test was also conducted in the i30 model car.

Table 1. The frequently selected color stimuli (6 times or above) of interface display for each of twelve types of in-car climate; the frequency among 36 participants in parentheses, Numbers in parentheses are the frequency.

In-car temperature	Blow level (0 ~ 8)			
	Low	Medium low	Medium high	High
Cold	Weak & Pale Greenish blue (11), Strong & Pale Greenish blue (7)	Weak & Vivid Greenish blue (7)	None (None above 6)	Strong & Vivid Blue (10), Weak & Vivid Blue (7), Strong & Vivid Greenish blue (7)
Mild	Bright White (7)	Weak & Pale Yellow (7)	None (None above 6)	None (None above 6)
Warm	Strong & Pale Red (8), Weak & Pale Red (8)	Weak & Vivid Red (10)	Weak & Vivid Red (9)	Strong & Vivid Red (14), Weak & Vivid Red (8)

5. PART III

In Part III, the concept of "Eco & Healthy Driving" derived from Part I was realized by using the relationship between the color of interface display and perceived quality of in-car climate found in Part II as its basis. It is a critical strategy to make sure that the drivers and the passengers can intuitively understand the message of 'Inappropriate in-car climate'. Therefore, to implement the concept of Eco & Healthy Driving, the interface display color from the results of Part II that correspond with the following questions were chosen:1) What is the most suitable color to indicate the in-car temperature for a condition where temperature is 23 °C?; 2) In a situation where the in-car temperature is above 26 °C, what is the color that indicates the 'operation of unnecessary heating' or 'hotness that requires cooling'?; 3) In a situation where the in-car temperature is below 20 °C, what is the color that indicates the 'operation of unnecessary cooling' or 'coldness that requires heating'?; and 4) To what attribute of luminescent color is increased blow level related to? By answering these questions, a design solution that specifically realizes the concept of "Eco & Healthy Driving" was proposed (see Figure 2).



(Left) Figure 2. The color scenario of "Eco & Healthy Driving". Numbers indicated in the figure are corresponding to the color number listed in Table 2.The logic of color scenario is now being applied for the Patent.

1: strong & vivid red
2: strong & pale red
3: weak & vivid red
4: weak & pale red
21: strong & vivid greenish blue
22: weak & vivid greenish blue
23: weak & vivid greenish blue
24: weak & pale greenish blue
43: medium dark white

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REFERENCES

DiLaura, D.L., Houser, K.W., Mistrick, R.G., & Steffy, G.R. 2011. *The Lighting Handbook (10th Edition),* New York: Illuminating Engineering Society.
Norman, D.A. 2003. *Emotional Design*, New York: Basic Books.

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Hue Discrimination under Different Lighting Including LED

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ABSTRACT

We are often misled to consider RGB LED lighting to be insufficient for white general lighting due to the narrow peaks of the spectrum. The problem is that the CRI does not fully match for LED lightings. Therefore other than comparing CRI values for each lighting, the performance of a simple task was compared. For experimental preparation three types of lightings were used; standard D65 fluorescent tube, general household fluorescent tube, and RGB LED lighting. All three lightings show high error for Purple-Red. All three lightings show similar error for all hues and prove that color discrimination is not affected by the lighting. This proves that LED consisted with R, G, B LEDs could be used as general lighting. LED lighting can improve the blue region spectrum for lighting.

1. INTRODUCTION

Lightning has developed in various types by aid of material and chemistry over these few years. Especially LED (Light-Emitting-Diode) has been replacing not only the special spot lights but also general home lighting. Although the CCT (correlated color temperature) is similarly matched to the contemporary lighting sources such as fluorescent lighting the spectrum differs and that can effect hue discrimination. We are often misled to consider RGB LED lighting to be insufficient for white general lighting due to the narrow peaks of the spectrum. Color rendering is an important criterion for quality of light source and is defined by CIE (Commission Internationale de l'Éclairage) as the "*effect of an illuminant on the colour appearance of objects by conscious or subconscious comparison with their colour appearance under a reference illuminant*" (CIE, 1987). White RGB LED light sources have spectral power distributions with three significant peaks corresponding to their R,G and B components. Therefore, they can cause large color differences compared to the reference illuminant which has broad spectral power distribution curves. The problem is that the CRI does not fully match for LED lightings. Therefore other than comparing CRI values for each lighting, the performance of a simple task was compared.

2. PROCEDURE

For experimental preparation three types of lightings were used; standard D65 fluorescent tube, general household fluorescent tube, and RGB LED lighting. The LED lighting consists of Red, Green, and Blue LEDs that can operate independently and the RGB levels are controlled to match CCT of 6500K. The 'Hue 100 Test' was used as the tool and participants were highly trained 20 females in their 20-30s'. They were asked to complete the task within four minutes under three lightings having 550lx. Figure 1 shows the color discrimination experiment.

Figure 1. Color discrimination experiment

2. RESULTS

Each participant's error data was recorded for 100 hues. The error data is a score of the incorrect order lining of the continuous hue. This shows discrimination level of the hue. The average of the error data is plotted against each hue. The error data shows the discrimination level of each hue.

The D65 lighting used in the experiment has a relevantly broad spectrum while LED and fluorescent has narrow bands at R, G, and B wavelengths. However, in spite of the thought that broadband would be more precise for color discrimination, all three lighting shows similar error for the hue test.

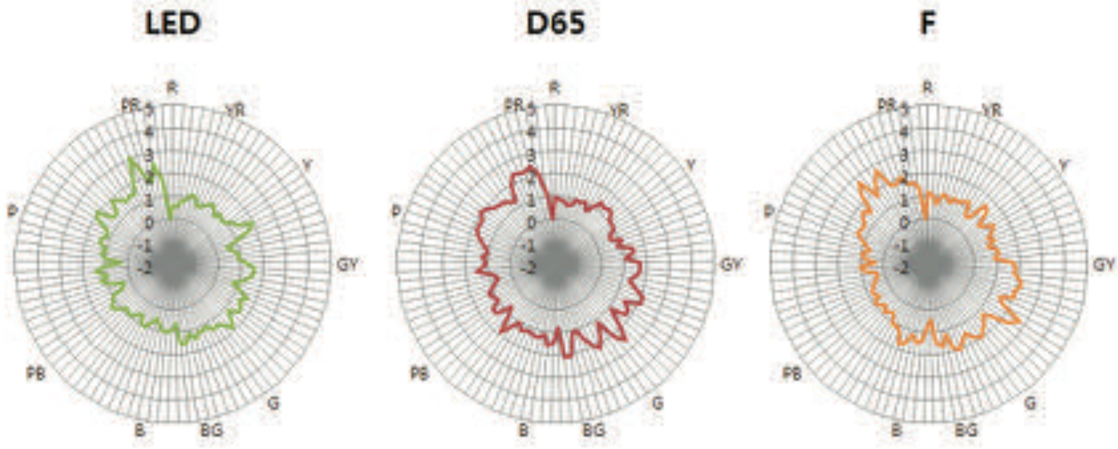

Figure 2. Color error results under LED, D65, F lighting

All three lightings show high error for Purple-Red. There are slightly higher errors under fluorescent lighting in Green-Yellow. All three lightings show similar error for all hues and prove that color discrimination is not affected by the lighting. This proves that LED consisted with R, G, B LEDs could be used as general lighting that has equal CRI (color rendering index) to general lighting and standard D65 lighting.

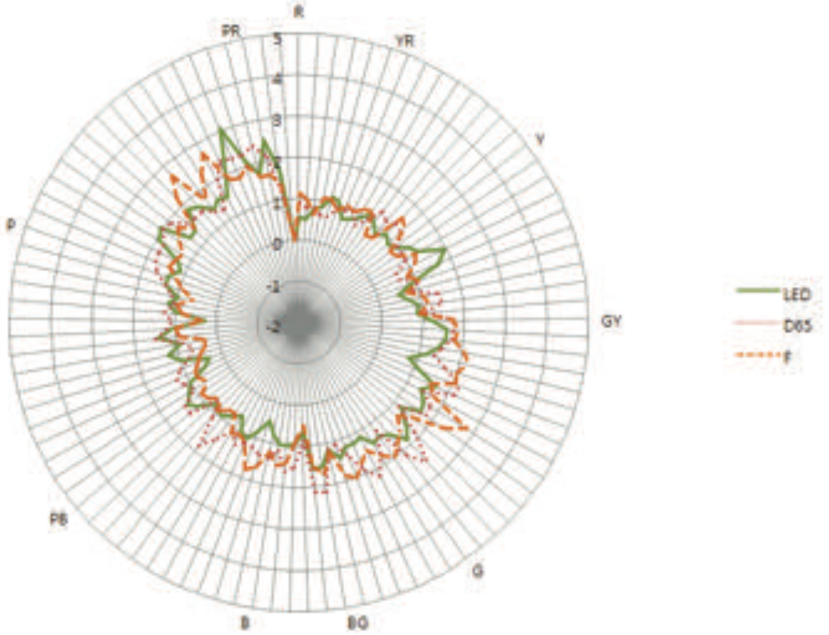

Figure 3. Color error results under LED, D65, F lighting plotted in a single diagram

Figure 3 shows Figure 2 in one diagram. LED is marked as a single line, D54 in small dotted lines and F in large dotted lines. The error is shown the largest in the P-PR region for all three lightings. Under F lighting GY-G shows large error while LED shows least error.

Table 1. Color error results for hues under LED, D65, F lighting

	LED	D65	F
R	0.54	0.77	1.23
YR	1.00	0.92	0.92
Y	0.85	0.92	0.77
GY	1.08	1.69	1.77
G	1.38	1.23	**2.15**
BG	1.38	2.23	1.85
B	0.77	1.23	1.62
PB	1.23	1.38	0.85
P	1.23	1.77	0.85
PR	**2.23**	**2.15**	1.38

Table 1 shows the error results for principle hues under LED, D65 and F lighting. The higher values show larger error for each hue. The important finding is that LED shows the least error in the B region. Blue region has the weakest power among most of the general lightings. This shows that LED lighting can improve the blue region spectrum for lighting. The other finding is that PR region has the largest error for D65 and LED lightings. However the G region has the largest error under F lighting. The least error has PB and P under F where LED and D65 lighting has large error.

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3. CONCLUTION

The finding of this paper is that LED consisted with R, G, B LEDs could be used as general lighting in spite of the narrow peaks of the spectrum. Another important finding is that LED shows the least error in the B region that has the weakest power among most of the general lightings. This shows that LED lighting can improve the blue region spectrum for lighting.

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REFERENCES

CIE Publication 17.4, 1987. International Lighting Vocabulary. Vienna, Austria, Central Bereau of the CIE.

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Colour and light: Concepts and confusions

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ABSTRACT

Colour and light are things that all seeing persons have often reason to refer to, comment and discuss. Such discussions often end up in misunderstandings due to the fact that both *light* and *colour* have several – and often conflicting – meanings. This causes problems for professionals in either colour or light or both, for example when quantifying light, discussing light qualities or specifying an exact colour and its characteristics. This paper summarises a project that aimed at sorting out the confusions and at contributing to a better understanding across different disciplines and professions dealing with colour and light. The project identified numerous conflicting usages and potential causes of misunderstanding in the colour and light terminology. A careful analysis of the most important concepts and their usages was carried out. Three main causes for potential misunderstandings of colour and light terminology were found: 1) confusing the different ways of understanding colour and light through physics, human perception or attempts to combine the two. 2) the confusions caused by different modes of appearance of colour and light and 3) the confusions arising from different of modes of perception.

1. INTRODUCTION

The study was carried out in English, with some references to Swedish and Finnish languages. Despite dealing with terminology, it was not a linguistic project; the focus was on concepts and their use, rather than linguistic differences. We therefore believe that the findings of this study can be readily used and tested in various language environments.

There are two basic approaches to formulating terms that define colour and light. The first is based on our visual experience of the world. This experience spans – as biologically inherited and culturally accumulated knowledge – the whole length of human evolution. The second is based on physics as a scientific way to explore and understand nature. This approach is only a few centuries old and is permeated by a tradition of exact quantification. Psychophysics is a branch of science that aims to bridge the worlds of experience and physics by formulating quantifiable relationships between the two. *Photometry* and *colorimetry* are examples of such endeavours.

Confusions usually arise from words or sentences being understood in diverging ways. One type of confusion arises from mixing concepts belonging to different academic or professional traditions, as in the photometrically defined measure *luminance* and the perceptually defined attribute *brightness*. Another type of confusion is exemplified by *lightness* and *brightness*. Both terms have specific definitions in perceptual science, but at the same time they have their different usages in everyday language.

A third type arises when general experiences or categories have to be further defined for scientific or technological purposes. These can be similar, but not exactly the same, in different conceptual systems. For example, in everyday language we can talk about *vividness* of a colour and be reasonably confident of being understood; but there are many terms in scientific and technical usage, such as *chroma*, *chromaticity* and *chromaticness*, that have similar or slightly different meanings that can still differ from the everyday concept of vividness. Especially problematic are words that are given alternative conceptual definitions in science, while having a more or less stable and established meaning in everyday usage. Take for example *saturation*: even if each of the scientific and technical definitions is clear, it is very confusing that one term can have so many different definitions.

There are also generic words and terms that have very specific meanings within a given scientific discourse, such as the concepts *inherent colour* and *identity colour*. The words *inherent* and *identity* have meanings that can lead to misinterpretations by those not familiar with the scientific discourse.

2. SOME CONCEPTS AND HOW THEY ARE CONFUSED

2.1 Lightness and brightness

The words *lightness* and *brightness* have both wide generic use and specified scientific applications. In everyday usage ‘light’ and ‘bright’ are sometimes used synonymously. For instance a room can be described as either “light” or “bright” with reference to either its surface colours or its illumination or both. Modern perceptual science has reserved separate and distinct meanings for these two words: “Lightness is the perceived reflectance of a surface – – Brightness is sometimes defined as *perceived luminance*.” (Adelson 2000).

Neither lightness nor brightness can be physically or psychophysically measured. Photometric units and measuring tools are based on methods of measuring electromagnetic radiation as weighed against a theoretical model of the light-sensitivity of the visual system. This gives information about such as the *reflectance* of a surface and the *illuminance* (lux) reaching the surface. The *luminance* referred to by Adelson is measured in candela/square metre and *can* be measured. Luminance has an indirect relationship with reflectance and illuminance, but none of these is the same thing as the experience of *brightness*.

2.2 Inherent, identity and nominal colour

The very word colour is used in a number of conflicting meanings, a matter that has been previously discussed by Paul Green-Armytage (2006). We have identified the following usages of the word: The perceptual aspect of colour includes conventional colour names and terms referring to artistic work, but also perceptually defined terms for scientific use, such as the NCS colour properties. The physical aspect of colour is defined by spectral power distribution. Technological colour concepts are defined from the way colour is produced in a specific process, such as RGB or CMYK, and are not applicable in other contexts. The aim of the psychophysical approach is to describe perceived qualities through the use of physically measurable quantities, such as the units of CIELAB or different colour appearance models. (Fridell Anter 2012).

In The Swedish Institute of Standards edition SIS 1993, 2.6 the terms *inherent colour*, *body colour* and *local colour* have been offered as translations of the Swedish word and concept “egenfärg”, which translates more literally into English as (an object’s) “own colour”. This was based on the work of Anders Hård, whose definition of *inherent colour* was as follows: ”… the colour that one imagines as belonging to a surface or a material, irrespective of the prevailing light and viewing conditions”. (Hård & Svedmyr 1995, p 215; our translation). Hård´s definition includes a method for operationally determining the inherent colour, which obscures the notion of an imagined ’real’ colour: “... it can be operationally determined e.g. through comparison with a standardised colour sample.” (Ibid.) Here Hård in effect refers to the standardised viewing conditions under which the NCS samples are perceived to correspond with their codes. Hård implies that the colour perceived under these conditions is equal to the ’real’ colour.

Karin Fridell Anter has used *inherent colour* in a meaning different to the above, as a reference point or 'helper concept', to which perceived colour changes of surfaces are compared. Unlike Hård, Fridell Anter makes no claims about the inherent colour representing any 'real' colour. (Fridell Anter 2000, pp 59–64). We suggest, therefore, that to avoid confusion, the term *nominal colour* be used as a more fitting description of the concept behind *inherent colour*.

Monica Billger has introduced in her thesis *Colour in Enclosed Space*, the concept of *identity colour*: "*Identity colour* is defined as the main colour impression of surfaces or parts of a room that are perceived as uniformly coloured." (Billger 1999, p 11). Billger remarks: "The perceived colour is analysed on two levels of reflective attention, one that can be called holistic and one that is more detailed" (Ibid.) By changing our mode of attention we are able to separate the various layers or spatial attributes of perception.[1] This shifting of attention between local and global or between object, light and shadow, is a part of the normal working methods of any visual artist. The difference between the reflective attentions of an artist or visual researcher and those of the 'man in the street' is one of level of consciousness. Neither *nominal colour* nor *identity colour* claims to represent 'the real colour of the object'. The important difference between the two concepts is that *nominal colour* can be measured by comparison to a colour sample, whereas *identity colour* cannot be measured or operationally determined in any way, only perceived through holistic reflective attention.

2.3 Saturation, purity, chroma, and chromaticness

The chromatic strength or vividness of a colour can be judged with perceptual, physical or psychometric criteria. If perceptual criteria are used, they usually apply to 'related' colours; if physical or psychometric criteria are used, they can refer also to 'non-related' colours. A colour's mode of appearance depends largely on its degree of relatedness. In related colours (surfaces, colour chips etc. viewed naturally) the scale of vividness is: neutral white, grey or black – fully vivid colour. In the Munsell colour system, vividness is called *Chroma* and is judged in proportion to a neutral grey of the same value (lightness). In the NCS vividness is called *Chromaticness* and is judged in proportion to the sum of the colour's blackness and whiteness. The NCS includes a concept of *saturation* that is unique and different from all other meanings of the word: colours that lie on a straight line connecting NCS black and any other colour of the same hue display a constant relationship of whiteness and blackness and thus, according to this NCS definition, possess equal saturation. (Arnkil 2012).

In non-related colours (a light source surrounded by darkness, a surface colour viewed through an aperture), the scale can be: darkness (no light or colour) – maximally bright chromatic light (devoid of blackness or whiteness). This is called *Chromaticness* in CIE terms. Alternatively the scale is from neutral achromatic (white) light to fully chromatic light of the same luminance. This is called *Saturation* in the CIE system. (Billmayer & Saltzman 1981).

There are two further terms related to the concept of vividness in the CIE system. *Excitation purity* is a term related to the CIE 1931 xy chromaticity diagram. It relates directly to the psychometric concept of tristimulus values of spectral sensitivity in the human visual system. (Optical Society of America 1973). *Chromaticity* is defined as the hue and saturation of a colour without regard to its luminance. In the CIE chromaticity model a very dark green and a very bright green could have the same chromaticity. The difference between colours of equal chromaticity and equal saturation, then, is that colours of equal saturation may vary in hue whereas those of equal chromaticity may not. (Arnkil 2012)

To add to the confusion, the various three-part formulations of colour of computer programmes, such as HSV, HSL and HSB (based on the concepts of hue, saturation and

[1] See for example: Merleau-Ponty, M. (2002). *The Phenomenology of Perception*. London and New York: Routledge.

brightness or lightness), all tend to treat the S-variable of saturation differently. It is judged in relation to either blackness (0 output in all RGB channels) or whiteness (maximum output in all RGB channels), but along different paths, depending on the shape of the HSV/L/B space in question.

3. CONCLUSION

The above are just a few of the examples of how misunderstandings can arise when talking about 'light' or 'colour' across disciplines. One of the greatest stumbling blocks is using the terms without reference to their context. Different applications and different modes of appearance of colour and light may require different terms and different definitions. The key to communication and understanding is in identifying the differences in conceptual approach. Only this way the wealth of knowledge about colour and light residing in the traditions of physics, psychophysics, perceptual experience and the various technologies will become fully available to research across disciplines. When speaking about human needs and endeavours in colour and light, the common denominator and final reference point for all the approaches is the human experience of 'colour' and 'light'.

REFERENCES

Adelson, E. H. (2000) 'Lightness Perception and Lightness Illusions'. In Internet article: http://web.mit.edu/persci/people/adelson/index/html. Last accessed 16.10.2011.

Arnkil, H. (2012) 'Lightness and Brightness and Other Confusions' in Arnkil H, K. Fridell Anter, U. Klaren. *Colour and Light – Concepts and confusions*. Helsinki: Aalto University of Arts, Design and Architecture.

Billmayer, F. W. Jr & Saltzman, M. (1981). *Principles of Color Technology*. Second edition. John Wiley & Sons.

Billger, M. (1999). *Colour in Enclosed Space: Observation of Colour Phenomena and Development of Methods for Identification of Colour Appearance in Rooms*. Doctoral dissertation, School of Architecture, Chalmers University of Technology, Göteborg, Sweden.

Fridell Anter, K. (2012) 'Light and Colour: Concepts and their use' in Arnkil H, K. Fridell Anter, U. Klaren. *Colour and Light – Concepts and confusions*. Helsinki: Aalto University of Arts, Design and Architecture.

Fridell Anter, K. (2000). *What Colour is the Red House? – Perceived colour of painted facades*. Doctoral dissertation. Royal Technical University KTH, Stockholm, Sweden.

Green-Armytage, P. (2006). 'The Value of Knowledge for Colour Design'. Color Research and Application 31(4), pp 253–269.

Hubel, D. (1995). *Eye, Brain and Vision*. Internet publication: http://hubel.med.harvard.edu/book/bcontex.htm. Last accessed 16.10.2011.

Hård, A. & Svedmyr, Å. (1995). 'Färgsystemet NCS. Tanke, tillkomst, tillämpning.' *Färgantologi bok 1*. Stockholm: Byggforskningsrådet,

The Optical Society of America (1973). *The Science of Color, Eighth Printing*. Ann Arbor: Edwards Brothers, Inc.

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Design of Digital Pseudoisochromatic Plate for Checking Deuteranomalous Vision

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ABSTRACT

A computer software named Digital Colour Vision Test Plate (DCVTP) was developed. It is operated on a well-calibrated LCD monitor. In our previous studies, the testing procedure for deuteranomalous vision based on just-noticeable chromatic difference (JNCD) was established. The results showed the DCVTP accurately detecting deuteranomalous vision. In this study, JNCD for deuteranomalous observer under three specified Y tristimulus values was compared with normal colour vision an (NCV) observers. It can be thought that a NVC observer can discriminate the specified coloured text on a coloured background, if colour difference between text and background are larger than the corresponding JNCD. However, a deuteranomalous observer could not distinguish the colour pairs (text colour and background colour) along the corresponding confusion lines of deutan in CIE 1931 chromaticity diagram. In the other way, the NCV observers have the same JNCD sensitivities in varying luminance levels when checking concentric circle plates. Deuteranomalous observers also gave the same results. Both types of observers had better discrimination abilities in checking the DCVTP under condition of higher Y tristimulus values.

1. INTRODUCTION

There are around 8% male and 0.2% female suffer from colour vision deficiency (CVD) [1]. The people with normal colour vision (NCV) are able to discriminate the combinations of text colour and background colour when colour difference between text and background are larger than a threshold, i.e. just-noticeable chromatic difference (JNCD). However, CVD observer would be confused by any of two colours along their corresponding confusion lines of the CIE 1931 chromaticity diagram.

Additionally, more and more problems of colour discrimination would occur for colour anomalies, due to the widely spreading of wide-colour-gamut displays and colour-varied illuminants using LEDs. If the CVD observer could be effectively diagnosed by a digital tool, this would help us to build a caring living environment by considering all human beings including both NCV and CVD types.

The colour vision tests generally are divided into three types: anomaloscope, dichotomous hue test and pseudoisochromatic plates. Among these types of colour vision test, the most widely used Ishihara test belongs to the latter [2]. In our previous studies, a computer software named Digital Colour Vision Test Plate (DCVTP) was developed on a colour-calibrated LCD monitor. And the experimental procedure for examining the degrees of deuteranomalous vision is based on JNCD and confusion line. The results demonstrated that the DCVTP can accurately detect deuteranomalous vision. The control parameters in the DCVTP include dot type, dot size, dot density and dot colour (see Figure 1). The symbols of L/M/S in Figure 1 mean large/ middle / small dot sizes respectively. The DCVTP can be described by the following Eq. 1,

$$DCVTP(i, j) = Text(i) + Ground(j); \quad i=1\sim3, j=1\sim3 \tag{1}$$

where *i* and *j* represent number of colour used as text and background respectively [3]. The examples for DCVTP are shown in Figure 2. For example, *DCVTP(3,3)* means the test plate composed of 3 kinds of text colours and 3 kinds of background colours.

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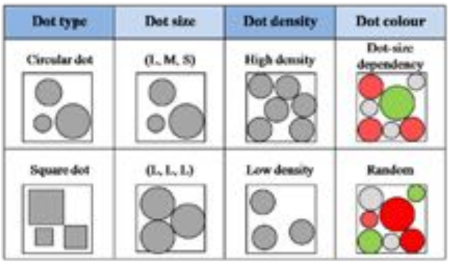

Figure 1 The parameters of the DCVTP

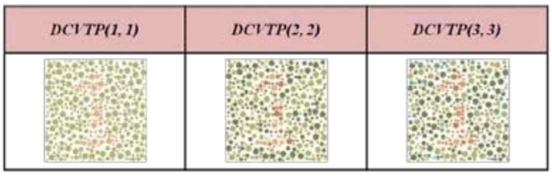

Figure 2 Examples of the DCVTP

2. METHODS

Our previous paper described a Graphic User Interface (GUI) for determining JNCD. In this study, we add one function to be able to alter the Y tristimulus values of each initial test colours (see Figure 4). Moreover, 4 CVD and 4 NCV male observers having a mean age of 25 participated in the experiment. Figure 5 shows five initial test colours selected from the centric colours within 25 MacAdam ellipses. Showing on a sRGB display, each initial test colour was set at three Y tristimulus values (5, 20 and 50), while the Y tristimulus value of peak white on the monitor is set at 100. There were 10 controlling paths designed for each initial colour in CIE u'v' chromaticity diagram, for which eight of them were 0, 45, 90, 135, 180, 225, 270, 315 degrees and the other two directions were along the line linking the initial colour towards the copunctal point for a deuteranope in CIE u'v' chromaticity diagram (see Figure 6). For each fixed direction, the observers were asked to adjust text colour at the fixed Y tristimulus values via a control bar until text colour and background colour can be perceived by the observer. Figure 7 shows the chromatic differences of three test plates in terms of Δu'v' of 0.00, 0.02 and 0.14, respectively. Three types of pseudoisochromatic plates in this study include two DCVTPs (i.e., *DCVTP(1,1)* and *DCVTP(3,3)*) and one concentric circle. Totally there were fifteen initial colours and three types of test plates in our experiment. On the other hand, the moving path of each initial colour had ten manipulated directions. In total, each observer performed 450 times (3 test plates x 15 initial colours x 10 manipulated directions). Each observer repeated the experiment three times. In total, 10800 (450x3x8 obs) data were accumulated.

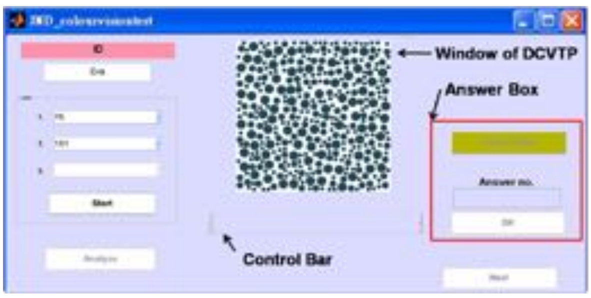

Figure 4 The GUI for determining JNCD

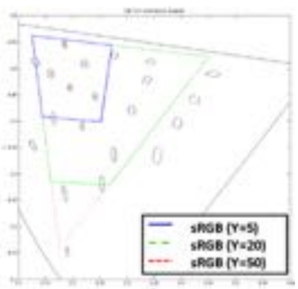

Figure 5 Five initial test colours (Represented with red points)

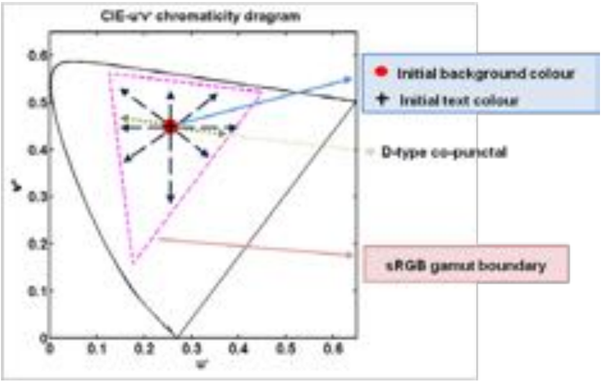

Figure 6 The 10 paths for each initial in CIE u'v' diagram

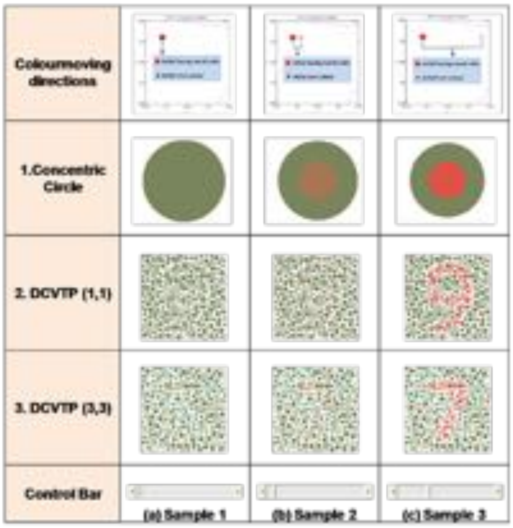

Figure 7 The examples set with different moving in colour steps. (a) Δ u'v'=0, (b) Δ u'v'=0.02 and (c) Δ u'v'=0.14 between text colour and background colour

3. RESULTS

Figure 8 shows three types of JNCD ellipses (i.e, concentric circle, *DCVTP(1,1)* and *DCVTP(3,3)*) at different Y values adjusted by four NCV observers and four deuteranomalous observers. The results showed that all of the NCV observers yield the ellipses close to a circle. However, the long axes of JNCD ellipses for the deuteranomalous observers lie approximately towards the direction of deutan co-punctal point, especially for Y values of 5 and 20.

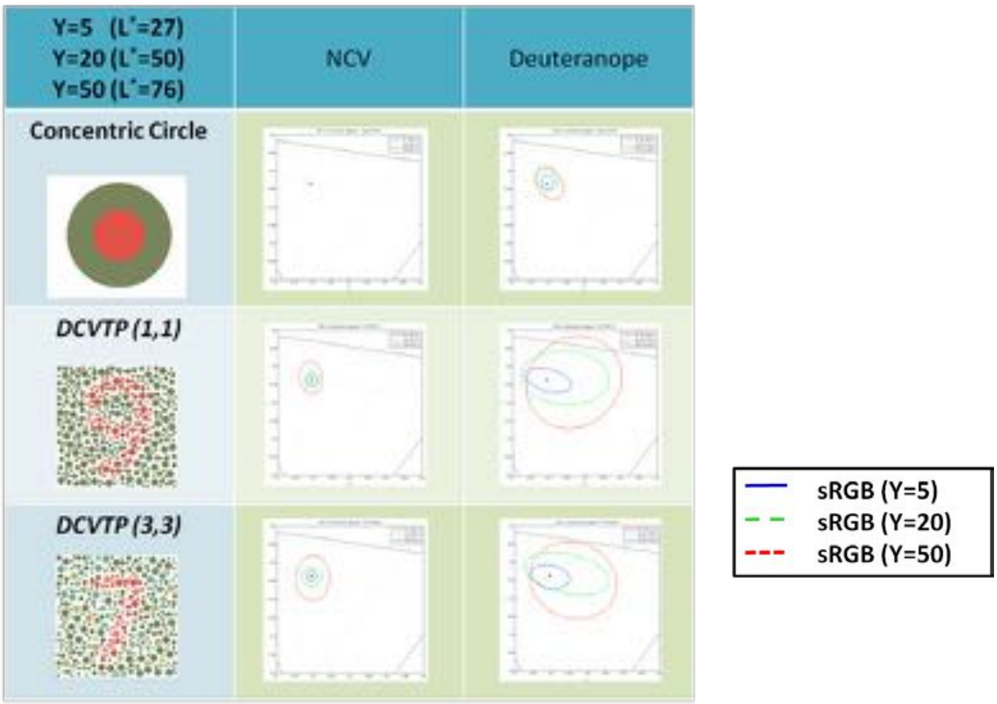

Figure 8 All of the average JNCD ellipses adjusted by four NCV observers and four deuteranomalous observers.

Furthermore, the average colour differences were analyzed in terms of CIE ΔE^*_{ab} for each type of test plates for NCV and D-type CVD respectively. Table 1 shows the experimental results of (a) concentric plate, (b) *DCVTP(1,1)* and (c) *DCVTP(3,3)*. These data were calculated based on the adjusted colour stimulus values of JNCD between the text colour and its background colour. Notice that ΔL^* was set to zero for each colour pair because their lightness attributes are not altered. Table 1 also delivers two important messages: First of all, for both groups of observers, their individual variations (ΔE^*_{ab}) for the concentric circle plates under conditions of three Y tristinulus values were quite close. This implies that the JNCD sensitivities of NCV observers are independent on Y tristinulus value of the concentric circle plates, and deuteranomalous observers also have the same tendencies. Secondly, for *DCVTP(1,1)* and *DCVTP(3,3),* the ΔE^*_{ab} derived from both groups of observers are dependent on the Y tristinulus value. Both of them had better discrimination ability in higher Y tristinulus values. It indicates that they have high sensitivities to discriminate the specified coloured text placed on the coloured background in higher Y tristinulus value.

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Table 1. The results of ΔE^*_{ab} for NCVs and four D-type CVD observers

(a) concentric plate

Concentric Circle	Observers	ΔE_{ab}^*
Y=5 (L=27)	NCV	3.74
	D-type	**11.28**
Y=20 (L=50)	NCV	3.18
	D-type	**11.70**
Y=50 (L=76)	NCV	4.34
	D-type	**12.08**

(b) DCVTP(1,1)

DCVTP (1, 1)	Observers	ΔE_{ab}^*
Y=5 (L=27)	NCV	13.75
	D-type	**39.60**
Y=20 (L=50)	NCV	13.59
	D-type	**35.17**
Y=50 (L=76)	NCV	12.79
	D-type	**28.34**

(c) DCVTP(3,3)

DCVTP (3, 3)	Observers	ΔE_{ab}^*
Y=5 (L=27)	NCV	17.01
	D-type	**35.35**
Y=20 (L=50)	NCV	15.78
	D-type	**41.52**
Y=50 (L=76)	NCV	14.78
	D-type	**29.72**

4. CONCLUSION

In this study, Digital Colour Vision Test Plate (DCVTP) for checking deuteranomalous vision in three levels of Y tristimulus values (5, 20 and 50) was compared with normal colour vision (NCV). The results showed that both groups of observers have the same JNCD sensitivities at different luminance levels in the concentric circle plates. The colour design with brighter Y tristimulus values (larger than 20) applied in text colour and background colour benefit to the deuteranomalous observer to recognize the content easily.

ACKNOWLEDGMENTS

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REFERENCES

[1] L. M. Hurvuch. 198 1. *Colour vision*. Sinauer Associates Inc.
[2] Birch J. 1997. *Efficiency of the Ishihara test for identifying red-green colour deficiency*. Ophthalmic Physiol Opt.17 (5), 403-8 (1997).
[3] Yi-Chen Tsai, Hung-Shing Chen and Ronnier Luo. 2011. *Development of a Digital Pseudoisochromatic Plate on Well-Calibrated LCD Monitor*. International Display Workshop: 1011-1014

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Study on color discrimination of the elderly sight considering yellowing and opacity of crystalline lens

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ABSTRACT

In this study, color discrimination with different light sources was quantitatively compared and analyzed in the elderly sight considering yellowing and opacity of crystalline lens. Light sources used in experiments are D65 standard light source and LED lamp. Also, the evaluation sheet is composed of Y and Y50R among NCS color specification system in the scope of less than 35% of blackness, and less than 20% of chromaticness. As a result of experiment, it was indicated that the result about color discrimination possible scope according to blackness and chromaticness in D65 standard light source and LED lamp was very similar. Also, Y and Y50R must be differentiated over 10% of blackness in color matching. When the blackness is same, Y must not use with the color of less than 20% of chromaticness in color matching, and Y50R has to be differentiated over 13% of chromaticness.

1. INTRODUCTION

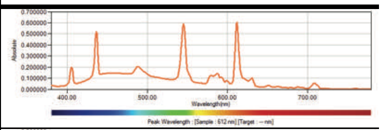
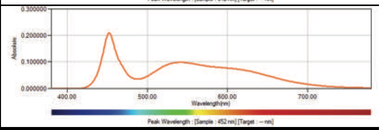
With the increase in age, the function of a sensory organ is aging. Due to aging of vision that takes over 80% of information acquisition, the elderly people may perceive colors in everyday environment differently and unpleasantly or may not perceive important information to cause inconvenience. Moreover, they are in a degraded state physically, there might happen a hazard to safety in a moment. From this point of view, in time of planning color environment, a substantial consideration about visual characteristics of the elderly people should be applied. Also, the elderly people tend to be more active inside than outside, and they may need to move around during nighttime. Artificial light environment as well daylight should be considered significantly.

Thus in this study, color discrimination with different light sources based on same illumination range and color temperature was quantitatively compared and analyzed in the elderly sight considering yellowing and opacity of crystalline lens.

2. EXPERIMENTAL METHOD

The experiment of color measurement by the eye was performed in the windowless space for excluding effect of surround light source such as daylight. The light source used in experiment is D 65 standard light source and LED, and the physical characteristic and spectral distribution of each lighting source is as table 1. The size of light cabinet installed of experimental lighting source is 610mm×500mm×450mm (width x length x height) and interior space is composed of dull-finished colored paper as achromatic color of medium brightness N5.

Table 1. The characteristics and the spectral distribution of light sources

Light sources	Color temperature (K)	Illumination (Lux)	Color rendering index (Ra)	Color coordinate		Spectral distribution
				x	y	
D65 Standard light source	7080 K	1030 lx	93	0.3048	0.3186	
LED	6337 K	1034 lx	85	0.3160	0.3280	

The 16 subjects participating in experiment have normal color visual sense, and are professionals who majored lighting and color, and trained extremely for measurement from naked eye. In experiment, the filter glasses for the aged subjects wear is guaranteed by 'Lighthouse International' organization of USA and is composed of two things. One is the filter glasses reproducing yellowed eye sight by yellowing of crystalline lens, and the other is filter glasses reproducing low contrast as like seen blurredly in recognizing the shape and color of material by cloudy crystalline lens. The subject estimated the discriminability of evaluation sheets after corresponding to each experimental light source for one minute in the state of wearing two glasses together in overlapping. At this time, one point was given to the case of seen as the same as the color in two evaluation sheets, and 2 points to the recognition of the difference but ambiguous to discern, and 3 points to the possible to division. The suggested evaluation sheets are Y and Y50R which was largely used as the dominant color and assort color for interior and exterior of the building in NCS color specification system, and it is less than 35% of blackness and less than 20% of chromaticness (high brightness/low chroma), and the detailed content is showing as table 2.

Table 2. Colors for the evaluation

S 0502-Y	S 1002-Y	S 1502-Y	S 2002-Y	S 0502-Y50R	S 1002-Y50R	S 1502-Y50R	S 2002-Y50R
S 2502-Y	S 3502-Y	S 0505-Y	S 0510-Y	S 0505-Y50R	S 0510-Y50R	S 0515-Y50R	S 0520-Y50R
S 0515-Y	S 0520-Y	S 1005-Y	S 1010-Y	S 1005-Y50R	S 1010-Y50R	S 1015-Y50R	S 1020-Y50R
S 1015-Y	S 1020-Y	S 2005-Y	S 2010-Y	S 2005-Y50R	S 2010-Y50R	S 2020-Y50R	S 3005-Y50R
S 2020-Y	S 3010-Y	S 3020-Y		S 3010-Y50R	S 3020-Y50R		
Total : 19				Total : 18			

3. RESULTS AND ANALYSIS

The experiment result was extracted the discrimination possible scope according to each color and blackness and chromaticness by light source through frequency analysis and average analysis. The analysis was used IBM SPSS Statistic Data Editor 19.0. The following table 3~6 are the frequency analysis result about the responders to discrimination possible for each color and light source (3 points). When over 10 persons (over 62.5%, average over 2.5) in total numbers responded to discrimination possible, it was evaluated as discrimination possible at final.

3.1 Discrimination possible scope according to blackness

The result about the discrimination possible scope according to blackness of D65 standard light source and LED lamp was indicated as very similar. When there was the same chromaticness in Y and Y50R and differentiated of blackness over 10%, it was indicated as discrimination possible. Also, in case of less than 5% of blackness, since the same color or the different color could be recognized, but the boundary was not clear, it was indicated to be confused when used together in color matching. However, even though 2020 and 3020 of Y50R was differentiated over 10%, it was indicated that the different color was recognized but it was confused because of ambiguous boundary.

Table 3. The discrimination possible scope according to blackness of Y color

	0502-1002	**0502-1502**	1002-1502	**1002-2002**	1502-2002	**1502-2502**
D65	5(31.3%)	13(81.3%)	1(6.3%)	16(100%)	5(31.3%)	16(100%)
LED	3(18.8%)	13(81.3%)	2(12.5%)	14(87.5%)	2(12.5%)	13(81.3%)
	2002-2502	**2002-3502**	**2502-3502**	0505-1005	**0505-2005**	**1005-2005**
D65	3(18.8%)	16(100%)	14(87.5%)	2(12.5%)	16(100%)	14(87.5%)
LED	2(12.5%)	16(100%)	14(87.5%)	3(18.8%)	16(100%)	15(93.8%)
	0510-1010	**0510-2010**	**1010-2010**	**1010-3010**	**2010-3010**	0515-1015
D65	2(12.5%)	16(100%)	13(81.3%)	15(93.8%)	13(81.3%)	2(12.5%)
LED	2(12.5%)	16(100%)	13(81.3%)	15(93.8%)	13(81.3%)	3(18.8%)
	0520-1020	**0520-2020**	**1020-2020**	**1020-3020**	**2020-3020**	
D65	2(12.5%)	16(100%)	13(81.3%)	16(100%)	11(68.8%)	
LED	2(12.5%)	16(100%)	11(68.8%)	16(100%)	10(62.5%)	

Table 4 The discrimination possible scope according to blackness of Y50R color

	0502-1002	**0502-1502**	1002-1502	**1002-2002**	1502-2002	0505-1005	**0505-2005**
D65	2(12.5%)	14(87.5%)	6(37.5%)	15(93.8%)	6(37.5%)	2(12.5%)	16(100%)
LED	1(6.3%)	14(87.5%)	3(18.8%)	15(93.8%)	4(25.0%)	1(6.3%)	16(100%)
	1005-2005	**1005-3005**	**2005-3005**	0510-1010	**0510-2010**	**1010-2010**	**1010-3010**
D65	14(87.5%)	16(100%)	13(81.3%)	4(25.0%)	16(100%)	14(87.5%)	16(100%)
LED	14(87.5%)	16(100%)	13(81.3%)	4(25.0%)	16(100%)	14(87.5%)	16(100%)
	2010-3010	0515-1015	0520-1020	**0520-2020**	**1020-2020**	**1020-3020**	2020-3020
D65	11(68.8%)	1(6.3%)	5(31.3%)	16(100%)	13(81.3%)	16(100%)	1(6.3%)
LED	11(68.8%)	1(6.3%)	6(37.5%)	16(100%)	13(81.3%)	16(100%)	3(18.8%)

3.2 Discrimination possible scope according to Chromaticness

The result about the discrimination possible scope according to Chromaticness in D65 standard light source and LED lamp was indicated as very similar. Also, when there was the same blackness, Y was indicated more difficult for the discrimination of the color according to Chromaticness than Y50R. It was indicated that Y was difficult to discriminate the color clearly in less than 20% of Chromaticness. Especially, it was indicted that the color was recognized as same in case of difference less than 5% of Chromaticness.

Table 5. The discrimination possible scope according to Chromaticness of Y color

	0502-0505	0502-0510	0502-0515	0502-0520	0505-0510	0505-0515	0505-0520
D65	0(0%)	0(0%)	0(0%)	3(18.8%)	0(0%)	0(0%)	3(18.8%)
LED	0(0%)	0(0%)	0(0%)	1(6.3%)	0(0%)	0(0%)	1(6.3%)
	0510-0515	0510-0520	0515-0520	1002-1005	1002-1010	1002-1015	1002-1020
D65	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	1(6.3%)	5(31.3%)
LED	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	3(18.8%)
	1005-1010	1005-1015	1005-1020	1010-1015	1010-1020	1015-1020	2002-2005
D65	0(0%)	0(0%)	3(18.8%)	0(0%)	0(0%)	0(0%)	0(0%)
LED	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)
	2002-2010	2002-2020	2005-2010	2005-2020	2010-2020	3010-3020	
D65	0(0%)	6(37.5%)	0(0%)	4(25.0%)	0(0%)	0(0%)	
LED	0(0%)	3(18.8%)	0(0%)	2(12.5%)	0(0%)	0(0%)	

It was indicated that Y50R was possible to discriminate in case of difference over 13% of Chromaticness. Usually, it was indicated that the difference of the color was recognized but the boundary was ambiguous in case of difference of less than 10% of Chromaticness. Especially, it was indicated that it was recognized as same in case of difference less than 3% of Chromaticness.

Table 6. The discrimination possible scope according to Chromaticness of Y50R color

	0502-0505	0502-0510	**0502-0515**	**0502-0520**	0505-0510	0505-0515
D65	0(0%)	7(43.8%)	11(68.8%)	15(93.8%)	12(75.0%)	7(43.8%)
LED	0(0%)	3(18.8%)	11(68.8%)	16(100%)	8(50.0%)	7(43.8%)
	0505-0520	0510-0515	**0510-0520**	0515-0520	1002-1005	1002-1010
D65	12(75.0%)	4(25.0%)	12(75.0%)	3(18.8%)	0(0%)	7(43.8%)
LED	11(68.8%)	2(12.5%)	11(68.8%)	0(0%)	0(0%)	6(37.5%)
	1002-1015	**1002-1020**	1005-1010	1005-1015	**1005-1020**	1010-1015
D65	11(68.8%)	16(100%)	1(6.3%)	6(37.5%)	13(81.3%)	8(50.0%)
LED	11(68.8%)	15(93.8%)	1(6.3%)	6(37.5%)	13(81.3%)	8(50.0%)
	1010-1020	1015-1020	2002-2005	2002-2010	**2002-2020**	2005-2010
D65	7(43.8%)	1(6.3%)	5(31.3%)	6(37.5%)	14(87.5%)	3(18.8%)
LED	6(37.5%)	1(6.3%)	4(25.0%)	7(43.8%)	13(81.3%)	1(6.3%)
	2005-2020	2010-2020	3005-3010	**3005-3020**	3010-3020	
D65	12(75.0%)	4(25.0%)	2(12.5%)	12(75.0%)	6(37.5%)	
LED	12(75.0%)	3(18.8%)	1(6.3%)	11(68.8%)	6(37.5%)	

4. CONCLUSION

In this study, color discrimination with different light sources was quantitatively compared and analyzed in the elderly sight considering yellowing and opacity of crystalline lens. The summarized result is as followings.

(1) It was indicated that the result about color discrimination possible scope according to blackness and chromaticness of D65 standard light source and LED lamp was very similar.

(2) It was indicated that Y and Y50R both were facilitated the discrimination according to the blackness than chromaticness.

(3) In color plan in interior and exterior with the color of light-grey colors and whitish and pale colors scope (high brightness/low chroma) of Y and T50R, it must be differentiated over 10% of blackness in the necessary part of security. Also, Y must not use with color matching between the colors less than 20% of chromaticness when the blackness is same. Y50R has to be color matched to differentiate over 13% of chromaticness when the blackness is same.

REFERENCES

Ji-young Park, So-yeon Kim, Jin-sook Lee. 2011. Research on the Elderly People's Color Distinction Scope subsequent to Color. AIC 2011 Midterm Meeting Zurich : 649-652

Jin-sook Lee, Ji-young Park, So-yeon Kim. 2012. Analysis of the effect of color temperature of white LED lighting on color recognition in the elderly. Journal of Korea Society of Color Studies, 26(1): 55-67.

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A study on the preference for the dwelling landscape in agricultural and fishing village according to location type

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ABSTRACT

The purpose of this study is to compare the difference in preference among the variables which affect the preference for dwelling landscape according to location type. The subjects were divided into expert and non-expert and the people between 10 and 60 were compared to observe various preferences. For analysis, questionnaire was used to survey.

1. INTRODUCTION

With the introduction of artificial materials and coating materials into buildings in farming and fishing areas in the 1970s. However, farmers and fishermen lacking expert knowledge of farmhouses mass-produced housing which managed to satisfy functions with the minimum costs, and they were let to build at their will, resulting in scenic image in farming and fishing communities inevitably lagging behind. And use of stimulative primary colors out of keeping with the surrounding natural environment colors has significantly damaged the scenery in farming and fishing communities(Table1). To study before and after the change in dwelling landscape of agricultural and fishing village, therefore, 11 color palettes by location type where the natural environment of Korean agricultural village and dwelling image are well matched were selected to contribute to improving the quality of agricultural environment.

Table 1. Present condition

2. STUDY METHOD

2.1 Study Subjects and Scope

Every research interprets differently what the factors are affecting the preference. The generally known theory is that the preference may be different depending on 'Region, People, Trend, Age, Sex, Income'. Therefore, this study was performed from understanding that the preference may be different depending on 'Region(Location type), Sex' among the factors affecting. For the subject, 109 non experts in 10's and 60's were selected. Looking into demographical characteristics of respondents(Table2), gender rate is almost similar but the rate of male is high and 73% of subject was not experts, most of subject were composed of 20's and 30's were 23%.

Table 2. Subject's Composition

Variable		Frequency	%
Sex	Man	62	57.9
	Woman	47	43.1
	Total	109	100%
E/A	Expert	30	27.5
	Amateur	79	72.5
	Total	109	100%
Age	10	11	10.1
	20	36	33
	30	25	22.9
	40	18	16.5
	50	12	11
	60	7	6.4
	Total	109	100%

2.2 Research tools

The questionnaires were based on the 'location type of guideline' proposed in 'Framing an Application Model for Environment color to Make Rural Landscape Image' issued by 'Korea of Ministry for Food, Agriculture, Forestry and Fisheries and Chung-nam National University' on 2009(Table4). Next, the questionnaires delivered to the subject ask respondents to select from 1. Not really to Exactly yes, using Likert 5 Points with on Fig. 1. To evaluate the after image, color palette was each before and after image as shown used for reference.(Table3)

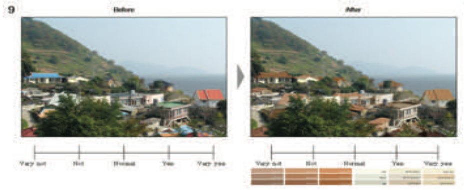

Table 3. Composition of Survey

Table 4. Location type of guideline

Sort		Type	Part	Color range	Color palette
Suburban - rural		T-1	Roof	N5~N8, 5YR, 10YR Brightness 5~8 over / Chroma 0.5 sequentes	N 8, N7.5, 10YR 8/0.5 N7, N6.5, 10YR 7.5/0.5 N6, N5, 10YR 7/0.5
			Wall	Brightness 6 over / Chroma 0.5 sequentes	5YR 9/1, 5YR 9/2, 10YR 9/0.5 10YR 8/1, 10YR 8.5/0.5, 10YR 8.5/1 10YR 7/1, 10YR 7.5/0.5, 10YR 7.5/1
Agricultural village in plain area	Red yellow soils	T-2	Roof	YR, Brightness 3~5 / Chroma 4 sequentes	5YR 5/2, 7.5YR 5/2, 7.5YR 5/4 5YR 4/2, 7.5YR 4/2, 7.5YR 4/4 5YR 3/2, 7.5YR 3/2, 2.5YR 3/2
			Wall	Brightness 6 over / Chroma 4 sequentes	10YR 8/1, 10YR 8/2, 5YR 8.5/1.5 10YR 7/1, 10YR 7.5/1.5, 10YR 8.5/1 10YR 6/1, 10YR 6/2, 10YR 6/4
	Brown forest soil	T-3	Roof	YR, Brightness 4~6 / Chroma 2 sequentes	10YR 6/1, 10YR 6/2, 7.5YR 6/2 10YR 5/1, 10YR 5/2, 7.5YR 5/2 10YR 4/1, 10YR 4/2, 7.5YR 4/2
			Wall	Brightness 6 over / Chroma 4 sequentes	10YR 8/1, 10YR 8/2, 5YR 8.5/1.5 10YR 7/1, 10YR 7.5/1.5, 10YR 8.5/1 10YR 6/1, 10YR 6/2, 10YR 6/4
Agricultural village in mountain area	North part Temperate Climate Regions	T-4	Roof	YR, Brightness 5 sequentes / Chroma 2 sequentes	10YR 5/1, 5YR 5/1, 7.5YR 5/2 10YR 4/1, 5YR 4/1, 7.5YR 4/2 10YR 3/1, 5YR 3/1, 7.5YR 3/2
			Wall	Brightness 6 over / Chroma 4 sequentes	10YR 8/1, 5YR 6/1, 5YR 6/2 10YR 7/1, 10YR 7.5/1.5, 10YR 8/2 10YR 6/1, 10YR 6/2, 10YR 6/4
	Central part Temperate Climate Regions	T-5	Roof	YR, Brightness 4~6 / Chroma 2 sequentes	10YR 6/1, 5YR 6/1, 7.5YR 6/2 10YR 5/1, 5YR 5/1, 7.5YR 5/2 10YR 4/1, 5YR 4/1, 7.5YR 4/2
			Wall	Brightness 6 over / Chroma 4 sequentes	10YR 8/1, 5YR 6/1, 5YR 6/2 10YR 7/1, 10YR 7.5/1.5, 10YR 8/2 10YR 6/1, 10YR 6/2, 10YR 6/4
	Southern part Temperate Climate Regions	T-6	Roof	YR, Brightness 4 sequentes / Chroma 4 sequentes	10YR 4/2, 7.5YR 4/4, 5YR 4/1 10YR 3/2, 7.5YR 4/2, 5YR 3/2 10YR 3/1, 7.5YR 3/2, 5YR 3/1
			Wall	Brightness 6 over / Chroma 4 sequentes	10YR 8/1, 5YR 6/1, 5YR 6/2 10YR 7/1, 10YR 7.5/1.5, 10YR 8/2 10YR 6/1, 10YR 6/2, 10YR 6/4
Fishing village in Island	Eastern Coast	T-7	Roof	10YR, Brightness 6 over / Chroma 1 sequentes, N6 over	N8, 10YR 7.5/0.5, 10YR 7.5/1 N7.5, 10YR 7/0.5, 10YR 7/1 N7, 10YR 6.5/0.5, 10YR 6.5/1
			Wall	N7 over, YR, Brightness 8 over / Chroma 2 sequentes	N9, 10YR 9/0.5, 10YR 8.5/1.5 N8, 10YR 8.5/0.5, 10YR 8.5/1 N7, 10YR 8/0.5, 10YR 8/1
	West Coast	T-8	Roof	5YR, 7.5YR, Brightness 4~6 / Chroma 6 sequentes	5YR 5/4, 5YR 5/6, 7.5YR 5/6 5YR 4/4, 5YR 4/6, 7.5YR 4/6 7.5YR 4/4, 7.5YR 5/4, 7.5YR 6/4
			Wall	N7 over, YR, Brightness 8 over / Chroma 2 sequentes	N9, 10YR 9/0.5, 10YR 8.5/1.5 N8, 10YR 8.5/0.5, 10YR 8.5/1 N7, 10YR 8/0.5, 10YR 8/1
	Southern Coast	T-9	Roof	5YR, 7.5YR, Brightness 4~7 / Chroma 4~8 sequentes	5YR 7/4, 5YR 7/6, 5YR 7/8 5YR 6/4, 5YR 6/6, 5YR 6/8 5YR 5/4, 5YR 5/6, 5YR 5/8
			Wall	N7 over, YR, Brightness 8 over / Chroma 2 sequentes	N9, 10YR 9/0.5, 5YR 9/1 N8.5, 10YR 8.5/0.5, 10YR 8.5/1.5 N8, 10YR 8/1, 10YR 8.5/1
	Je-ju Island	T-10	Roof	N6 sequentes, YR, Brightness 3 sequentes / Chroma 2 sequentes	N6, 10YR 3/1, 10YR 3/2 N5, 5YR 3/1, 5YR 3/2 N4, 5YR 2.5/1, 7.5YR 3/2
			Wall	Chroma 4 sequentes	7.5YR 7/2, 10YR 8/2, 10YR 8/1 7.5YR 5/2, 7.5YR 7/4, 10YR 7/1 7.5YR 3/2, 7.5YR 5/4, 10YR 6/1
Riverside village		T-11	Roof	YR, Brightness 4 over / Chroma 1 sequentes	10YR 6/1, 5YR 6/1, 10YR 7.5/0.5 10YR 5/1, 5YR 5/1, 10YR 7/0.5 10YR 4/1, 5YR 4/1, 10YR 7/1
			Wall	Chroma 2 sequentes	10YR 9/0.5, 10YR 8.5/0.5, 7.5YR 6/2 10YR 8/1, 10YR 8.5/1, 7.5YR 5/2 10YR 7/1, 10YR 7.5/1, 7.5YR 3/2

2.3 Data Analysis

For analysis, the collected date was statistically analyzed using SPSS(Statistical Package for Social Science)v. 18.0 Program after data coding process. The analysis method employed were Frequency Analysis and Mean analysis by group to observe the difference in preference for before and after change for each group.

3. RESULTS OF STUDY

3.1 Analysis of Amateur group preference

Table 5. Mean analysis by Amateur group for the before and after change

Amateur	Age	T-1	T-2	T-3	T-4	T-5	T-6	T-7	T-8	T-9	T-10	T-11
Before	10’	3.09	2.91	2.91	3.82	3.09	2.64	2.45	2.45	2.64	3.00	3.18
	20’	2.81	2.84	2.72	2.84	2.53	2.53	2.63	2.53	2.53	2.84	2.69
	30’	2.75	2.63	2.75	3.50	2.75	2.63	2.38	2.38	3.00	3.13	3.00
	40’	2.80	2.70	3.40	3.20	2.50	2.30	2.60	2.60	2.20	3.10	2.50
	50’	2.09	2.27	3.00	3.09	2.27	2.55	2.55	3.36	3.00	2.91	2.82
	60’	3.43	2.86	2.86	3.14	2.43	2.71	3.14	4.14	3.14	2.86	2.71
	Total	2.80	2.73	2.89	3.15	2.58	2.54	2.61	2.77	2.67	2.94	2.78
After	10’	3.27	3.27	3.91	3.55	3.82	3.64	3.36	4.27	4.18	3.45	3.55
	20’	3.53	3.31	3.56	3.69	3.50	3.44	3.31	3.69	3.97	3.72	3.22
	30’	3.13	2.50	3.13	3.38	3.13	3.38	3.00	3.50	4.13	4.00	3.38
	40’	3.10	2.90	3.00	3.40	3.10	3.00	2.80	3.30	3.70	3.20	3.10
	50’	3.91	3.45	3.45	4.00	3.73	3.64	3.73	3.91	4.45	4.00	3.82
	60’	3.71	3.14	2.86	3.86	3.86	3.29	3.86	3.71	4.14	2.86	4.29
	Total	3.47	3.18	3.42	3.66	3.52	3.42	3.33	3.73	4.06	3.61	3.44

Table 5 shows the characteristic of preference of Amateur group, All of 10’s ~ 60’s show responses. The highest preference type before change was T-4(3.15) which was preferred by 10’s ~30’s and after change T-9(4.06) which was preferred by all age groups except 10’s and 60’s. Looking into difference of preference of non expert group, there is no significant difference from expert group. However, in low preference, T-6 was before change, T-6(2.54) was mostly ‘average’ which showed lower preference. This is because attractive B and BG series were used which were well matched with surroundings. Also, after change, T-2(3.18) was low preferred. This is because the simulation work was insufficient like the expert group.

Amateur Group High preference

4  9 

Before — After

Amateur Group Low preference

6  2 

Before — After

3.2 Analysis of expert group preference

Table 6. Mean analysis by expert group for the before and after change

Expert	Age	T-1	T-2	T-3	T-4	T-5	T-6	T-7	T-8	T-9	T-10	T-11
Before	20’	1.50	2.75	1.50	2.75	1.50	1.75	1.25	1.25	1.50	2.50	1.50
	30’	2.47	2.88	2.18	2.65	2.12	1.94	2.00	1.88	1.88	1.94	2.53
	40’	2.75	2.75	2.13	3.25	2.13	2.63	2.38	2.13	2.25	2.88	2.25
	50’	2.00	3.00	3.00	4.00	2.00	2.00	3.00	3.00	3.00	3.00	3.00
	Total	2.40	2.83	2.10	**2.87**	2.03	2.10	2.03	**1.90**	1.97	2.30	2.33
After	20’	4.25	4.00	4.75	3.75	4.00	4.25	4.50	4.25	4.75	4.50	3.75
	30’	3.88	3.41	4.06	3.76	4.12	3.94	3.88	4.12	4.29	3.59	3.53
	40’	4.13	3.63	4.00	3.75	4.00	3.50	3.88	3.75	4.38	4.13	3.75
	50’	3.00	1.00	4.00	4.00	4.00	3.00	4.00	2.00	4.00	3.00	3.00
	Total	3.97	3.47	4.13	3.77	4.07	3.83	3.97	3.97	**4.37**	3.83	3.60

Table 6 shows the characteristic of preference of expert group, which is the result of Mean analysis by group for the before and after change. As it is expert group, the response of 10's and 60's were not shown. The highest preference type was T-4(2.87) before change which was preferred by 20's, 40's and 50's and T-9(4.37) after change which was preferred by all age group. This is because warm and calm colors with brightness 5 and chrome 3 of YR series were used. In the meantime, the types with lower preference before change were T-8(1.90) which was unfavorable by age group except 50's and T-2(3.47) after change. This is because T-8 used visible B and R series which was not matched with surroundings and simulation work was insufficient for T-2. Looking into more details of characteristics by age, 50's after change show overall high preference but shows no preference for T-2.

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Expert Group High preference		Expert Group Low preference	
4 	9 	8 	2 
Before	After	Before	After

4. CONCLUSION

This study is to compare the difference in preference of before and after change in dwelling landscape in agricultural and fishing village according to age and expert and non expert group among the other variables affecting the preference.

- Characteristic of preference of Amateur group. The highest preference type before change was T-4 and after change T-9. Looking into difference of preference of non expert group, there is no significant difference from expert group. However, in low preference, T-6 was before change, and T-2 is after change.
- Characteristic of preference of expert group. The highest preference type was T-4 before change, T-9 after change. The types with lower preference before change T-8 and T-2 is after change.

It is meaningful to improve quality of environment by selecting and applying 11 color palettes by location type where the natural environment and dwelling image of agricultural and fishing village are well matched to survey preference. However, this study has limitation as number of subject and experts were limited. As the preference may be different depending on 'Region, People, Trend, Age, Sex, Income' as explained earlier, it would be necessary to continue further study.

REFERENCES

Framing an Application Model for Environment color to Make Rural Landscape Image. 2009. Korea of Ministry for Food, Agriculture, Forestry and Fisheries and Chung-nam National University, 91-399

Y. Hee-cheol. 2010. A Study on The Differences of Reasonable Value between Roof & Body Color of Lower Bulidings, Journal of Korean Society of Color Studies

H. Kyu-won. 2009. An Experimental study on Restaurant's Color Image, Journal of Korean Society of Color Studies

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Color constancy on red-green color deficient observers under illuminant change on confusion line

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ABSTRACT

Strength of color constancy performance was measured on 3 color normal observers and 3 color deficient observers (1 protanomalous trichromats and 2 deuteranopes). On a CRT monitor, a standard pattern was presented as if it was under illuminant D65, and a test pattern was presented under test illuminants which were obtained by changing a certain amount of M-cone stimulation for deuteranopes and L-cone stimulation for a protanomalous observer from D65 along individual confusion lines and a pseudo-confusion line for the protanomalous observer. Observers were asked to make the test patch appearance as if it were cut from the same piece of paper presented in the standard patch. While the color constancy performance of the protanomalous observer was similar with that of the color-normal observer, deuteranopes had the partial color constancy except some of standard colors, while they could not perceive the color difference between standard illuminant and test illuminant.

1. INTRODUCTION

Color constancy is a phenomenon where the color appearance of objects is invariant upon changes in illumination. Many researchers performed asymmetric color matching experiment on color constancy of color normal observers by presenting two illuminations scenes side by side at the same time (Arend and Reeves: 1986) or successively at the same position (Troost and Weert: 1991). Rüttiger (2001) investigated the color constancy of color deficiency and his experiment showed that color deficient observers display color constancy similar to that of normal observers along red-green cardinal axis. Under the task of discriminating between the change of surface reflectance and the change illuminant, the color constancy of dichromats was measured under illuminant changes along the line perpendicular to daylight locus (Amano, Foster and Nascimento: 2003) and along daylight locus (Baraas et al. 2010).

In this present study, in order to investigate if the color constancy of dichromats is mediated by perception of color difference between two illuminants, we set the chromaticity coordinates of two illuminants as located on the individual confusion lines of color deficient observers.

2. METHODS

2.1 Apparatus

The stimuli were presented on the screen of a CRT color monitor (Sony, Trinitron G420), controlled by PC with a VSG Visage-256 MB graphics card (Cambridge Research Systems, Inc.) providing 14-bit resolution for each RGB phosphor. Gamma correction was carried out using light measurement instrument (ColorCAL, CRS), although all photometric values of stimuli and matchings were directly measured by a Luminance & Color Meters (Konica-Minolta, CS-200) after the experiment. A 90*60 cm black paper board was put in front of the screen and separated presentation of screen into two halves, which made left half of screen viewed from left side and right half viewed from right side. For color normal and protanomalous observers, two buttons of a response box (CB6, CRS) were used to control color along red-green direction; another two were used along blue-yellow direction; and last two were used along dark-bright (intensity) direction. Deuteranopic observers did not control color along red-green direction.

2.2 Stimuli

The standard illuminant was illuminant D65 and invariant in all experiment sessions. There were totally five test illuminants, one D65, as the control, and four constructed illuminants obtained by increment (labeled Green) or decrement (Red) of M-cone stimulation in 5% (labeled Small) or 10% (Large) from D65 along the individual confusion line for dichromats and along standard confusion line for color normal observers. For protanomalous observer, test illuminants were obtained by changing L-cone modulation in 2.5% or 5% from D65 along the pseudo-confusion line, which was defined as the longer axis of the color discrimination ellipsoid of the Cambridge Color Test (CCT). In each stimulus pattern, 1-degree central patch stimulus was surrounded by a background consisting of many ellipsoids. The reflectance spectrum of the standard patch was selected randomly from 12 different Munsell surfaces: Munsell R5/6, YR5/6, Y5/6, GY5/6, G5/6, BG5/6, B5/6, PB5/6, P5/6, RP5/6, GY5/6, N5/. The reflectance spectra of ellipsoids were composed of eight surface colors taken from Munsell Book of Color in Chroma 5 and Lightness 6, as approximately making 45 degree distance in the hue circle of the Munsell Color System (Lightness was changed to 4 or 8, if the hue was randomly matched to one of 12 surface colors above). There are six sets of the eight surface colors and one was used in order for each session on all observers. Chromaticity coordinates of Munsell color chips under five illuminants were calculated using the CIE 1931 standard color matching functions. Spectra were sampled at 5-nm intervals, and the integration was performed over 380 to 780 nm. The intensity of all illuminants was adjusted to make the same luminance (25 cd/m^2) on the white patch (Munsell N5/).

2.3 Procedure

We have already measured two deuteranopic observers, LX (male, 26 yrs.) and OK (male, 21 yrs.) and one protanomalous observer, GY (male, 25 yrs.) with three color normal observers, RK (male, 19 years), TM (female, 19 yrs.) and RK (female 19 yrs.). The observers' color vision was classified by five clinical methods; Ishihara pseudo-isochromatic plates, the Farnsworth D-15 test, Standard pseudoisochromatic plates, Farnsworth-Munsell 100 hue test and Neitz anomaloscope. The CCT (CRS) was used to measure color discrimination ability of observers and to determine the individual confusion lines.

In each session, totally 6 sessions, observers firstly adapted D65 illuminant white for 5 min and then performed paper match haploscopically over twelve central patches under 5 test illuminants, totally 5*12=60 trials. Before performing match under each illuminant, the observer adapted for 5 min to a certain chromatic structure of the ellipsoids background, but without the central patch. Dichromats finished the additional 3-session experiment in which the color of the test and standard illuminants was the same to determine theoretical points projected onto blue-yellow axis. The observers' task was to adjust the color and brightness of rectangular patch in the test pattern in order to make the test patch look as if "it were cut from the same piece of paper as the corresponding patch in the standard pattern".

3. RESULTS

Arend's constancy index was used to calculate the constancy index of color constancy performance. Perfect color constancy is indicated by index=1; no color constancy is indicated by index=0. For color normal observers, standard points, theoretical points and matched points scattered on the whole (u',v') plane. Because dichromats obtained matched points by adjusting color along blue-yellow axis, matched points were located on blue-yellow axis; standard points and theoretical points were projected onto blue-yellow axis by dichromats' additional same illumination experiment. The constancy index of dichromats was calculated on blue-yellow axis.

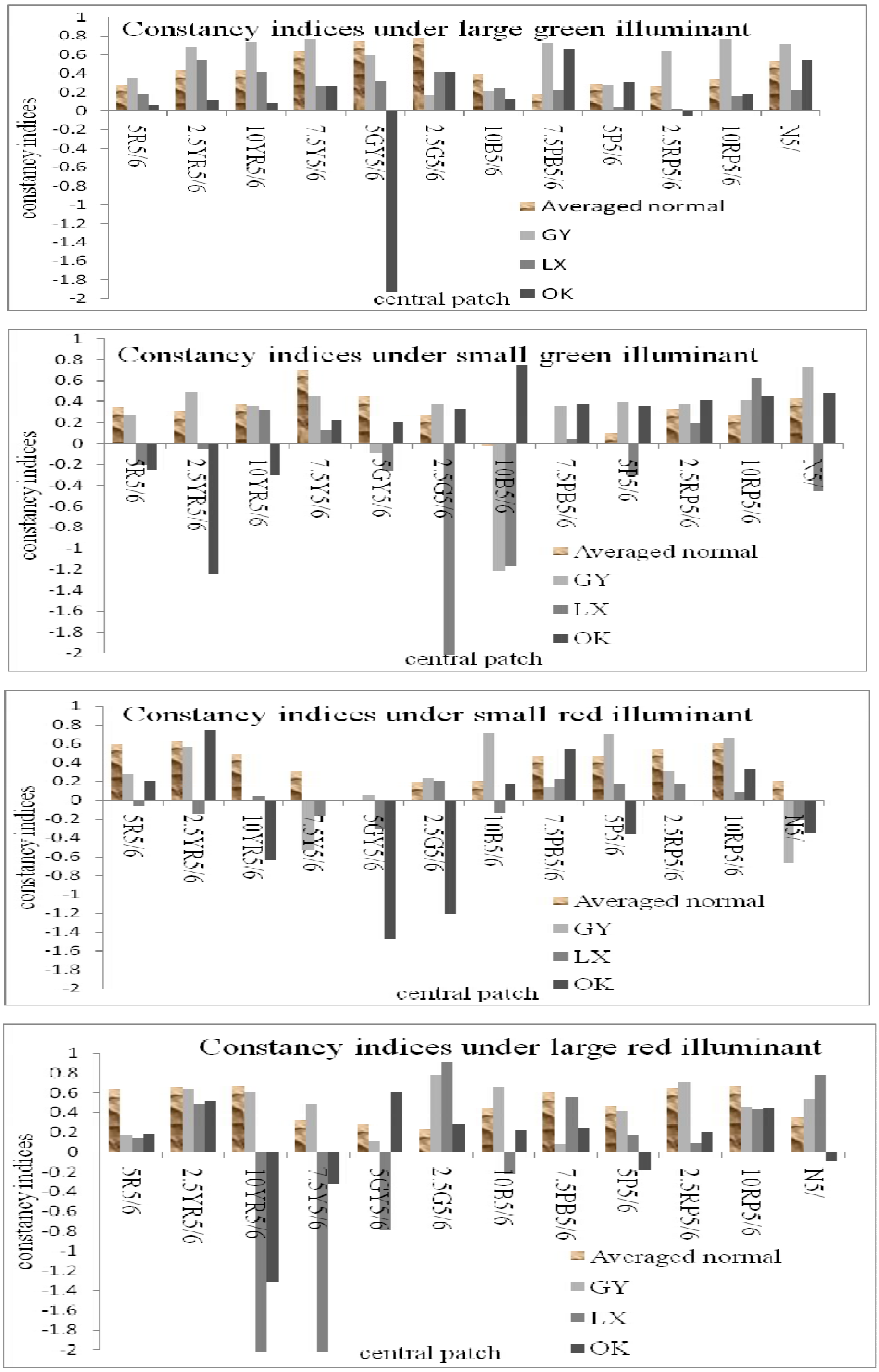

Figure 1. The color constancy indices of the mean of three color normal observers, the protanomalous observer GY, the deuteranopic observers LX and OK (denoted by bars from left to right in each surface color condition) under different test illuminants conditions.

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3.1 Results of color normal observers and the protanomalous observer

Figure 1 shows the color constancy indices for each standard color. It should be mentioned again that the deuteranopes' index value includes only the distance on the blue-yellow axis.

Between color normal observers, RK (the mean index for all colors and illuminants, 0.54) was better than other observers (TM, 0.29 and OC, 0.40). RK had best color constancy performance. The color constancy of protanomalous observer GY (index, 0.37) was similar to color normals.

3.2 Results of dichromats

Under all illuminant conditions, unexpectedly, two deuteranopic observers had relatively good color constancy except the case that there were some negative values with large absolute values. In such the case, the standard and theoretical points were located on the confusion line and were projected to almost the same point on the blue-yellow axis. Although deuteranopes need not to adjust the color of test patch in such the case, in fact, they adjusted more or less with some adjustment errors, which leaded to these large negative values. Because the case depended on the fact that the standard and theoretical points were located on the individual confusion line, it happened accidentally in some of illuminant and 12 surface color conditions. Thus, these large negative values look like as if spread randomly in Figure 1, because they have different individual confusion lines. Without these extreme values, the color constancy indices for deuteranopes are unexpectedly and reasonably large as 0.19 for LX and 0.27 for OK, indicating that dichromats can have good color constancy.

4. DISCUSSION

Dichromats participated in the present study could not perceive the color difference between standard and test illuminants. Initially, it was expected that dichromats would have no or little color constancy because the perception to the color difference of illuminant changes would provide no cue. However, when the chromaticity coordinates of standard and theoretical points were not located onto the same confusion line, dichromats had the partial color constancy, which is somehow reasonably accurate and is bounded along the blue-yellow chromatic opponent.

The result of this study reflects that the color constancy of dichromats is not mediated only by perception of illuminant's color, but also by sensation mechanism like cone adaptation.

ACKNOWLEDGEMENTS

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REFERENCES

Amano, K, Foster, DH, & Nascimento, SMC.2003. Red-green colour deficiency and colour constancy under orthogonal-daylight changes. *Normal and Defective Colour Vision* (ed. Mollon, JD, Pokorny, J, Knoblauch, K.), 225-230. Oxford: Oxford University Press.

Arend, L, & Reeves, A.1986. Simultaneous color constancy. *J. Opt. Soc. Am. A, 3,* 1743-1751.

Arend, LE, Jr, Reeves, A, Schirillo, J, & Goldstein, R.1991. Simultaneous color constancy: Papers with diverse Munsell values. *J. Opt. Soc. Am. A, 8,* 661-672.

Baraas, RC, Foster, DH, Amano, K, & Nascimento, SMC.2010. Color constancy of red–green dichromats and anomalous trichromats. *Investigative Ophthalmol. Vis. Sci., 51,* 2286–2293.

Rüttiger, L, Mayser, H, Sérey, L, &Sharpe, LT.2001. The color constancy of the red-green color blind. *Color Res. Appl., 26(Suppl.),* S209-S213.

Troost, JM, & CMM de Weert. 1991. Naming versus matching in color constancy. *Percept.Psychophys., 50(6),* 591-602.

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On the Environmetal Role of Blue

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ABSTRACT

The alerting effect (increased speed of reading) is found from 21 o'clock to midnight, when melatonin excretion is expected to increase in density, in a real environment, that is, in a normally furnished office lit by bluish white or blue green (BG) light, but not by minus blue neither, in particular by yellowish green light. The distinction between the effects of cold and warm "color of light" is thus demonstrated in a peculiar range of circadiancy, while it is not confirmed in other times of day. Moreover, a peculiar manifestation of the ambiguity of the response to green emerges from our data.

1. INTRODUCTION

The natural environment in our temperate zones, which we are evolutionarily adapted to, is dominated by blue and green. In principle, these two hues are considered as distinct from the cellular and psychophysical stand points. However, the literature is rich of reports describing on one side the cases of agreement between green and blue facts and responses, on the other side, of disagreement. The present paper aims at describing an experiment where a global response, the reading time (R), is recorded at different times of day in a complex real environment like a traditionally furnished office is. We compare the responses under cold and warm SPD's by paying particular attention to blue and green lights. Blue is of relevance, being called to the stage by the modern sources, in particular after the discovery of the novel detector (like the ipRGCs), the lacking link of the exogenous light-dark transition with the brain locations responsible for the circadiancy (Ronchi, 2011). Green is of interest in particular because its traditional ambiguity, here mirrored by a particular functional of agreement / disagreement with blue.

2. MATERIALS AND METHOD

Data are recorded in a 7m by 7m traditional office, with middle brown wooden furnitures, located at the first floor of a building on a hill, surrounded by relatively close evergreens. In sessions devoted to natural lighting indoor, the two windows are open, one on the southern, the other in the western side. In the sessions devoted to electric lighting the installation is such as to allow the illumination of the whole room, in addition to the desk where the test object is placed. It consists of a set of ten lines cut off from a black on white printed book, forming a 8.5 cm wide, 4.0 cm high rectangle. Its average luminance is denoted by L. The background is an 1 meter square white cardboard. Its luminance being about 2L. That of the surround varies from a zone to another. The content of the text changes from trial to trial. The language is German, the "third" for our Italian observers. The task consists in correctly reading aloud. The reading time (R) measured by the use of a stop watch generally varies from a minimum of 0.5 to a maximum of about 1.20 minutes, the intertrial interval being of 5 min. The eye test distance (vd) is 30 cm in some sessions, where easy close vision is allowed. It is about 60 cm in other sessions, so chosen as to increase the reading time, the correct vision being yet allowed, but less easier. A "working day", from noon to midnight is reconstructed by combining the data recorded in four consecutive days lasting three or four hours each. Three highly skilled observers, familiar with experiments on circadiancy took part in the experiment. The sources used are either commercial lamps or their combination with colored eyeglasses. The illuminance, chromaticity coordinates an luminance are measured by the use of Minolta devices. The characteristics of the used SPD are as follows.

Incandescent lamps: (x=0.479; y=0.413); Blue. Green (BG) PAR Phylips Partytone PAR 8 Economy E27 ES, (x=0.133, y=0.208); Cool 1, Starlite REFR, (x=0,399; y=0.387); Cool 2, Phylips Daylight (both Bluish White) (x=0.395; y=0.390): Green 2, (x=0.325; y=0.573); Green 1, (x=0.314; y=0.637), both yellowish green; Minus blue, mB, (x=0.575; y=0.345); Yellow, x=0.529; y=0.455; Pink Violet, PV, (x=0.551, y=0.287): Red Orange, RO x=0.461, y=0.287.

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3. EXPERIMENTAL FINDINGS

The reading time (R) was recorded in sunny days with some white clouds where the illumination at the walls of the office was highly variable in intensity and in SPD. The chromaticity coordinates of the illumination at the test object, varied from x=0.361 and y=0.379, to x=0.297 and y=0.320).The strong wind produced numerous transient distracters. The observers enjoyed in this other than monotonous situation which, however, was complicating its intrinsic fluctuations, probably also due to the cyclical variability of attentive involvement (Figure 1, left). The frequency distribution of the R data is not normal (Figure 1, right) because of skewness and of flanking lobes, suggesting a noise like conceptualization (Levi et al. 2005) Thus natural light does not seem to be appropriate for the collection of quantitative data. Therefore, we passed to electrical lighting, of constant illuminance and SPD.

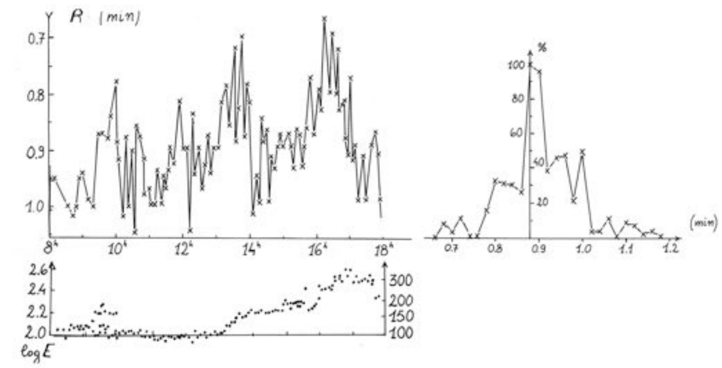

Figure 1 - (left) R vs time of day, natural light; indoor; with environmental distracters; vd=30 cm; (right) %t frequency distribution of R. Bottom, diurnal variability of illumination.

Figure 2, which refers to incandescent lighting, shows a reduced amplitude of oscillation compared to Figure 1. In particular note that the "after eight" branch shows a progressive (even if oscillating) increase in reading time. The circadian plot is known to depend on a large number of factors (Figueiro and Rea 2011), and the contradictions among various authors often are due to the fact that they use different "fixed" but often unspecified conditions. Therefore, the independent variable and the frosted parameters are clearly indicated by us. Our three observers are in a good agreement.

In Figures 3 to 6 the "after eight" data, recorded in sessions lasting from 21h to midnight are displayed. Note the trend of the oscillating carrier of these plots of reading time R versus time. Figure 3 shows the reading time decreases in the case of blue green (BG) and of cool (bluish white) light, probably denoting the increasing alertness due to blue This is not the case of the warm light minus blue, incandescent and yellowish green as well as yellow, pink violet and orange red lights, as is shown in the left portion of Figure 4. A synoptic view of these findings is shown in the right portion of Figure 4, where the line segments represent the range of recorded R. The arrows refer to the R value at midnight (low value for cool light, higher values for warm lights). Figures 5 (vd=30 cm) and 6 (vd=60 cm)show the effects of increasing L.

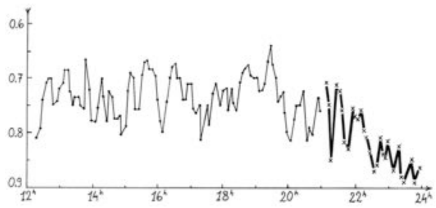

Figure 2 - R vs time, inc. source, L=65 cd/sq.m, vd=30 cm. Note the trend "after eight".

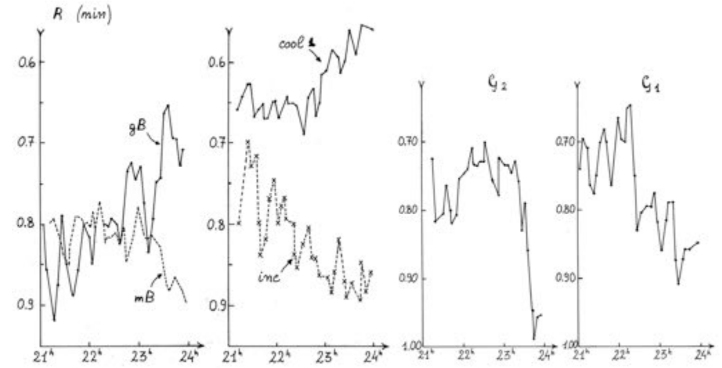

Figure 3 - Plots of R vs time; vd=30 cm; L=12 cd/sq.m. Note the differences in trend for cool and warm light, respectively.

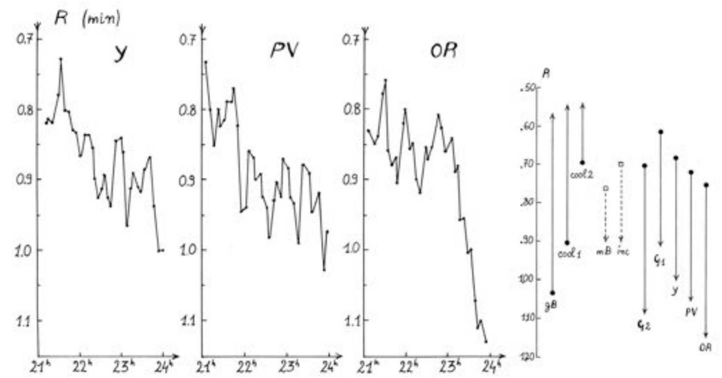

Figure 4 - (left) R vs time, r other warm lights; (right), the synopsis; vd=30 cm, L=12cd/sq.m.

DISCUSSION

Our data suggest a peculiar SPD dependence, related to the warm-cool distinction, "after eight", from 21 o'clock to midnight. It is here entrusted to visual inspection as carrier of the trend of oscillations. The statistical significance, tested by the "cluster test" will be displayed elsewhere, being here incompatible with the allowed space. The main result is that, after eight, the reading time decreases, blue being involved in "cool" lighting. The alerting effect of blue at night is thus once more confirmed (Figueiro and Rea, 2011 and quoted bibliography). On the other hand, the reading time increases in the case of "warm" lighting, including the yellowish green. Accordingly, our data seem to confirm the ambiguity of green, by considering now the functional aspect (rather than the traditional appearance), say the inversion of trend, passing from BG to yellowish green.

The visual literature is rich of reports on cases where blue and green produce both similar and opposite effects. In conclusion, the blue is "excentric", (Ronchi and Sandford, 2009): the duplicity of short wavelength sensitive receptors is a matter of fact, and the blue is expected to play a role when interacting with the non visual, non imaging effects (Ronchi, 2011). The green is known to be ambiguous, and here we show some ambiguous blue and green relations.

Our plans for the future include the study of the effects of the structure of the environment, by reconsidering the inhomogeneities across the visual field (Ronchi, 2010) with consequences on driving behavior, as referred to alertness and fatigue. In particular, the attempt will be made to compare the luminance dependencies of the “after eight” plots under various SPD’s. Figure 5 shows that the working range seems to rather narrow for cold lighting, contrary to some exploratory results with warm light. The question arises what happens to circadiancy when the constraint imposed by the minimum (and irreducible) limit for reading time (0.5 min) is approached. It is as if the carrier would become flat, while the oscillation persists. Is it due to non-visual, non-imaging effects? Anyhow, Figure 6 shows that the trend differences, when passing from cold to warm light persist also when easy close vision is replaced by less easy vision, by doubling the viewing distance.

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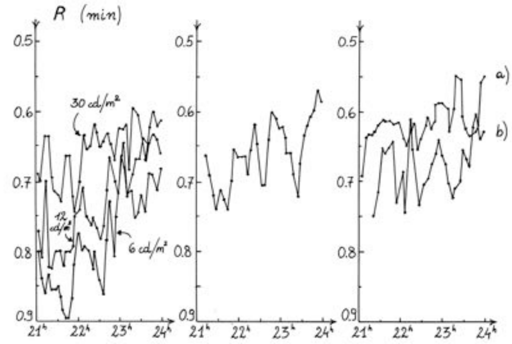

Figure 5 - BG light. vd=30 cm; increasing L from 6 to 100 (middle) and 800(right), cd/sq.m.

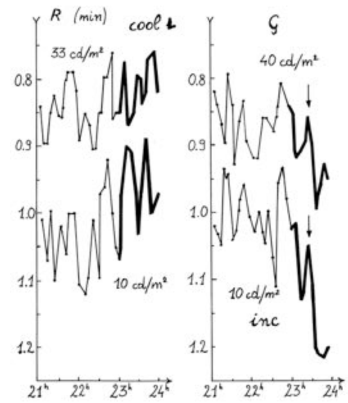

Figure 6 - Now vd=60 cm; (left), cool light; (right) yellowish green (up), incandescent, bottom.

REFERENCES

Figueiro M.G. and Rea M.S., 2011, *Sleep opportunities and periodic light exposure: impact of biomarkers performance*, Lighting Res, & Technol., 432, 349-369 (*and quoted bibliography*).

Levi D.M., Klein A. and Chen. J., 2005, *What is the signal in noise?*, Vision Res., 45:1835-1846.

Ronchi L. and Sandford J., 2009, *The excentric Blue*, Florence, Fond. G. Ronchi, Vol. 97.

Ronchi L., 2010, *Diurnal variability of visual field response under constant electrical lighting*, In Proc. CIE Symp. Light quality and Efficiency, Vienna, 14-17 March.

Ronchi L., 2012. *On the interacting visual and non-visual effects*, Florence: Fond. G. Ronchi, Vol. 103.

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Color preference style for twelve tones in the Practical Color Co-ordinate System (PCCS)

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ABSTRACT

The color preference style for the twelve tones described in the Practical Color Co-ordinate System (PCCS) was examined. Data from 343 undergraduate students were analyzed. The card on which 144 color chips were pasted (in twelve rows by twelve columns) was distributed to the participants. Twelve rows corresponded to the twelve PCCS tones. Participants judged the degree of preference for each tone by marking on visual analog scale (VAS). We analyzed indices of the color preference style for the PCCS tones and found different properties from the style for the basic hues that has been clarified in our previous study. The overall level of liking was lower for the PCCS tones than for the basic hues. Moreover, the range of 12 VAS scores from the lowest to the highest was wider in females than in males, showing that female participants had more choosy preference style than male participants. Such a sex difference was not found in the color preference style for the basic hues.

1. INTRODUCTION

We have the preference for many colors at various degrees. Someone may prefer a certain color extremely and dislike other colors. The others may prefer many colors almost equally. Hanari & Takahashi (2009) called the individual profile of the preference for many colors *color preference style.* Our previous research (e.g., Hanari & Takahashi, 2005) studied the color preference style for the basic colors (hues); red, orange, yellow, yellow green, green, blue, purple, pink, brown, black, white, and gray. In the present study, we examined the color preference style for the twelve tones described in the *Practical Color Co-ordinate System* (PCCS). PCCS is the color system developed by the Japan Color Research Institute, and has been used in Japan as widely as other popular systems such as the Munsell system and the NCS. The PCCS describes all colors in two dimensions, hues and *tones*. The PCCS tone is the concept that combines the value and the chroma, and is classified in twelve categories; pale, light grayish, grayish, dark grayish, light, soft, dull, dark, bright, strong, deep, and vivid. For example, the pale tone has the highest value and the lowest chroma, and the vivid tone has a middle value and the highest chroma.

Some studies have suggested features of the preference for the PCCS tones. For example, the vivid tone and the light tone are likely to be preferred most, and the difference of preference for the PCCS tones appears more clearly than that for hues (e.g., Japan Color Research Institute, 1995). However, detailed feature of the preference for the PCCS tones has not fully understood. Above all, the color preferece *style* for the PCCS tones has not been studied so far. Therefore, we made the first attempt of clarifying the color preference style for the PCCS tones. We employed the same procedure as used in our previous research that analyzed twelve basic hues (Hanari & Takahashi, 2005, 2008; Takahashi & Hanari, 2008).

2. METHODS

2.1 Participants

Data from 343 undergraduate students (67 males and 276 females) were analyzed.

2.2 Procedure

The card on which 144 color chips were pasted was distributed to the participants. The color chips were arranged in twelve rows by twelve columns on the card. The size of each chip was 7mm x 7mm, and open space was 2mm between the columns and 14mm between the rows. Twelve columns corresponded to twelve PCCS hues; red, reddish orange, yellowish orange, yellow, yellow green, green, blue green, greenish blue, blue, violet, purple, and red purple. Twelve rows corresponded to twelve PCCS tones mentioned above. Consequently, twelve color chips in each row had the same tone of different hues; for example, pale red, pale reddish orange, pale yellowish orange, and so on. Another sheet of questionnaire was given to the participants to ask his (her) preference for the twelve PCCS tones. In the questionnaire, twelve horizontal lines were drawn to serve as visual analog scales (VAS) as shown in Figure 1. Participants were asked to judge the degree of preference for the whole twelve color chips in each row; that is, to judge his (her) general preference for the chips having the same tone with different hues. They answered that by marking a slash (/) on each line. The left edge of the line indicated 'dislike the most,' and the right edge indicated 'like the most.' Most participants finished answering within a few minutes.

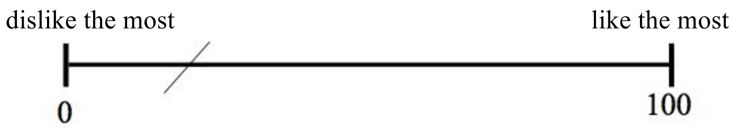

Figure 1. A sample of visual analog scale (VAS).

3. RESULTS AND DISCUSSION

We analyzed the mean VAS score for each tone to figure out the general tendency of preference (i.e., popularity) for the PCCS tones. As shown in Table 1, both females and males liked the bright and vivid tones, and disliked the grayish tone. Some sex differences were also found showing higher scores in females than in males for light, bright, soft, and pale tones, whereas higher scores in males for deep and dark grayish tones.

Next, we rearranged 12 VAS scores in a rank order from the most liked one to the least liked one, regardless of which tone was given which rank, in each participant (Table 2). Based on these data, we calculated six indices of the color preference style in each participant, as in our previous studies; the average, the standard deviation, the highest and the lowest of 12 VAS scores, the degree of extremity of the highest (DEH) and the degree of extremity of the lowest (DEL). The DEH is the mean difference between the highest score and other 11 scores. Similarly, the DEL is the mean difference between the lowest score and other 11 scores. Thus, these indices indicate how extremely the most preferred (or the least preferred) tone stands out from other tones.

We analyzed these indices to discuss the nature of the color preference style for the PCCS tones (Table 3). The color preference style for the PCCS tones showed different properties from that for the basic hues. The average, the highest, and the lowest scores were smaller for the PCCS tones than for the basic hues, suggesting the overall level of liking was lower for the PCCS tones than for the basic hues. Moreover, the highest score was larger and the lowest score was smaller in females than in males, indicating the range of 12 VAS scores was wider in females than in males. The DEH and the DEL were also larger in females than in males. These results showed the consistent tendency that female participants had more choosy preference style than male participants. That sex difference was not found in the case of the color preference style for the basic hues.

It was suggested that the PCCS tones reflect the difference of color preference style more sensitively than the basic hues. Not only the sex difference, which was shown in the present results, but also the differences among individuals, ages, or cultures may appear more clearly for the PCCS tones than for the hues. In that sense, the color preference style for the PCCS tones could be useful index for describing the characteristics of the color preference.

*Table 1. Mean VAS scores for 12 tones. Asterisks indicate the sex difference is significant. ** p<.01, *p<.05*

	bright**	light**	vivid	strong	pale**	soft*	deep*	dull	light grayish	dark	dark** grayish	grayish
all	73.0	71.7	68.9	62.8	55.7	54.2	45.7	41.1	37.0	32.3	30.0	23.5
(SD)	(19.6)	(22.2)	(19.1)	(20.3)	(26.0)	(22.2)	(21.9)	(20.0)	(21.5)	(21.2)	(26.7)	(19.1)
female	75.7	75.6	69.3	62.2	58.8	55.2	44.4	40.3	37.5	31.4	27.0	22.7
(SD)	(18.1)	(20.1)	(18.3)	(19.9)	(25.6)	(23.1)	(22.0)	(20.0)	(21.7)	(21.1)	(25.6)	(18.4)
male	64.3	59.1	67.7	64.6	45.8	50.9	49.9	43.8	35.4	35.3	39.8	26.1
(SD)	(21.8)	(24.0)	(21.4)	(21.7)	(24.6)	(19.0)	(20.9)	(19.5)	(20.9)	(21.3)	(27.8)	(21.4)

*Table 2. Mean VAS scores from the highest rank to the lowest rank. Asterisks indicate the sex difference is significant. ** p<.01, *p<.05*

	Ranking											
	1*	2	3	4*	5	6	7	8	9	10	11	12
all	86.7	80.7	74.7	67.5	59.9	52.4	45.2	38.7	31.6	25.6	19.9	13.1
(SD)	(10.9)	(12.4)	(13.3)	(14.4)	(14.8)	(14.8)	(15.0)	(14.6)	(14.2)	(14.1)	(13.8)	(12.0)
female	88.1	81.8	75.7	69.0	60.7	53.1	45.4	38.4	31.3	25.2	19.2	12.3
(SD)	(10.3)	(12.2)	(13.0)	(13.3)	(14.2)	(14.4)	(14.8)	(14.7)	(14.4)	(14.3)	(13.9)	(11.3)
male	82.1	77.0	71.3	62.7	57.2	50.4	44.5	39.6	32.8	27.2	22.1	15.7
(SD)	(11.7)	(12.5)	(13.6)	(16.8)	(16.5)	(15.9)	(16.0)	(14.6)	(13.4)	(13.5)	(13.3)	(14.0)

*Table 3. Indices of color preference style. Asterisks indicate the sex difference is significant. ** p<.01, *p<.05*

	The highest*	The lowest	Average	Standard Deviation	DEH*	DEL*
all	86.7	13.1	49.7	25.5	40.4	39.9
(SD)	(10.9)	(12.0)	(9.8)	(7.5)	(12.3)	(11.5)
female	88.1	12.3	50.0	26.3	41.6	41.2
(SD)	(10.3)	(11.3)	(9.8)	(7.1)	(11.6)	(10.8)
male	82.1	15.7	48.6	23.0	36.6	35.8
(SD)	(11.7)	(14.0)	(10.3)	(8.1)	(13.6)	(13.3)

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4. CONCLUSION

There were some differences between the color preference style for the PCCS tones and that for the basic hues. The overall level of liking was lower for the PCCS tones than for the basic hues. Sex difference was also found in the color preference style for the PCCS tones. The range of 12 VAS scores from the highest to the lowest was wider, and the DEH and the DEL were also larger, in females than in males. These results indicated that female participants had more choosy preference style than male participants for the PCCS tones, which was not the case for the basic hues.

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REFERENCES

Japan Color Research Institute. 1995. *Color preference in Japanese 1979-1992*. Japan Color Research Institute.

Hanari, T. and S. Takahashi. 2005. Relationship between cognition/attitude on colors and color preference style. In *AIC Color 2005, Proceedings*, ed. by J. L. Nieves and J. H. Hernández-Andrés. Granada: Gráficas Alhambra, S.A., 329-332.

Hanari, T. and S. Takahashi. 2008. Particular self images related to the preference for achromatic colors. In *AIC Color 2008, Proceedings*, ed. by I. Kortbawi, B. Bergstrom, and K. F. Anter. Stockholm: Hotel Rival, Paper no 063.

Hanari, T. and S. Takahashi. 2009. Color preference style for multi colors and individual characteristics in color cognition. *Journal of the color science association of Japan* 33(4): 319-326. (in Japanese).

Takahashi, S. and T. Hanari. 2008. Cognitive factors in color preference (2): Generalization of previous findings by using modified procedures. *Journal of the color science association of Japan* 32(4): 282-289. (in Japanese).

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Hue Adjustments for Stereoscopic 3D Perception

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ABSTRACT

This paper discusses the effect of hue on stereoscopic 3D (S3D) perception from a psychophysical viewpoint. It considers the way in which S3D perception is influenced by different decisions of colour hue, and identifies the thresholds of S3D perception in several hue adjustments, which can provide guidance during colouring decisions for S3D imaging. In particular, different levels of hue are tested on foreground and background objects in computer graphic scenes. Psychophysical trials are utilized to examine the thresholds of observers' depth perception. A polarised projection system is built for stereoscopic viewing and the image stimuli are rendered from stereoscopic virtual cameras by renowned 3D film making programme during experiments. The data indicates that it was able to provide a significant effect over the hue adjustments in controlling the perceived depth in stereoscopic perception, but there is no significant difference between warm and cool hue arrangements in foreground and background objects.

1. INTRODUCTION

Colour is a remarkable monocular depth cue that advantages binocular depth performance; it is also highly related with depth perception in graphic design. Hue is a crucial consideration in S3D imaging design where depth is most concerned. Brewster's (1851) work in colour stereopsis has shown that long-wavelength stimuli, such as red or yellow, compete with short-wavelength stimuli such as blue or green, when viewed binocularly, reds and yellows appear closer than blues or greens. In other words, warmer hues associated with longer wavelength helps objects standout; cooler hue associated with shorter wavelength helps objects recede.

2. COLOUR IN DEPTH PERCEPTION

Some colours may attract attention away from other colours in the visual field, the colour red in particular. Verhoeff (1928) pointed out that red is readily seen as nearer than other colours. Bugalski (1967) used the red signal in traffic lights as an example to explain this point. Nakayama and Silverman (1986) had demonstrated a correlation between perceived depth in geometric configurations and selective visual attention. When viewed binocularly, with the aided or unaided eye, Hartridge (1947), Dengler and Nitschke (1993) indicated reds and yellows appear closer than blues or greens. When the colors were lighter than the background, the long-wavelength color orange was seen in front of the short-wavelength color blue; when the colors were darker than the background, blue was seen in front.

While these findings clearly indicate that color cues interact with depth perception, their significance with regard to stereoscopic depth perception has not been further investigated. From design aspect, Kopacz (2004) mentioned either a warm hue with long-wavelength for the foreground objects or a cool hue with short-wavelength for background objects can contribute to depth perception. However, is warm hue really a preference for the foregrounds regard to S3D imaging? Are these design aspects applicable for current stereoscopic imaging productions? This paper examines the thresholds of warm and cool hues for stereoscopic depth perception based on human factor experiments.

3. METHODS

3.1 Psychophysical Trials

To provide the examinations of different hues in stereoscopic perception, this paper employed psychophysical experiment for the measurement of threshold values. The method of constant stimuli was chosen as Farell and Pelli (1998) indicated the method is considered to provide robust and precise estimations of threshold and other parameters. Psychometric functions were constructed based on seven stimulus levels and 50 trials per level, using a 2AFC procedure. Johnson *et al* (1984) pointed out 2AFC minimises the likelihood of criterion shifts and also reduces the possible effects of interval-selection bias.

3.2 Apparatus

A polarized projection system was built for stimuli observations. Verrier (2009) pointed out current RealD 3D cinema uses circularly polarized light to produce stereoscopic image projection. The stimulus images were projected by two same model DLP projectors to a silver screen, observers were required to wear polarized glasses to fuse the left and right images at a fixed viewing distance.

3.3 Stimuli

The image stimuli were rendered in Autodesk Maya 2012 and composed simply by a foreground small square located in the centre of a background large square, which avoid any other possible depth cue. The two objects in the scene were located within stereoscopic comfort viewing zone that suggested by the visualization tool in Maya. In order to provide equal comparisons, contrasts between foreground and background colours were controlled in certain ratios. Seven levels of different contrast ratios from 2.0:1 to 2.6:1 between foreground and background colours with 0.1:1 step size difference were associated to colour wavelength ranging from 490nm to 550nm for cool hue and 550nm to 610nm for warm hue.

3.4 Procedure

The first section of the two is to examine warm hue in foreground with cool hue in background (warm-cool); the second section is for cool hue in foreground with warm hue in background (cool-warm). Seven subjects who met the minimum criteria of 20/30 vision, stereo-acuity at 40 sec-arc and pass the colour vision test participated the experiment. Every observation includes a standard stimulus with the contrast ratio 2.3:1 side by side with a comparative stimulus presented randomly from contrast ratio 2.0:1 to 2.6:1. Observers been asked to record their decision by choosing the image they perceive more stereoscopic depth between the foreground object and the background object.

4. RESULTS

Psychometric function which shows the relationship between the percentage of times that a stimulus is perceived and the corresponding stimulus intensity. Point of subjective equality (PSE) is then obtained at 50% of psychometric function. The mean score and standard deviation for two sections are shown in Table 1.

Table 1. Mean and std. deviation of PSE

	Subject	LD	AM	RE	EN	MJ	GC	JK	Mean	St. Dev.
Warm-Cool (w-c)	PSE (Contrast ratio)	2.31	2.27	2.31	2.53	2.28	2.32	2.29	2.33	0.09
Cool-Warm (c-w)	PSE (Contrast ratio)	2.32	2.29	2.30	2.29	2.30	2.30	2.32	2.30	0.01

In warm-cool trial, three subjects out of seven have lower contrast ratio than standard ratio 2.30:1 and the mean is 2.33:1 which is very close to standard ratio. In cool-warm trial, two subjects have lower contrast ratio and the mean is equal to the standard. The results from Paired T-Test comparisons between PSE in two trials revealed that there is no statistically significant different between warm hue and cool hue. $p>0.05$, fail to reject H_0. See Table 2.

Table 2. T-test result concerning w-c and c-w trials

Hypothesis	Two-tailed P value	Conclusion
H_0: $\mu_{w-c} = \mu_{c-w}$ vs. $\mu_{w-c} > \mu_{c-w}$	.15	Fail to reject H_0

The coefficients in linear regressions indicate slopes in two trials are significant different from 0, which means there is a significant relationship between hue and S3D perception as $\beta\neq0$ at $p<0.05$. See Figure 1, Figure 2 and Table 3.

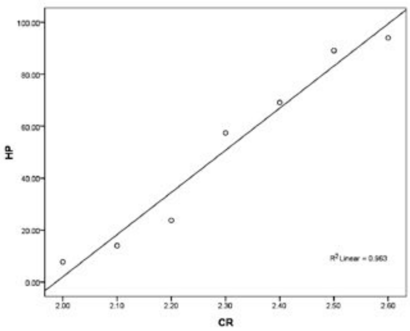

Figure 1. Linear regression of warm-cool trial

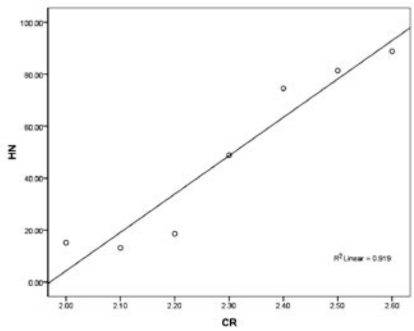

Figure 2. Linear regression of cool-warm trial

Table 3. T-test results of slopes

Hypotheses	P value	Conclusion
H_0: β=0 vs. H_1: $\beta\neq$0	.000	Reject H_0
H_0: β=0 vs. H_1: $\beta\neq$0	.001	Reject H_0

A univariate analysis of variance was then performed on the comparison concerning the slopes. The result showed there is no significant difference between the variances in warm-cool trial and cool-warm trial as $p>0.05$. See Table 4.

Table 4. Univariate analysis of variances

Source	Sum of Squares	df	Mean Square	F	Sig.
w-c * c-w	29.765	1	29.765	.363	.560

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5. CONCLUSION

In this study, thresholds for alternative forced choice of colour hue with stimulus levels controlled by contrast ratio were measured. Statistics confirmed that it was able to provide a significant effect over the hue adjustments in controlling the perceived depth in stereoscopic perception. We also learn that even the cool hue in foreground and warm hue in background could also effect on stereoscopic perception. However, there were indications in our results suggesting that with fixed contrast ratio there is no significant difference between warm and cool hue arrangements in foreground and background objects.

It is proposed that the considering hue is beneficial on stereoscopic perception, but viewers can perceive same stereoscopic intensity under certain contrast whether the image is associated with warm hue or cool hue.

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REFERENCES

Brewster, D. 1851. Notice of a chromatic stereoscope. *Philosophical Magazine, 4th Series* 3: 31.

Bugelski, B. R. 1967. Traffic signals and depth perception. *Science* 157: 1464–1465.

Dengler, M., & Nitschke, W. 1993. Color stereopsis: a model for depth reversals based on border contrast. *Perception & Psychophysics* 53: 150–156.

Farrell, B. & Pelli, D. G. 1998. *Vision Research: A Practical Guide to Laboratory Methods*. New York: Oxford University Press.

Hartridge, H. 1947. The visual perception of fine detail. *Philosophical Transactions of the Royal Society* 232: 519–671.

Johnson, D. M., Watson, C. S. and Kelly, W. J. 1984. Performance differences among the intervals in forced-choice tasks. *Perception & Psychophysics* 35: 553-557.

Kopacz, J. 2004. *Color in Three-Dimensional Design*, New York: McGraw-Hill Companies, Inc.

Nakayama, K., & Silverman, G. H. 1986. Serial and parallel processing of visual feature conjunctions. *Nature* 320: 264–265.

Verhoeff, F. H. 1928. An optical illusion due to chromatic aberration. *American Journal of Ophthalmology* 11: 898–900.

Verrier, R. 2009. 3-D technology firm RealD has starring role at movie theaters. *Los Angeles Times,* retrieved on 2011-02-05.

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Blackness of japanese lacquer and its relation to surface property

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ABSTRACT

Relation between perceived blackness, KANSEI properties, and physical properties of the surface of black lacquer was investigated. We prepared small wooden plates painted with 2 different lacquers produced in Japan and Myanmar. For each of them, 3 plates with different surface property were prepared. In the psychophysical measurements, perceived blackness of the real lacquer and fake plates was evaluated by comparing its blackness with that in the central circular field surrounded by white annulus in the blackness matching box. Physical properties, such as luminance measured from the observing position, surface roughness, reflectance, and BRDF (Bidirectional Reflectance Distribution Function) were measured. Strong correlation was observed between perceived blackness and the luminance.

1. INTRODUCTION

In Japanese, there is a word to express a kind of black, “Shikkoku” which means “lacquer-black” indicating deep black. This is interesting that sometimes it indicates a blackness of dark space with no lights, while at other times it indicates a glossy black, implies that the expression tightly relates to the appearance of lacquer materials which varies from simple matt to gorgeous luster. Such difference of appearance of lacquer is based on the difference of physical properties of surface resulted from the difference in the polishing and finishing process (Lee et al., 2002). So we become interested in investigating that what kind of physical property causes the difference of material appearance of black lacquer. The purpose of this study is to explore the relations between perceived blackness and other KANSEI properties and some physical properties of the lacquer surface.

2. EXPERIMENT

2.1 Laquer plates

In experiments, we prepared small wooden plates (80mm×100mm) painted with 2 different lacquers produced in Japan and Myanmar. For each of them, plates were stopped at 3 different steps in the process of making lacquer products, called “Nuritate (just painted)”, “Do-zuri (in polishing)” and “Roiro-migaki (polished up)”, corresponding to the early, middle, and the last steps of making lacquer objects. Three Japanese plates are noted as “JP1

(Nuritate)", "JP2 (Do-zuri)", and "JP3 (Roiro-migaki)", respectively, and those of Myanmar plates are similarly noted as "MM1 (Nuritate)", "MM2 (Do-zuri)", and "MM3 (Roiro-migaki)", respectively. In addition to these lacquer plates that all appear black, we prepared fake plates painted by various grays from dark to medium reflectance in order to let observer's judgement keep neutral in the experiment.

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2.2 Blackness matching experiment

We carried out the experiment to evaluate perceived blackness of the lacquer plates using the blackness matching box (BMX) which was utilized in our previous studies (Eda et al., 2010, Ayama et al., 2011). Visual field of the BMX is the dark central circular area surrounded by white annulus with 99% reflectance. Luminance of the center field can be varied by the experimenter. BMX was set on a desk on the left-side of the observer. The luminance of the surround area was fixed at 150.75cd/m^2, while the luminance of the central area was varied 12 levels from 0.24 to 38.63cd/m^2.

Another box called the test box (TX) was used for the presentation of the lacquer plates. They were presented one plate at a time, in one of the two conditions, with and without a thin gray sheet with a circular hole in the center, called 'with-window' and 'without-window' conditions, respectively. Average luminance of the surrounding area is about 109.6cd/m^2 and 117.51cd/m^2 in with-window and without-window conditions, respectively.

At the beginning of the session, the observer was adapted to a non-bright environment inside the experimental booth for five minutes. In a session, window condition was fixed either with or without window. Experimenter adjusted the current for the LED to set the blackness of the central area in the field of BMX. Then, a plate chosen from the 6 lacquer plates and 4 fake plates was presented in the TX. Observer was asked to answer which is more blackish, the central area seen in the BMX, or the plate presented in the TX. The same procedure was repeated for all of the 6 lacquer and 4 fake plates in a random order.

Ten observers, five males and five females participated the experiment. All were the student of the Art University.

Spectrophotometer (Konica-Minolta, CS-2000) was used to measure the luminance of the center and the surround field of BMX, and the surface of the lacquer plates and the surrounding area in the TX from observer's view point.

2.3 Subjective evaluation of KANSEI property

After all sessions of the blackness matching were done, the test plates were presented one at a time, and then observer was asked to answer the subjective evaluation of perceived blackness, from deep black (0) to bright gray (10), and KANSEI properties, such as glossiness, smoothness, feeling of depth and preference of black lacquer by SD method, from none (0) to much (6). This is done only in the without-window condition.

3. MEASUREMENT OF PHYSICAL PROPERTIES

Following properties were measured; 1) surface roughness using a profile meter (Surfcorder SE-3400, Kosaka Lab), 2) BRDF (Bidirectional Reflectance Distribution Function) using a Gonio-Spectrophotometric Color Measurement System (Murakami Color Research Lab., GLMS-WIN), 3) luminance from observer's view point using a spectroradiometer (Konica

Minolta, CS-2000), and 4) spectral reflectance factor using a spectrophotometer (JASCO Corporation, V-650DS).

4. RESULTS AND SUMMARY

Figure 1 indicates results of the blackness matching experiment for MM2, (a) with-window, and (b) without-window. Horizontal and vertical axes indicate the luminance of the central circular field of the BMX, and the percentage of the answer that the test plate is blacker, respectively. One observer's results were omitted from the data analysis because of large deviation from the average results in most of the conditions. From the results shown in Figure 1, the luminance of the central circular field of the BMX that corresponds to the 50% of the vertical axis was read out for all the test plates for with- and without-window conditions. The value is called matched luminance and plotted in Figure 2. Filled circles in Figure 2 show the luminance of the test plate from observer's view point measured using spectrophotometer. As shown in Figure 2, matched luminance is roughly close to the measured luminance, and strong correlation with r=0.955 was obtained. It is interesting that the matched luminance becomes larger than the measured luminance as the luminance value increases, and the tendency is more eminent for the without-window condition.

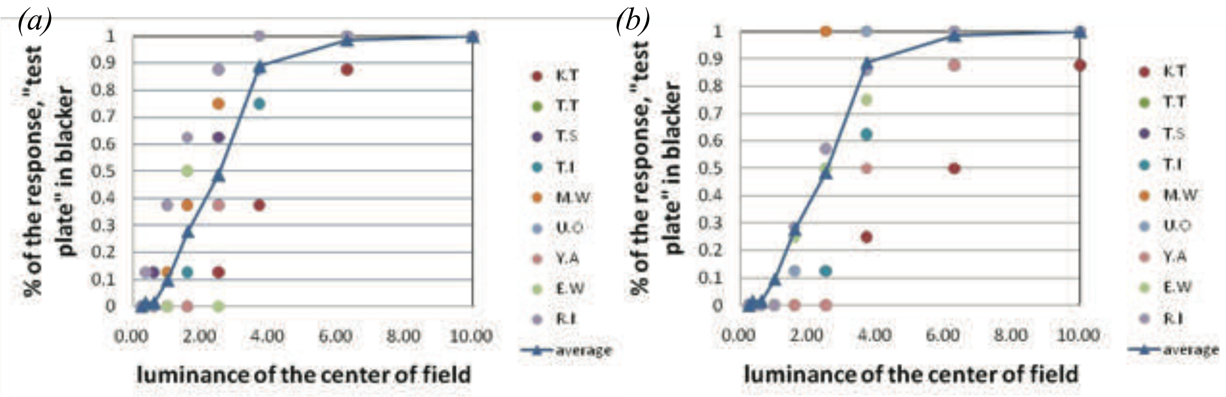

Figure 1. Results of the blackness matching experiment for MM2 (Myanmar, Do-zuri) plate. (a) and (b) are the results of with- and without-window conditions, respectively

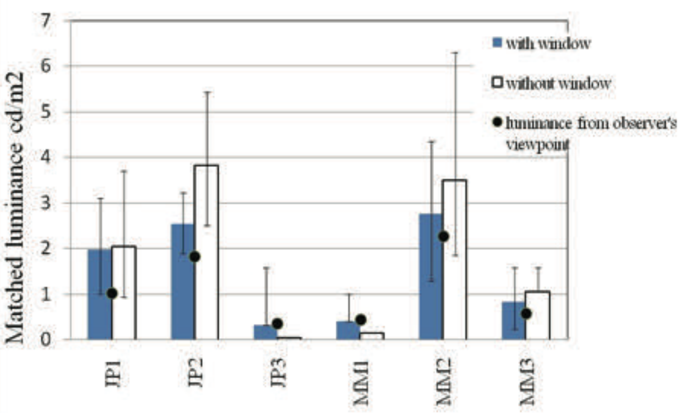

Figure 2. Matched and measured luminance of 6 lacquer plates

Figure 3 and 4 show results of the subjective evaluation of perceived blackness and preference, respectively. Numerals in parenthesis indicate the correlation coefficient with the luminance from observer's viewpoint. Result of the perceived blackness is similar to those of the blackness matching and the measured luminance, indicating a reliability of observers' blackness judgment. It is interesting that the scores of preference evaluation becomes roughly opposite to perceived blackness evaluation, indicating that the blacker the surface, more preferable, for most of the observers in this experiment. However, recent report on KANSEI evaluation for black lacquer plates showed that most observers prefer glossy surface, while there exit observers who strongly prefer matte surface (Komatsu et al., 2012).

Although peak values of the BRDF measurement using 6 plates seem to correlate with glossiness evaluation, more detailed analysis is necessary to clarify the precise relations between them. Further study is needed to explore rather complicated relations between the physical properties and perception of lacquer surface.

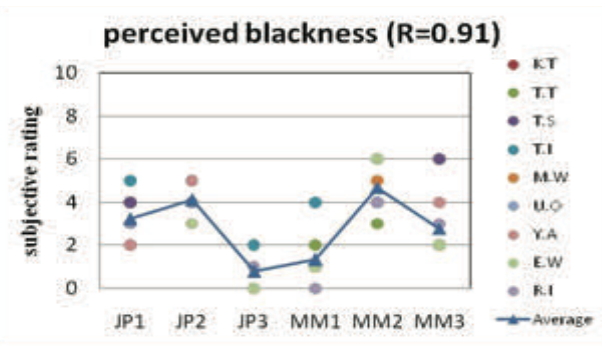

Figure 3. Results of perceived blackness

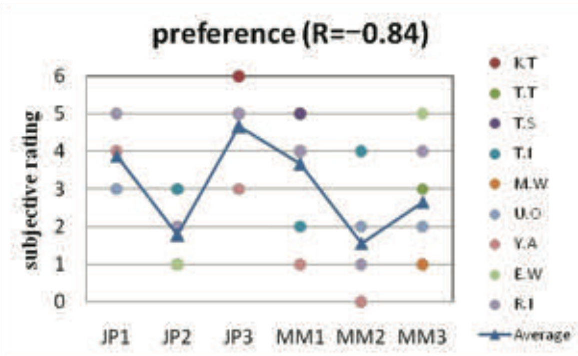

Figure 4. Results of preference evaluation

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REFERENCES

Lee, W., M. Sato, T. Asami, H. Oyabu, S. Tominaga. 2002. Relation of Light Reflection to Visual Texture on Black Coating Films of Urushi (Japanese Lacquer) and Various Synthetic Resins. Journal color science Association of Japan , Vol.26, No4, pp236-247.

Eda, T., Y. Koike, S. Matsushima, T. Ishikawa, K. Ozaki, M. Ayama. 2010. Influence of Blackness on Visual Impression of Color Images. KANSEI Engineering International, Vol.10, No.1, pp.49-58.

Ayama, M., T. Eda, T. Ishikawa, S. Matsushima. 2011. Effect of Observers' Property on KANSEI Impression of Blackness in Artistic Digital Images. Proceedings of the International Colour Association (AIC) 2011, CD-ROM. Zurich.

Komatsu T., M. Ohkura, T. Ishikawa, M.Ayama. 2012. Assessment of material perception of black lacquer, Proceedings of the 4th International Conference on Applied Human Factors and Ergonomics.

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Comparison of Color Preference in Different Color Appearance Mode Between Thai and Japanese People

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ABSTRACT

We investigated color preference in different color appearance mode of Thai and Japanese people. Twenty four color chips consisted of eight hues (5R, 5YR, 5Y, 5GY, 5G, 10BG, 10B, and 5P) with three value (5/2, 5/5 and 5/8) were presented in different color appearance modes. Subjects were asked to rate his/her color preference on each color. They were asked to judge color appearance mode of each color whether it appeared as object color mode or unnatural object color mode or light source color mode. The result indicated that both Thai and Japanese people preferred colors appeared as unnatural object color mode and light source color mode to those appeared as object color mode. However, Thai people preferred cool colors such as green, blue and cyan to warm colors (red, and orange), whereas Japanese people preferred warm colors to cool colors. Yellow color was the least preferable hue for both groups of people.

1. INTRODUCTION

Color preference was a powerful tool to attract a subject's attention and to arouse the desire to consume in marketing. Several factors such as age, gender, cognition, and circumstances were said to be responsible for color preference. Culture was also one of factors which influence color preference. For example, in Thailand, red color refers to meaning of "healthy, wealth and prosperous". However, for Japanese people, red color is related to "danger, blood, and irritation". Therefore Thai people are more prefer to use red color in their daily life than Japanese people. There were previous researches compared color preference between several nations, but none of them include mode of color appearance as a factor. Most of those works studied color preference with real and simulated reflected surface which appeared in object color mode. In our daily life, however, colors are perceived not only as an object color mode, but also as other modes.

In this work, the color appearance mode was classified based on the *Recognized Visual Space of Illumination theory* into three modes: object color mode (OB-mode), light source color mode (LS-mode), and unnatural object color mode (UN-mode). For object color mode, color appeared as a color on a paper or a reflected surface. For light source color mode, color appeared as a light or color from self-emitting source. However, there was an ambiguous mode which color was hardly classified into those two modes because it contained both properties of those two modes. For example, color which seemed to be a color on reflected surface but also looked like color appear from light behind the hole. This mode was named unnatural object color mode. In this study, we investigated color preference in different color appearance mode of Thai and Japanese people.

2. METHODOLOGY

2.1 Apparatus

The schematic diagram of apparatus was illustrated in Figure 1. Two rooms (subject room and test chart room) were separated by a wall with a small square aperture. In the test chart room, there was a rotating wheel for placing color chips. The color chips were illuminated by a set of intensity-controllable fluorescent lamp (FL_T) faced to the rotating wheel. The illuminance in the test chart room denoted by I_T was controlled by the experimenter. In the subject room, the inside wall was covered with white wall paper. A set of intensity-controllable fluorescent lamp (FL_S) was attached on the ceiling. The subject room illuminance (I_S) was measured by an illuminometer placed on the shelf closed to the front wall. On the front wall, there was a 1°×1° aperture placed at the subject eye's level. The distance between the front wall and the subject's eye was fixed at 1.3 m. When the subjects looked through this aperture, the color chip in the test chart room appeared as if it was placed on the front wall in the subject room.

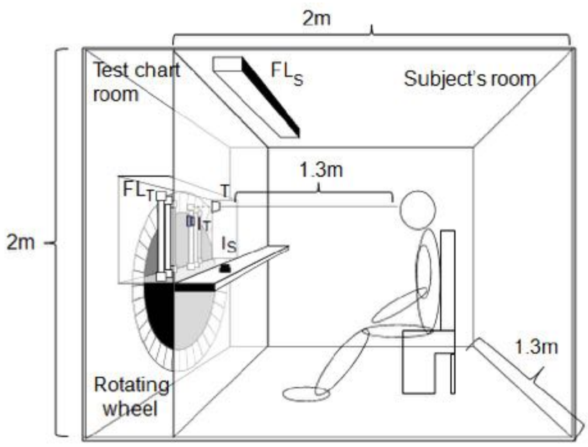

Figure 1 Schematic diagram of the apparatus

2.2 Subjects

Eleven Thai and nine Japanese (age: 22-36) were participated in this experiment. All subjects had normal or corrected to normal visual acuity. All passed Ishihara test to check normal color vision.

2.3 Stimuli and Conditions

Eight Munsell colors (5R, 5Y, 5G, 10B, 5YR, 5P, 5GY, and 10BG) were selected to represent red, yellow, green, blue, orange, purple, greenish yellow and bluish green colors. Each hue consisted of three values/chromas (5/2, 5/5 and 5/8) which was a total of twenty four color chips. The color chips were presented in the different color appearance modes by changing the subject room illuminance and the test room illuminance. The experimental condition was consisted of a combination of two subject room illuminance levels (I_S: 50, and 500 lux) and three test chart room illuminance levels (I_T: 300, 500, and 700 lux).

2.3 Experimental Procedure

The experiment composed of two tasks. One was the color preference score task. Another was color appearance mode task. In the color preference score task, the subjects were asked to rate their color preference on each color according to the categories of like, dislike, or neutral by using a color preference scale. The scale was divided into seven steps from -3 to +3, where -3 means *"most dislike"*, +3 means *"most preferable"*, and 0 means *"neutral"*. In the second task, the subjects were asked to judge the color appearance mode of the color chips whether it appeared as an *"object color mode"*, *"unnatural object color mode"* or *"light source color mode"*. Each subject was asked to complete both tasks. Each task was done in separated session.

To analyze color appearance mode quantitatively, the color appearance mode index (i_{CAM}) was defined by equation (1):

$$\text{Color appearance mode index } (i_{\mathrm{CAM}}) = \frac{-1(N_{OB}) + 0(N_{UN}) + 1(N_{LS})}{N_{OB} + N_{UN} + N_{LS}} \quad (1)$$

where N_{OB}, N_{UN}, and N_{LS} are the numbers of response in the OB-mode, UN-mode, and LS-mode, respectively. If the i_{CAM} is higher than +0.5, the color chip is classified in the LS-mode. On the other hand, if the i_{CAM} is lower than -0.5, the color chip is classified in the OB-mode. An i_{CAM} between -0.5 and +0.5 is classified in the UN-mode.

3. RESULT AND DISCUSSION

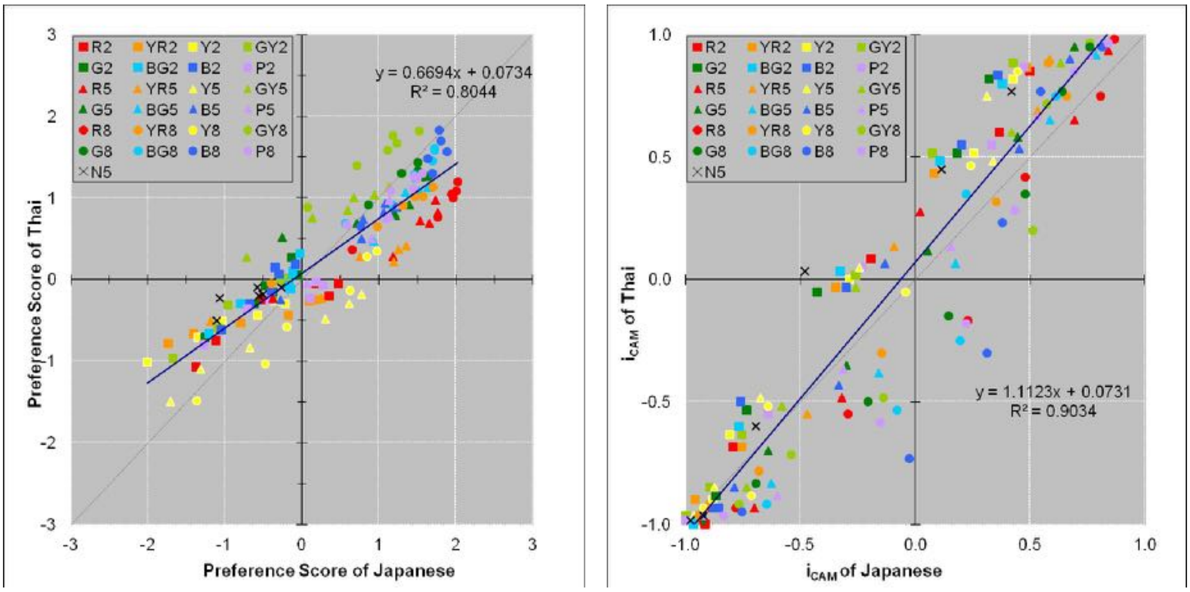

Figure 2 Relationship of results between Thai and Japanese subjects. Square, triangle, and circle represent color chips with chroma 2, 5, and 8, respectively. Left: Color preference score. Right: i_{CAM}.

Relationship of color preference between Thai and Japanese subjects was shown in Figure 2 (Left). The result indicated that Thai and Japanese people had similar color preference as their preference score had positive correlation. Both Thai and Japanese people preferred vivid color (circle symbol) to pale color (square symbol). In this experiment, yellow hue was the least preferred color while blue and red hues were the high preferred colors for both groups.

Figure 2 (Right) showed relationship between color appearance mode perceived by Thai and Japanese subjects. The result showed that both Thai and Japanese subjects perceived each color in similar color appearance mode. There was no strong conflict in color appearance mode. For example, one perceived color in object color mode and the other perceived color in light source color mode.

When color preference of color appeared in each mode were compared, the result of both Thai and Japanese people also showed similar tendency. Color appeared as unnatural object color mode and light source color mode were preferable to those appeared as object color mode as shown in Figure 3. The explanation of this result is that colors appeared in unnatural object color mode and light source color mode contain less blackness than colors appeared in object color mode. The results agreed well with previous work done by our colleague (Tangkijviwat et al (2010a, 2010b)).

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We also found an unexpected result of color preference between the two groups. Thai people preferred cool colors such as green, blue and cyan to warm colors (red and orange), whereas Japanese people preferred warm colors to cool colors. One possible explanation is that country location and climate possibly play an important role in color preference.

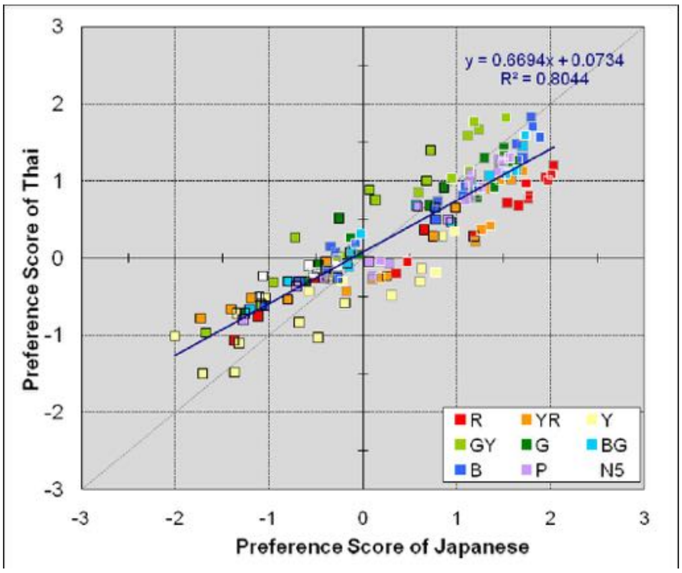

Figure 3 Relationship of preference score between Thai and Japanese subjects was replotted by including result of color appearance mode. Black, gray, and white border represent color appeared in OB, UN, and LS Mode, respectively.

4. CONCLUSION

Compared between Thai and Japanese people, color preference of the two groups was quite similar. Both groups preferred colors appeared as unnatural object color mode and light source color mode to those appeared as object color mode. Vivid colors were more prefer than pale color. Yellow was the least preferable hue for both groups of people.

REFERENCES

Tangkijviwat, U., K. Rattanakasamsuk, and H.Shinoda 2010a Color Preference Affected by Mode of Color Appearance. *Color Research and Application* 35 (1): 50-61.

Tangkijviwat, U., K. Rattanakasamsuk, and H.Shinoda 2010b Modeling Color Preference for Different Color Appearance Modes Based on Perceived Color Attributes. *Optical Reviews* 17 (4): 425-434.

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Categorical color perception in color defective observers -Effect of viewing condition and degree of defect-

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ABSTRACT

Although people with color vision defective are difficult to discriminate certain color combinations, they can classify various color names based on clues in surrounding environment. In this paper, in order to clarify the mechanism of color recognition in color defective people, we investigate how their categorical color perception changes if viewing conditions and clues for color judgment changed and how categorical color perception is influenced by the degree of color deficit. In the experiment, observers made categorical color judgment of color chips by a free sorting task and a categorical color naming method. In addition, conditions showing chips one by one at a time and showing all chips at the same time were compared. We also tested an effect of a color reference for color judgment. As a result, the color categories of ordinary deuteranomals (deuteranomalous trichromats) were almost the same as those of normal trichromats, whereas those of extreme deuteranomals were different in most conditions. It was suggested that the difference in categorical color perception of color defectives from normal trichromats were correlated with the degrees of defect. Furthermore, the clue of colors in surround plays an important role in categorical color perception.

1. INTRODUCTION

A lot of color information is used in our life. However, conventional color design has not considered color vision defectives enough. Therefore, color universal design to take into account color vision defectives should be needed. Various studies (e.g. Brettel et al. 1997) have been performed on the visual characteristics of color vision defective. It is known that ability of color discrimination largely depends on the degree of defect in the case of anomalous trichromat.

Here, color name is important since we treat color by classifying various colors into different color categories in everyday life. This type of perception is called categorical color perception. It has been suggested that dichromats are able to categorize red or green color despite a lack of red-green hue discrimination ability, implying that they use finer difference in color appearance and acquiring color terms for color categorization (Jameson and Hurvich 1978, Montag and Boynton 1987, Komine et al. 2007). We could consider that color vision defectives would determine color name using a variety of clues within colors and surrounding environment. If so, color naming may be influenced by viewing conditions with different levels of clues.

In this study, we investigate how categorical color perception of color defectives would change if viewing conditions and clues for color judgment change. We also examine how the degree of color defect influences categorical color names. First, a free sorting task and a categorical color naming method were compared. Second, two presentation conditions were compared: one presenting color chips one by one at a time and the other presenting all chips at the same time. Third, clue conditions with and without a color reference were compared.

2. EXPERIMENT

2.1 Experimental environment and stimulus

A light box (H228 × W86.5 × D71 cm) for color judgment was placed in a darkroom as shown in figure 1. Fluorescent lamps simulating illuminant D65 was used for light source. Illuminance on the location where color chips were placed was set at 500 lx.

Munsell color chips (7.0×5.5 cm) with 149 different colors were used for color judgment. They were the combinations of ten Hues (5R, 5YR, 5Y, 5GY, 5G, 5BG, 5B, 5PB, 5P, 5RP) and achromatic color (N), Value (2/, 4/, 6/, 8/), and Chroma (/2, /4, … , maximum). Background was covered with N5 gray paper.

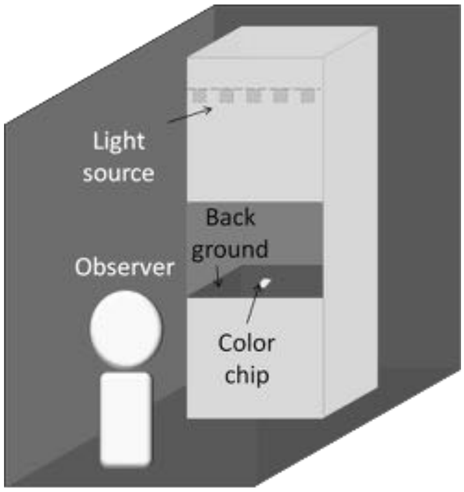

Figure 1 Experimental environment

2.2 Observers

Three normal trichromats and five deuteranomals (three extreme deuteranomals D1, D2 and two ordinary deuteranomals D3, D4, D5) participated. An anomaloscope, Ishihara's tests for color deficiency, panel D-15 and standard pseudoisochromatic plates (SPP) were used for color vision test.

2.3 Experimental procedure

Observers answered color names of 149 Munsell color chips in random order after 5 minutes-adaptation to the light box during one session. Three sessions were conducted in each condition. We tested two following responding methods.

Free Sorting Task (FST) is a task without restriction of the number of color names. Observers divided color chips into different category groups, then assigned color name to each group. The number of groups was not limited and it was possible to leave color groups without color names if observers could not answer.

Categorical Color Naming Method (CCNM) is a method using color names restricted to eleven categories. Observers chose a color name representing the color of a chip the best from 11 basic color names (white, black, red, green, yellow, blue, brown, orange, purple, pink, and gray).

In categorical color naming method, we conducted two conditions; a single observation condition judging chips one by one and a multiple observation condition judging all chips at the same time.

To test the influence of clues in surround, we also conducted conditions with a Macbeth Color Checker as a reference for color judgment. In this condition observers were instructed color names of several patches in the color checker corresponding to one of basic color names orally before the experiment.

3. RESULT AND DISCUSSION

In FST conditions, all observers were able to categorize colors to different groups. However, there were large individual differences and no systematic trend in either the way of grouping or the number of color categories depending on normal trichromats and defectives. Extreme deuteranomals tended to assign chromatic color even to achromatic color chips.

Figure 2 shows the response of color name in CCNM conditions for Value 6 and 4 on Munsell hue circle. In the case of normal trichromats, each symbol shows color name which was answered more than 6 times out of 9 responses from three observers. In the case of ordinary and extreme deuteranomals, it shows the color name answered more than 2 times out of 3 responses. A response of deuteranomals depends on the degree of defect. Color categories of ordinary deuteranomals are almost the same as those of normal trichromats, whereas those of extreme deuteranomals are different in most conditions. Ordinary deuteranomal D1 tends to use gray more than others and extreme deuteranomal D4 shows more green response than normal trichromats.

□red ■green ◆yellow ◇blue △brown ▲orange ×purple ⊠pink ○gray

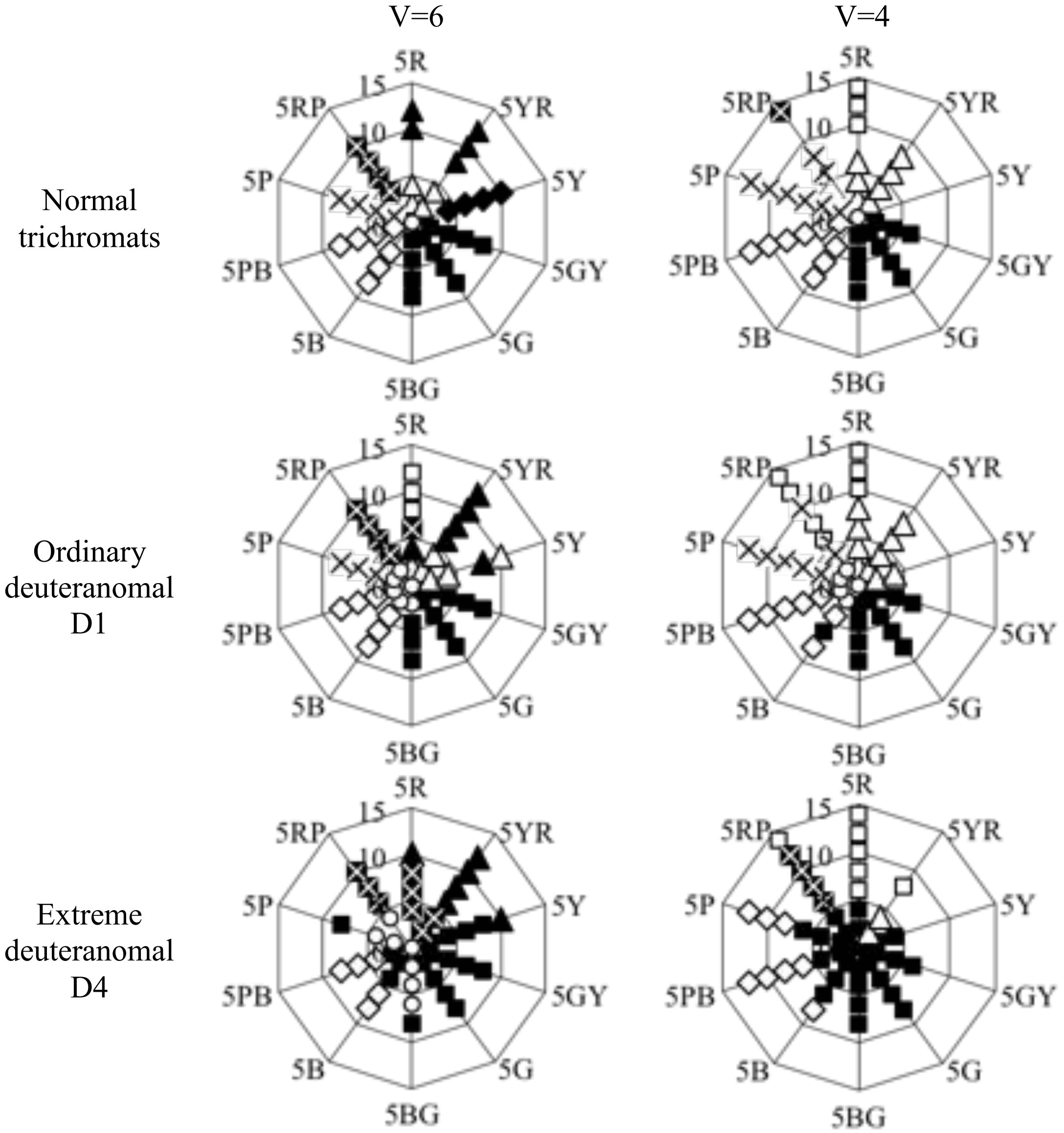

Figure 2 The response of color name for normal trichromats, ordinary deuteranomal D1 and extreme deuteranomal D4 in Value 6 and 4

Next, we compare the results of different conditions. Here, we define the number of color chips that were responded as the same color name for all three judgments as the number of stable color names. Figure 3 shows the number of stable color names for normal trichromats, extreme deuteranomals and ordinary deuteranomals in each condition. Each bar shows the average of each color vision groups and error bars show standard deviations.

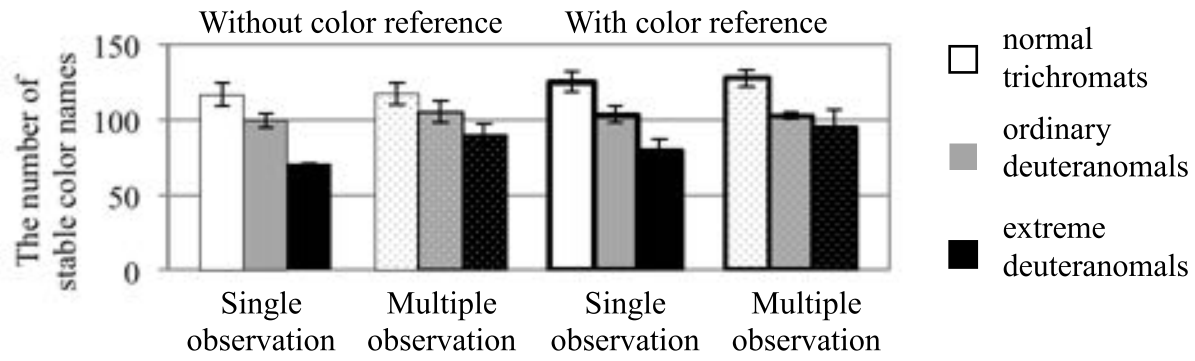

Figure 3 The number of stable color names

In each condition, the number of stable color names of normal trichromats is larger than that of color vision defectives. The number of stable color names for extreme deuteranomals increases under multiple observation condition and condition with color reference. These results suggest that the response of extreme deuteranomals was more stabilized and closer to the response of normal trichromats. The clue of colors in surround would help the judgment of categorical color.

4. CONCLUSION

It was shown that difference in categorical color perception of observers with color defective from normal trichromats was correlated with the degrees of defect. The color category of normal trichromats and ordinary deuteranomals do not depend on viewing conditions, whereas those of extreme deuteranomals are different. Thus, the clue of colors in surround plays an important role in categorical color perception of extreme deuteranomals.

REFERENCES

Brettel, H., F.Vienot, and J. D. Mollon, 1997. Computerized simulation of color appearance for dichromats. *J. Opt. Soc. Am. A* 14 (10): 2647-2655.

Jameson, D., L. M. Hurvich, 1978. Dichromatic color language: “Reds” and “Greens” don’t look alike but their colors do. *Sensory Processes* 2: 146-155.

Montag, E. D., and R. M. Boynton, 1987. Rod influence in dichromatic surface color perception. *Vision Research* 27 (12): 2153-2162.

Komine, H., K. Shinomori, and S. Nakauchi, 2009. Representation of color naming category boundaries on dichromats along their confusion loci using a chromatic-opponent channel model. *Journal of Vision* 9 (8): 321.

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The Relativity between Color Imagery and Harmony of Color-Apparel Images in Yellow Series of Color Combinations

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ABSTRACT

The relativity between color imagery and harmony of 23 samples of fashion color-apparel images having various color combinations accumulated in this study was investigated. The visual assessment experiments were divided into two sections I and II to estimate color imagery and color harmony for each color-image specimens tested under a dark room. The experimental results indicate that there exists a significant relativity between color imagery and color harmony, with the exception of the Potency color-imagery factor.

Keywords: color imagery, color harmony, color combination, color-apparel image

1. INTRODUTION

Color has been as an important role in human life since ancient, and so far, a lot of efforts of working on color have also been completed. But, all systematical studies on color have just started for several centuries. Meanwhile, color colorimetry has long had the purpose of measuring color or estimating or predicting color difference for more than eight decades since 1931. And, it is also able to be employed in specifying a color by color coordinate or color appearance, but not in indicating one by harmony or color imagery. The latter had been further studied since 1956 at the Budapest Technical University (Nemcsics 2007: 477) or 1980's by Kobayashi (1981: 93), and there were advanced theories of color harmony or color imagery also subsequently proposed, for example: Szabo et al. (2009:34), Kuo and Kuo (2000: 137) and Kuo (2007: 463). Furthermore, following those theories, a lot of researches were carried out and published during the past decade, such as Ou and Luo (2004: 232), Xin et al. (2004: 451), Solli and Lenz (2011: 210), Ou et al. (2011: 355), etc.

The color imagery scales or spaces have been discussed for over three decades since those proposed by Nippon Color and Design Researchers Institute (abbreviated as the NCD) (Kobayashi 1981: 93) while the color harmony systematically investigated since 1956 at the Budapest Technical University. However, it is still doubted whether there exists any relationship between assessment results of both experiments using color-combination samples in color imagery and harmony respectively or not. Therefore, an experiment containing two sections that one had the apparel image samples assessed by observers in color imagery while the other in color harmony was conducted to discuss and verify it in this study.

2. EXPERIMENTALS

There were 169 pairs of semantic differential words accumulated from the latest Chinese dictionary issued by the West-North Publication Co. and other related studies and writings (Kuo 2007: 463), and used in this study. These pairs of semantic differential words were further classified into 66 groups, and those in the same group had the same or similar meaning. Moreover, a specific semantic differential pair of words among those in the same group was chosen as the representative one for this group, and totally a set of 66 independent pairs of semantic differential words were obtained and used in the psychophysical experiments of scaling color imagery in this study.

In the visual assessment experiments of scaling color imagery and color harmony in section I and II separately, 23 color-image specimens in yellow series of fashion apparel images having a large size of 3×3 square inch that subtends 10^0 at the observer's eye were used. Every sample was assessed by a panel of sixteen (for the color-imagery assessment experiment) and twenty-six (for the color-harmony one) observers, the former including seven female and nine male while the latter eleven female and fifteen male, and all of them being within the age of 20 and 35 using a psychophysical method combined both magnitude estimation method and semantic differential method. In addition, each observer had taken two-hour training to be familiar with the procedure of this psychophysical experimental method, and her / his color discrimination ability of vision been examined employing the color flags of Munsell 100 hue tests before performing the visual assessment experiments. The procedure of this psychophysical visual assessment experiment using the color imagery scale in semantic differential pair of words was described by Kuo (2007: 463).

3. RESULTS AND DISCUSSION

3.1 Observer variation

In this study, a series of color-imagery or color-harmony assessing experiments were carried out under a dark room using the magnitude estimation method. The coefficient of variation (CV%) proposed by Coates et al. (1981: 179) was used to indicate the observer variation, and can be calculated used the following equation:

$$CV(\%) = 100[\sum(x_i - y_i)^2 / n]^{1/2} / \tilde{y},$$

where n is the number of samples in x_i and y_i sets of data, and $\tilde{y}$ is the mean value of the y_i set data. The larger the value of CV is, the worse the agreement between the two sets of data compared. For a perfect agreement, the value of CV should be zero. The results show that a general stability can be found for the visual results, i.e. the total mean values of 53 and 79 in CV unit for the assessments of color-imagery and color-harmony respectively. And, it is obvious that the stability of the observers in assessing color-imagery or color-harmony is less or equal to that for those experiments of color appearance or color difference assessment (Luo et al. 1996: 412; Kuo and Luo 1996: 312).

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3.2 The relativity between color imagery and harmony

The experimental results obtained from the series of color-imagery or color-harmony assessing experiments described above were further employed to estimate the relationship between color imagery and color harmony. And, the values of visual color harmony for the yellow series of samples tested were plotted against those of each color-imagery axial factor for those corresponding ones. The results indicate that as shown on Figures 1~3, color harmony has good and positive relativity with the Evaluation color-imagery factor Beautiful-Ugly (abbreviated as B) while negative one with the Activity color-imagery factor Complex-Simple (abbreviated as C). But, there exists no significant relationship between color harmony and the Potency color-imagery factor Heavy-Light (abbreviated as H).

4. CONCLUSIONS

In this study, 23 color-image specimens in yellow series of fashion apparel images having a large size of 3×3 square inch that subtends 10^0 at the observer's eye were used. The visual assessment experiments were divided into two sections I and II to estimate color imagery and color harmony for each color-image specimens tested under a dark room. The results indicate that there exists a significant relativity between color imagery and color harmony, with the exception of the Potency color-imagery factor.

ACKNOWLEDGMENTS

Special thanks are due to the financial assistance from the National Science Council in Taiwan. And, particular thanks are also due to all observers taking part in the visual assessment experiments.

REFERENCES

Nemcsics, A., 2007, Experimental determination of laws of color harmony. Part 1: harmony content of different scales with similar hue, *Color Research and Application* 32 (6): 477~488.

Kobayashi, S., 1981, The aim and method of the color image scale, *Color Research and Application* 6: 93-106.

Szabo, F., Bodrogi, P. and Schanda, J., 2009, Experimental modeling of color harmony, *Color Research and Application* 35 (1): 34~49.

Kuo, W. G. and Kuo Y. C., 2000, The Investigation on the Relationship between DRP Color Image Scale and CIEL*a*b* Color Space, *Proceedings of the Conference on the Color Application and Color Science in 2000*: 137~144.

Kuo, W. G., 2007, The Feasibility of Establishing New Colour Image Scales Using the Magnitude Estimation Method, *Color Research and Application* 32 (6): 463~468.

Kuo, W. G., Lee, C. K., Wei, Y. C. and Huang, Y. Y., 2011, Effect of different sample patterns on color harmony, *Proceedings of 12th International Conference on Color Design, Application and Science in 2011*: 187~194.

Ou, L. C., Luo, M. R., Woodcock, A.,Wright, A., 2004, A study of colour emotion and colour preference. Part I: Colour emotion for single colours, *Color Research and Application* 29: 232~240.

Xin, J. H., Cheng, K. M., Taylor, G., Sato, T. and Hansuebsai, A., 2004, Cross-regional

comparison of colour emotion Part I: Quantitative analysis, *Color Research and Application* 29: 451~457.
Solli, M. and Lenz, R., 2011, Color emotions for multi-colored images, *Color Research and Application* 36 (3): 210~221.
Ou, L. C., Chong, P. and Luo, M. R., 2011, Additivity of color harmony, *Color Research and Application* 36 (5): 355~372.
Torgerson, W. S., 1958, *Theory and Methods of Scaling,* John Wiley & Sons, New York, USA: 205~246.
Coates, E., Fong, K. Y. and Rigg, B., 1981, '*Uniform Lightness Scales,*' J.S.D.C. 97: 179-183
Luo, M. R., Lo, M. C. and Kuo, W. G., 1996, The LLAB(l:c) Colour model, *Color Res. Appl.* 21: 412-429.
Kuo, W. G. and Luo, M. R., 1996, Methods for quantifying metamerism. Part I – visual assessment, *J. Soc. Dyers Colour.* 112: 312-320

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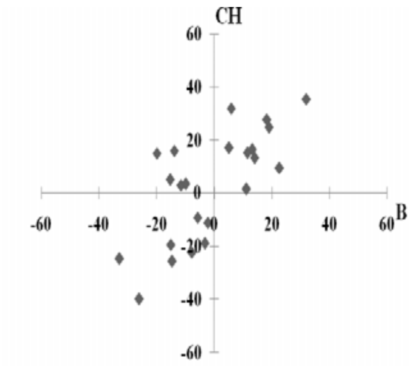

Figure 1 Color harmony (CH) of experimental samples plotted against the color imagery factor B (Beautiful - Ugly)

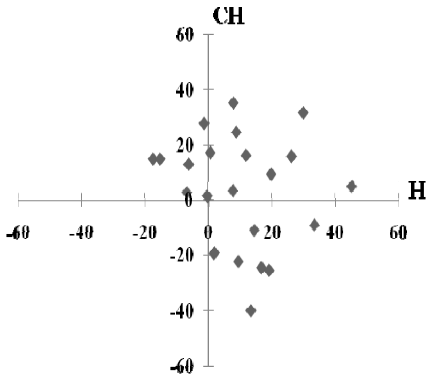

Figure 2 The same as Figure 1, but against the color-imagery factor H (Heavy- Light)

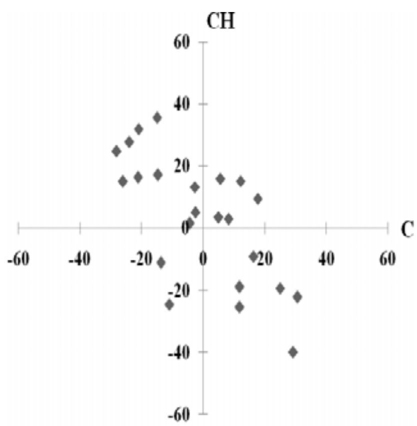

Figure 3 The same as Figure 1, but against the color-imagery factor C (Complex- Simple)

Preference for Product Color Combinations
- Differences in constructing color numbers -

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ABSTRACT

The author conducted two experiments in which subjects rated color-simulated product images. These experiments utilized similar procedures, but the number of areas in which colors were changed differed: two for the first experiment and three for the second. The first principal component, derived from principal component analysis using mean values of ratings, shows high values: 74% for the first experiment and 70% for the second. These results suggest small differences in color combination preference among products. These results are different from the past study dealing with one color products. The preference of color combination depends mainly on the colors used. Combinations containing high-value colors show high values, while patterns containing high-saturation colors show low values. This result suggests that color tone more strongly influences preference, rather than color difference or similarity of hue or tone among colors used.

1. INTRODUCTION

A study on product color preference was presented at the AIC Interim Meeting in 2008. In that study, subjects reported their preferences for product images in which various colors were interchangeably used in a color area covering the entire area of the product. The data obtained showed that people tend to prefer light blue, red, or black personal products (purses, glasses, etc.) over general use products (air conditioners, sofas, etc.) of the same colors. The opposite tendencies, people prefer general use products over personal products, were obtained when white or beige was used.

In the present study, two experiments were conducted using products with multiple color areas. The purpose is to determine the differences and tendency in the preference of color combination.

2. EXPERIMENT

The products in the first experiment had two color areas. Four hundred product images, all combinations of twenty-five color patterns and sixteen products, were displayed on a screen using a liquid crystal projector. The second experiment used products with three color areas, utilizing the combined images of fourteen products (including an abstract image) and forty color combinations. The latter colors were representative of various sample clusters obtained by a cluster analysis of the color difference data of 637 product images collected from websites.

Thirty female students in the first experiment and forty in the second rated each product using a seven-point scale.

3. RESULT

3-1. The preference tendency difference among items

In the first experiment, the contribution of the first principal component, derived from principal component analysis of the mean values of ratings, was 74%. The value obtained in the second experiment was also high, more than 70% (Table 1).

Table 1. Principal components

(1)Experiment 1

	Item	Image	Prin 1	Prin 2	Prin 3
A	Sofa		0.89	-0.19	-0.16
B	Punch		0.96	-0.17	-0.07
C	Muffler		0.84	0.32	-0.11
D	Paper shredder		0.90	0.01	-0.09
E	Pencil case		0.92	0.15	-0.21
F	Commuter-pass case		0.93	-0.10	0.03
G	Basket		0.91	-0.04	0.15
H	Pouch		0.85	-0.30	0.28
I	Tie		0.76	0.33	0.40
J	Magnet		0.87	-0.32	0.21
K	Bowl		0.77	0.26	-0.01
L	Cap		0.85	0.28	0.04
M	Knit hat		0.77	-0.07	-0.44
N	Tote bag		0.89	0.12	-0.12
O	Clip		0.76	-0.48	0.00
P	Socks		0.89	0.24	0.13
	Contribution (%)		74.4	6.0	3.9

(2)Experiment 2

	Item	Image	Prin 1	Prin 2	Prin 3
A	Apron		0.88	-0.11	0.06
B	Towel		0.85	-0.16	0.04
C	Mouse		0.88	-0.23	0.08
D	Sneakers		0.81	0.18	0.25
E	Handcream		0.89	0.16	-0.03
F	Pot		0.83	0.17	-0.20
G	Refrigerator		0.89	-0.17	-0.12
H	Travel bag		0.83	-0.03	-0.37
I	Handbag		0.86	-0.12	0.37
J	Legless chair		0.83	-0.34	0.28
K	Book		0.51	0.81	0.15
L	Printer		0.88	-0.08	-0.21
M	Keyboard		0.81	0.04	-0.30
N	Abstract pattern		0.92	0.21	0.05
	Contribution (%)		70.47	7.47	4.61

These results indicate small preference differences among products having the same color pattern. It suggests that product category (private use or general use, material categories, etc.) and composition of color area (lines in large area, houndstooth check, etc.) do not significantly influence the ratings.

The “book” in experiment two was the only exception to this tendency. The preferred colors were different from that of other items of similar brightness combination. In this case, the legibility of letters seemed a strong consideration.

3-2. The preference tendency difference among color patterns

To explain the preference scores, I executed regression analysis using dummy variables for each item and color combination. The regression coefficients of color combinations derived from the analysis are shown in figures 1 and 3.

The high-value patterns in figure 1 contain one or two high-brightness and low-saturated colors. Middle-value patterns consist of middle-brightness and middle-saturated colors. Low values were obtained for combinations containing at least one highly saturated color.

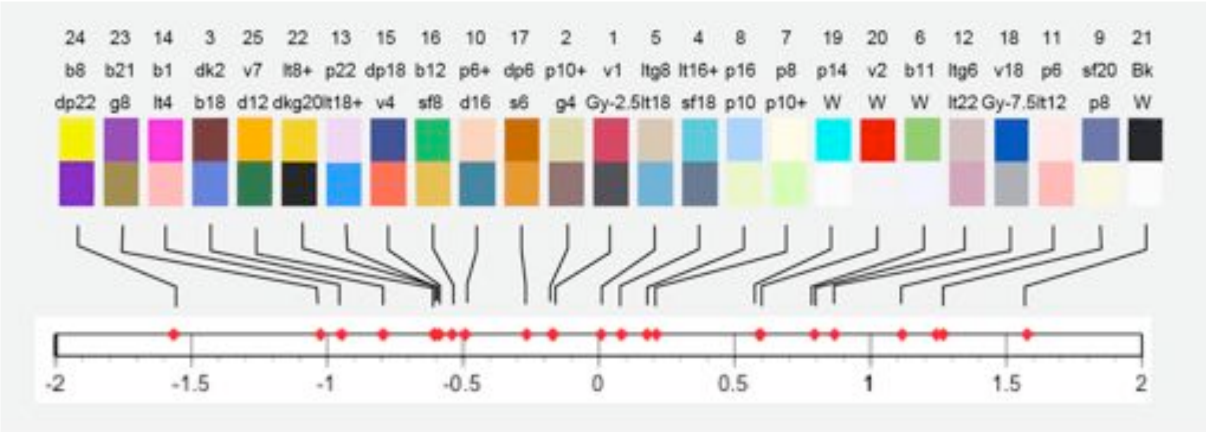
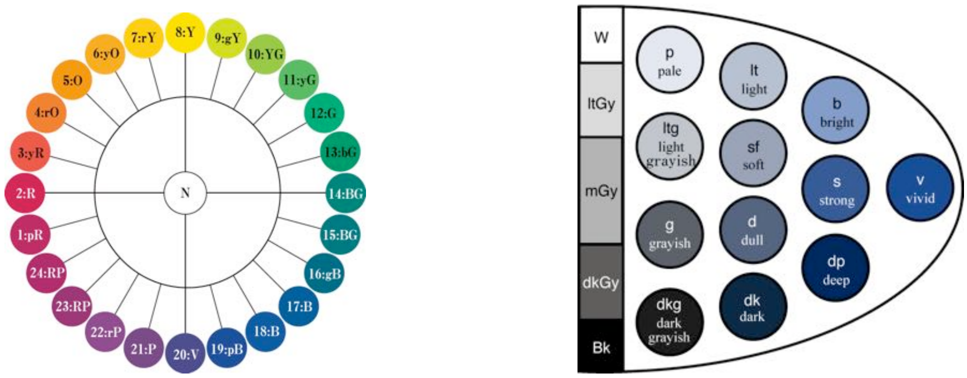


Figure 1. Regression coefficients of color patterns (Experiment 1)



(1) P.C.C.S. Hue *(2) P.C.C.S. Tone*

The codes in figures 1 and 3 (ex. b8, dp22) indicate the nearest color in the P.C.C.S. The selecting activity was executed by experimenters using the P.C.C.S. color chart.

Figure 2. The concept of the Practical Color Co-ordinate System

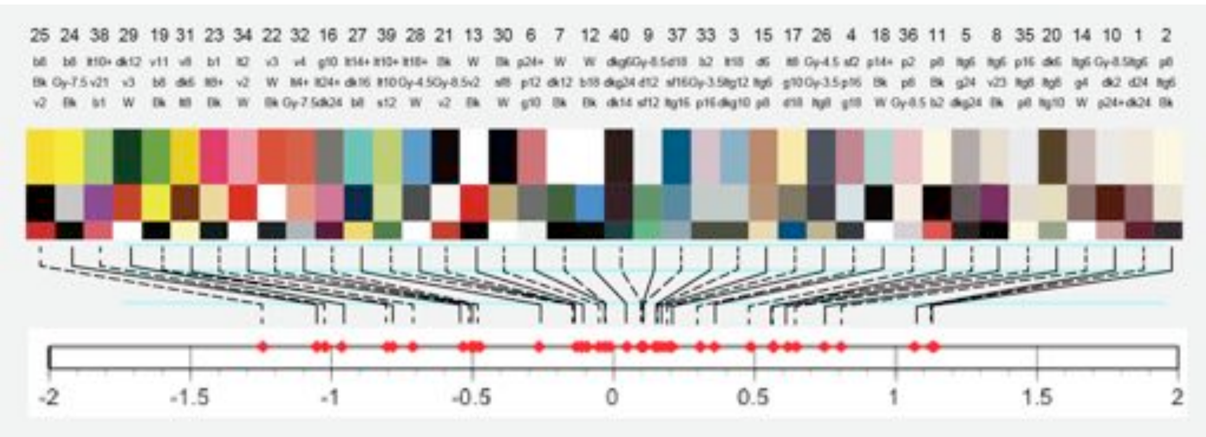


Figure 3. Regression coefficients of color patterns (Experiment 1)

These tendencies were maintained for experiment two. Patterns including a high-brightness and low-saturated color for the largest area obtained high values; those including a middle-brightness and middle-saturated color for the largest area obtained middle values; and those including a high-saturated color for the largest area obtained low values. Patterns using white or black for the largest area obtained middle values. The colors for the largest area show large influence to the preference ratings.

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4. DISCUSSION

The preference tendency for products with multiple color areas differs from that for products with a single color area; the rating differences among products are small. Moreover, no results were obtained regarding the preference differences between personal products and general use products. The constructing color numbers of product have a great influence on preference judgment on these two points.

The order of preference is strongly influenced by the actual colors used as components in a particular combination, rather than the relationships among the component colors, such as in a combination of similar or contrasting colors. Thus, theories on color harmony for products should focus on the component colors themselves.

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REFERENCES

Maki, K., S. Kitamura. 2008. Preference for product color - Dealing with the evaluation differences among presentation methods - . Proceedings of the AIC Interim Meeting, Stockholm, 237-238.

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Effect of Ambient Illumination on Color Preference

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ABSTRACT

A color of object not only was observed under white illumination, but also various colored illuminations. This study, hence, was carried out to explore the influence of ambient illumination on color preference. Eight color chips and one achromatic color chip chosen from the Munsell notation were presented under various ambient illumination conditions that consist of reddish, greenish and white illuminations. The empirical evidence indicated that color preference was inconstant when the colors are viewed under colored illumination. We concluded that a colored illumination has an effect on color preference. In addition, we found that color illumination had a small effect on color preference in the light source color mode.

1. INTRODUCTION

It is well known that color is one of the critical factors influencing customer's satisfactory; an understanding of color preference is thus important in many fields, for instance, product design, advertisings, marketing, lighting designs and so on. Color preference indicates whatever a color or color combination is preferred by a group of viewers. It was also referred to as an estimate for the pleasantness of a color so that the color preference is a powerful tool to attract a subject's attention and to arouse the desire to consume. Studies on color preference have long focused on the hue effect; what colors were generally preferred and what colors were not. Many researchers have attempted to deal with color preferences and their variations as a function of age, gender, geographical region, culture, and circumstances (e.g., Guilford, 1934; Eysenck, 1941; Guilford and Smith, 1959). Along with the aforesaid variations, color preference also depends on illumination. Much of the earlier work dealing with color preferences has failed to observe colors under white illumination. In our daily life, color is observed under plenty of ambient illuminations. For instance, the color of interior design at restaurant and products at department store are viewed under colored illumination. Is there consistency in color preference on different illumination? The major aim of this work, hence, is to investigate the relationship between color preference and ambient illumination.

2. EXPERIMENT

As shown in Figure 1, the apparatus was composed of subject's room and test chart's room separated by a wall having a 1^o square aperture. The subject's room was 1.3 x 2 x 2 m^3 (W x L x H) and a wall inside the room was covered with wallpaper of about N9 and illuminated by two set of adjustable fluorescent lamps. The one set is of two daylight lamps covered by colored filter and the other ones is of one uncovered lamp. The intensity of the lamps was adjusted by a light controller and the room illuminance was measured by an illuminometer placed on a shelf below the test stimulus at a distance of 44 cm. Many objects such as artificial flowers, dolls, books were put into this room. Color patches to serve as the test stimuli were attached to a rotating wheel placed in test chart's room. They were illuminated by daylight fluorescent lamps. The subject sat in subject's room and looked at them through the aperture from a distance of 1.3 m.

Color stimuli were selected from four chromatic elementary hues and four intermediate hues between them and one achromatic. The appropriate Munsell colored papers for presenting them were 5R 4/14, 5YR 6/14, 5Y 8/14, 5GY 6/10, 5G 3/10, 10BG 4/9, 10B 4/10, 5P 4/10, and N5. All of them were observed under seven illuminations (three reddish and greenish illuminations and white illumination). It was namely RI_1, RI_2, R_3, GI_1, GI_2, GI_3, and WI. The experimenter randomly adjusted illumination condition in the real room. For reasonably perceiving different color appearance mode, the illumination condition was kept constantly at 50 lx in subject's room and 700 lx in test's chart room for perceiving color in light source color mode and at 100 lx in subject's room and 30 lx in test's chart room for perceiving color in object color mode.

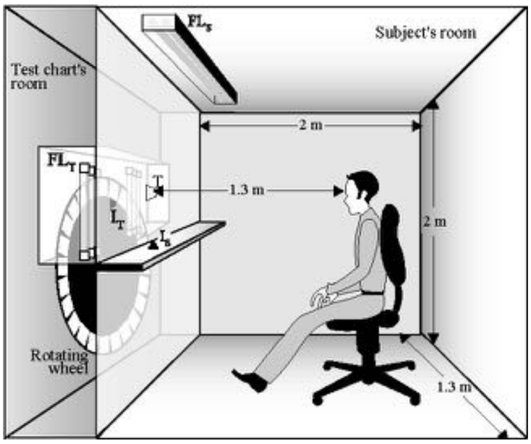

Figure 1. Schematic diagram of the apparatus.

In the experiment, the subject engaged in three tasks. First, the subject were asked to rate the degree of color preference for each given color by using the scale which was divided into 7 levels, as -3 (dislike) to +3 (like). Second, subjects were asked to perform elementary color naming on the basic of the NCS color system. In the last one, subject judged the color appearance mode. The subject was instructed to look around and not stare at the color chip during evaluation. One session is composed of 9 color patches observed under 16 illumination conditions. Each session had 5 times of repetition.

3. RESULTS AND DISCUSSIONS

Figure 2 shows the average of color preference score of N5, 5R 4/14, and 5G 3/10 in reddish and greenish illuminations. The abscissa represents to x and y value of CIExy color space and the ordinate represent to color preference score. The opened symbol denoted a color chip appearing in light source color mode (LS mode) and the other denoted that appearing in object color mode (OB mode). The color appearance mode of each color chip was quantitatively expressed using the color appearance mode index, i_{CAM}. This index was determined using the following equation:

$$\text{Color appearance mode index } (i_{CAM}) = \frac{-1(N_{OB}) + 0(N_{UN}) + 1(N_{LS})}{N_{OB} + N_{UN} + N_{LS}} \qquad (1),$$

where N_{OB}, N_{UN}, and N_{LS} are the numbers of responses in OB mode, UN mode, and LS mode, respectively. If $i_{CAM} \geq 0.5$, the color chip was classified as the LS mode. On the other hand, if $i_{CAM} \leq -0.5$, the color chip was classified as the OB mode. An i_{CAM} between -0.5 and +0.5 was classified as the UN mode.

The result in reddish illumination condition showed that the color preference score in LS mode has a small change when the subject's room was redder. On the contrary, the score in OB mode started to decrease and then grew up except the score of 5R 4/14. In the greenish illumination condition, the score in LS mode resulted as same as the result in reddish illumination condition except the score of 5G 3/10 whereas the score in OB mode decreased when the room was greener. The same tendency occurred on the most of color patches. Regarding the result in OB mode, the color of chips that were opposite to the color of illumination would be improved. This feature implied that a colored illumination has an influence on a color preference. An increase in color preference might be explained by color constancy. Hence, a perceived color attribute was investigated.

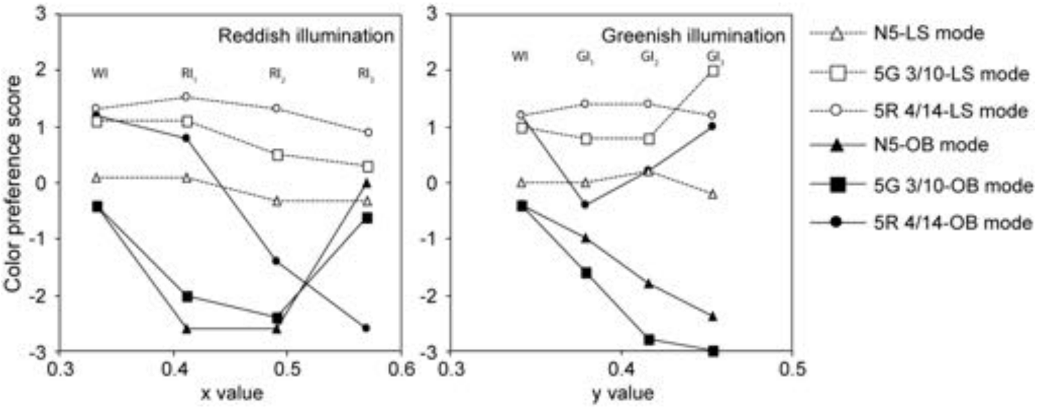

Figure 2. Mean color preference score of red, green, and gray color patches observed under reddish and greenish illuminations.

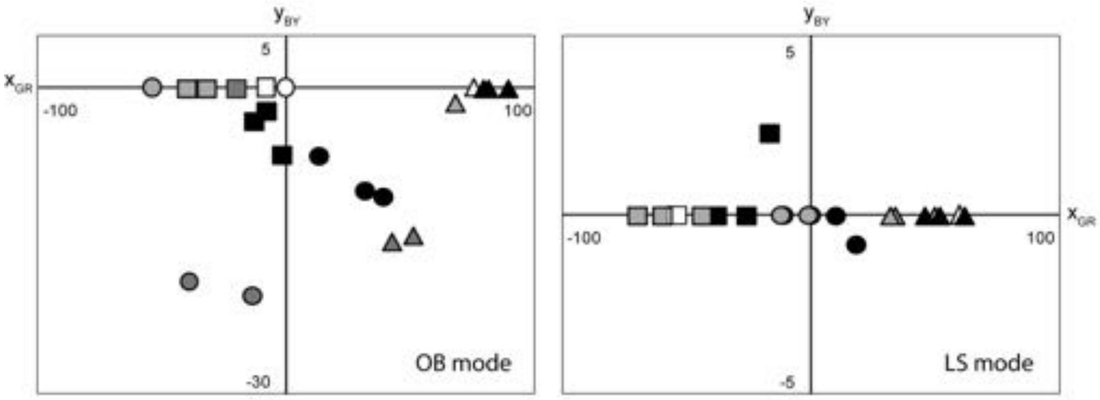

Figure 3. Results for perceived hue coordinates of N5 (circle), 5R 4/14 (triangle), and 5G 3/10 (square) classified into 3 illumination conditions (white, WI; gray, RI; black, GI).

Figure 3 showed the result of the perceived hue coordinates obtained from elementary color naming. The abscissa represents the x_{GR} values and the ordinate, the y_{BY} values. The outermost axis corresponds to a perceived chromaticness. The position of a point is expressed using the perceived hue coordinates (x_{GR},y_{BY}), and is represented by the following equation:

$$x_{GR} = \begin{Bmatrix} R \times C_P \\ (-1)G \times C_P \end{Bmatrix} \times \frac{1}{100}, \; y_{BY} = \begin{Bmatrix} Y \times C_P \\ (-1)B \times C_P \end{Bmatrix} \times \frac{1}{100} \qquad (2),$$

where *R, G, B,* and *Y* are the amounts of the perceived red, green, blue, and yellow, respectively and C_P is the amounts of perceived chromaticness. As shown in Figure 3, a color chip appeared greener in the reddish illumination, whereas it appeared redder in the greenish illumination. For instance, a gray color chip appeared gray under white illumination (○) and transformed to greenish under reddish illumination (●) and to reddish under greenish illumination (●). Besides a change of perceived hue, a perceived chromaticness of color patches is also changeable. This feature implied that the reddish illumination gave the green patch more saturation and the greenish illumination gave the red patch more saturation. Most of previous study claimed that a vivid color was preferred to grayish color. This feature occurred in both color appearance modes. This result corresponds to the RVSI concept expressed by Ikeda *et* *al.*(2002). An increase in color preference score of green patch and red patch in Figure 2 might be yielded from the effect of color constancy.

In the addition, the result in different color appearance mode was reported. The scores of LS mode were higher than that of OB mode. The result agrees well with our previous studies (Tangkijviwat et al., 2010). However, the color preference in different color appearance mode might be to meet together at some point when a room was illuminated by colored lamp.

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5. CONCLUSION

In present study, a color patch was assessed on various colored illumination. Findings showed that the color appearing in object color mode which have a color opposite to a color of illumination were found to give an improving color preference. Although colored illumination has an influence on color preference, this effect does not strong in light source color mode. Color preference might be constant when a color appearing in light source color mode. Colors in our daily life are never viewed in white illumination only. This study, therefore, attempts to contribute to the preference response for colors in different colored illumination. The results of the study may be used in design application such as interior design, product design, advertising board, etc.

This study has focused on how the ambient illumination affects color preference. The results of this study obtained from a small number of subject and color patch. Thus, more subjects and color patches will be recruited for improving the results.

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REFERENCES

Eysenck, H. J. 1941. A critical and experimental study of colour preferences. *American Journal of Psychology* 54: 385-394.

Guilford, J. P. 1934. The affective value of color as a function of hue, tint and chroma. *Journal of Experimental Psychology* 17: 342-370.

Guilford, J. P. and Smith, P. C. 1959. A system of color preferences. *American Journal of Psychology* 72: 487-502.

Ikeda, M., Mizokami, Y., Nakane, S., and Shinoda, H. 2002. Color appearance of a patch explained by RVSI for the conditions of various colors of room illumination and of various luminance levels of the patch. *Journal of Optical Review* 9:132-139.

Ou, L. C., Luo, M. R., Woodcock, A., and Wright, A. 2004. A study of colour emotion and colour preference. Part III: Colour preference modeling. *Journal of Color Research and Application* 29: 292-298.

Tangkijviwat, U., Rattanakasamsuk, K., and Shinoda, H. 2010. Color preference affected by mode of color appearance. *Journal of Color Research and Application* 35: 50-61.

Tangkijviwat, U., Shinoda, H., and Rattanakasamsuk, K. 2010. Modeling color preference for different color appearance modes based on perceived color attributes. *Journal of Optical Review* 17: 452-434.

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Sensibility Factors of Single Colors for Product Design

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ABSTRACT

This study was conducted to identify general sensibility factors for single colors needed in current product design based on exclusive sensibility word selection and systematic clustering method. A wide range of vocabularies that reflect psychological characteristics of colors in everyday situation were collected from literature searches, and categorization experiments on 30 non-professionals and professionals were performed to clusterize 160 vocabularies extracted from fitness evaluation procedures. In the main experiments, 30 untrained subjects evaluated 35 single colors using 43 sensibility words derived from cluster analysis. Factor analysis has revealed main sensibility factors of "lively-elegant" and "natural-unique", and this result well reflects the keywords of contemporary product design.

1. INTRODUCTION

Many studies have been done on sensibility factors of single colors. The representative literatures include studies by Wright and Rainwater (1962), Hogg et al. (1979), Kobayashi (1981), Sato et al. (2000), Park (2002), and Ou et al. (2004). Various sensibility factors have been extracted from these studies, however, derived factors varied according to the evaluation scales developed for the respective research purposes. This study aims to characterize practical sensibility factors that well fit design concepts and serve well for product designers' sensibility word selection tasks. To extract expanded range of vocabularies on single color sensibility compared with previous studies, this research was conducted according to the following procedures.

After performing vocabulary survey on single color sensibility, sensibility words were selected through categorization research, evaluation scales were developed through SD method, and subjective assessment experiments on single colors were conducted. Main factors were yielded through factor analysis, and sensibility words were located within the single color sensibility space.

2. METHODS

2.1 Sensibility word extraction

Primary selection of vocabulary

850 color related sensibility words were collected from the literatures above and specialty books and magazines from various design or color related fields. Idioms and idiomatic phrases were also included in the selection. After the initial selection, redundant words were excluded and similar words were combined, and then a survey was conducted on color design students, psychologists, and color design professionals. In the survey, subjects were asked to choose vocabularies that showed high relation to color. As a result, 230 words were screened based on the high frequency criteria.

Fitness evaluation

Color sensibility fitness evaluation was performed on the primary selection of 230 adjectives on non-experts and color or design experts. Subjects were a total of 475 people: 364 non-professionals and 111 professional men and women. The survey was created with 230 adjectives and 7-step evaluation scales. For example, if the adjective “light” seemed appropriate for illustrating feeling, emotions, notions associated to the given color, subjects were to check “7”, and if not appropriate, to check “1”.

From the respective survey results of the non-professional group and the professional group on 230 adjectives, adjectives with mean evaluation higher than the overall mean and with high frequency values were selected. The selection consisted of 106 adjectives from the non-professional group, and 135 adjectives from the professional group. Adjectives chosen from the two groups were compared and reviewed by psychologists and color scientists, and were repeatedly screened several times based on fitness for sensibility word extraction for product design. 160 sensibility words were finalized.

Table 1. 43 sensibility words extracted from cluster analysis.

Words extracted from cluster analysis			
mild	exotic	natural	masculine
cool	strong	stylish	luxurious
soft	unique	elegant	charming
pure	sturdy	delicate	eco-friendly
cute	cheery	dynamic	traditional
neat	lovely	hopeful	interesting
deep	casual	classic	high-tech
retro	mature	cheerful	mysterious
light	simple	romantic	sophisticated
clean	sensual	modern	unconventional
bright	modest	emotional	

Categorization research

30 participants (17 non-professionals /13 professional psychologists) were asked to classify the 160 selected words based on color sensibility similarities. Each group had to contain at least 2 words, and no more than 20 words. The entire list of 160 words or words in each group could be viewed and replaced at all times. Participants were asked to make careful consideration before classification. The survey took approximately 1 hour.

Similarity matrices were derived from the categorization research data. The similarity value between two words in the same group was formulated so that its value would increase when the number of other words in the same group grew smaller (Park, 2002). A similarity matrix for a single participant is calculated as follows: a similarity value for pairs located outside of the diagonal is defined as 100 / (k × ${}_nC_2$), and pairs on the diagonal will be assigned a similarity value of 10. K here indicates the number of group (= 30), and n indicates the cluster size the two words were together contained. (Therefore, ${}_nC_2$ is the number of the pairs between group members). The whole similarity matrix is a sum of all participants' similarity matrices.

With these similarity matrices, cluster analysis was conducted so that the cluster would number to 30, 40, and 50. Comparison of the analysis results showed that clustering results from 40 clusters best clusterized the vocabularies. 1~2 words were selected from 40 clusters respectively, and finally, 43 words were extracted (see Table 1). Vocabularies were selected so that words from the same group would not overlap in their meanings, would well represent the group, and would be highly related to color. 43 words were utilized for the sensibility evaluation on color.

Table 2. Specifications of the 35 color samples.

Sample	Tone	Hue	L^*	a^*	b^*	C^*	h
1	Pale	Red	85.3	5.7	2.7	6.3	26
2		Orange	90.1	3.3	12.6	13.0	75
3		Yellow	90.2	-2.1	16.5	16.6	97
4		Green	85.4	-12.7	6.8	14.4	152
5		Blue	80.5	-1.6	-5.7	5.9	254
6		Purple	80.5	4.2	-3.1	5.2	323
7	Lignt+	Red	77.0	34.7	10.2	36.2	16
8		Orange	85.7	13.9	38.1	40.6	70
9		Yellow	91.6	-1.4	48.7	48.7	92
10		Green	80.0	-22.9	8.6	24.4	159
11		Blue	69.4	1.8	-29.7	29.7	274
12		Purple	71.6	23.4	-16.7	28.8	324
13	Vivid	Red	45.6	60.4	24.4	65.2	22
14		Orange	70.6	42.0	63.7	76.3	57
15		Yellow	83.4	11.0	78.3	79.1	82
16		Green	56.4	-56.7	24.9	61.9	156
17		Blue	45.4	0.5	-44.7	44.7	271
18		Purple	35.4	41.6	-30.7	51.7	324
19	Dark	Red	25.1	28.1	8.1	29.2	16
20		Orange	35.4	14.0	33.3	36.1	67
21		Yellow	40.7	0.7	37.8	37.8	89
22		Green	30.5	-22.1	9.3	24.0	157
23		Blue	20.3	-0.7	-22.2	22.2	268
24		Purple	20.2	19.0	-14.7	24.1	322
25	Grayish	Red	40.7	9.8	3.8	10.5	21
26		Orange	45.8	5.0	11.3	12.4	66
27		Yellow	45.9	-0.7	14.1	14.1	93
28		Green	40.8	-9.9	4.6	11.0	155
29		Blue	35.6	-1.1	-8.7	8.8	263
30		Purple	35.5	8.3	-6.6	10.6	322
31	Achromatic	White	95.1	-0.2	0.3	0.4	124
32		Light Gray	75.7	1.0	-0.6	1.2	329
33		Mid Gray	56.1	-0.1	0.2	0.2	117
34		Dark Gray	35.6	-0.1	0.1	0.1	135
35		Black	15.3	-0.1	0.3	0.3	252

2.2 Sensibility evaluation on single color

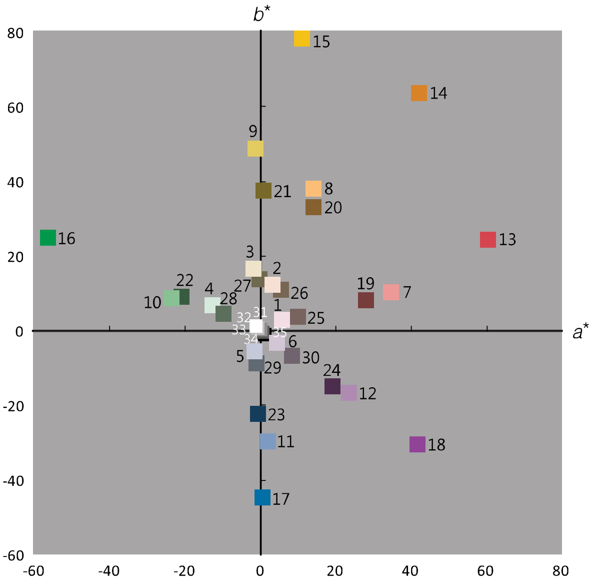

Fig.1. The 35 color samples in the CIELAB color space.

To extract sensibility factors for single color, evaluation scales were created from adjectives (Korean) in Table 1, and subjective assessment experiments were performed using single colors systematically selected from color space.

Color stimuli were selected so that a minimum number of stimuli could effectively represent a color space. 35 colors were systematically selected from the PCCS Color System: 6 primary hues and 5 tones for each hue group, and 5 additional achromatic colors. The stimuli were distributed within appropriate range in CIELAB Color Space as seen in Figure 1. Each color stimulus was presented on a medium gray background(*L** = 50) on a LCD monitor. Table 2 shows hue & tone classification for the 35 colors, and CIELAB values obtained from measurement by Minolta CS-1000 Spectroradiometer.

30 non-professional subjects(Korean female, age range 20s to 40s) participated in the experiments. 35 colors were randomly presented, and each color was assessed against 43 adjective scales utilizing 7-step evaluation scale. 7-step evaluation scale works as follows: when evaluating against "cold" scale, "7" is checked if coldness was strongly sensed, "1" if no coldness was felt, or "4" for moderate coldness.

The viewing distance was 50cm from the monitor, and 10º in visual angle. Each color stimulus was placed at the center of the monitor, and evaluation scales were located beneath. One experiment session took 1 hour 20 minutes including a 5 minute break.

3. RESULTS AND DISCUSSION

To extract sensibility factors for single color from the assessment experiment results, factor analysis was performed on 30 subjects for 43 scale value × 35 color matrix (see Table 3). As a result, two factors have been yielded explaining up to 60% of the cumulative proportion of Eigen values. The distribution of factor loading on a factor space with the two factor axes is shown in Figure 2.

In factor 1, it was postulated that words with positive factor loading contained the meaning "lively", and words with negative factor loading represented "elegant". Therefore, it was named "lively-elegant". In factor 2, positive values represented "natural", and negative values, "unique", and therefore it was named "natural-unique".

When product groups were macro classified along the two factor axes and viewed in relation to sensibility words, in factor 1, sensibility words needed for trend-sensitive small products such as small digital home appliances or mobile products were located along "lively", and typical high- priced major home appliances or furniture were located along "elegant". In factor 2, material-oriented products focusing on rehumanization and nature-friendliness were located along "natural", and words close to design concepts of product groups with creative edges were located along "unique". This indicates that practical sensibility factors that well satisfy sensibility words or design concepts necessary for product designers have been yielded.

To identify the correspondence between each factor's sensibility words and colors, a mapping in Figure 3 was produced using factor score. The mapping reveals that the

Table 3. The eigen values, variance, and cumulative proportions of up to the fifth factor from the factor analysis results.

factor	eigen value	variance %	cumulative %
1	21.0	48.8	48.8
2	9.6	22.3	71.2
3	3.7	8.7	79.9
4	2.8	6.6	86.5
5	1.7	3.9	90.3

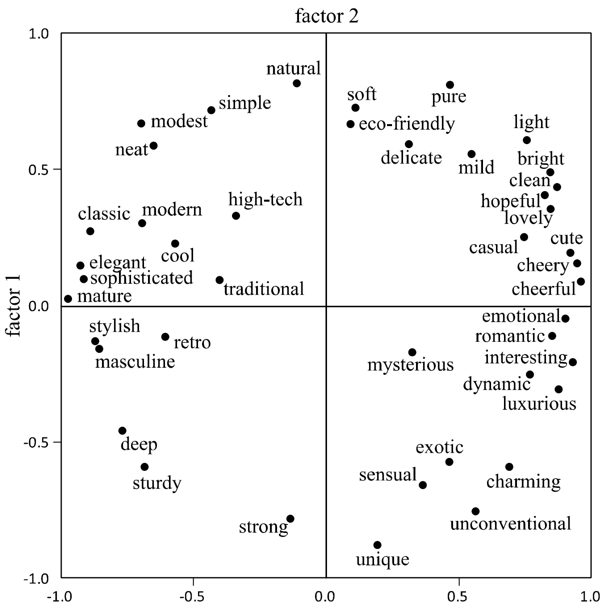

Fig.2. Sensibility word mapping based on factor loading.

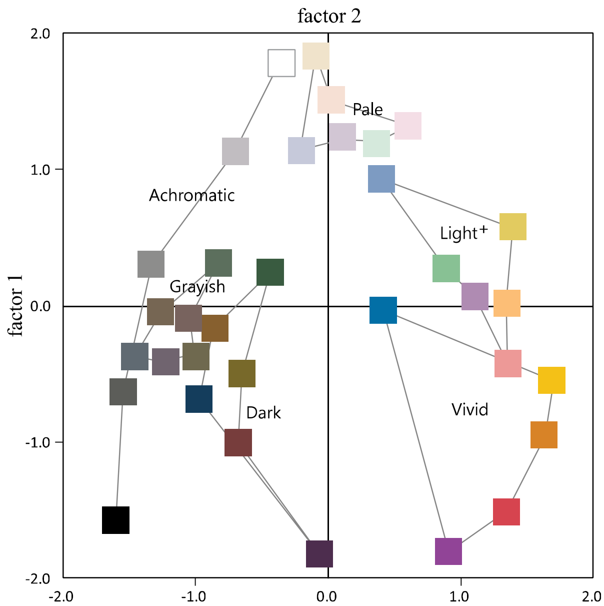

Fig.3. Distribution of 35 colors based on factor score.

overall distribution of sensibility words depends on the tone criterion rather than the hue criterion. In factor 1, colors of vivid tone were distributed along “lively”, and colors of grayish and medium grayish tone were arrayed along “elegant”. In factor 2, pale tone, light$^+$ tone, and white were distributed along “natural”, and “unique” drew dark tone and black. These results imply that a valid correspondence between a single color and a factor image was identified, and derivation of the two-factor structure was appropriate. In addition, the results reveal that tone is more influential than hue in creating sensibility for a certain color.

4. CONCLUSION

The results of this study show that sensibility words that well reflect the keywords needed in current product design were successfully derived, and the two factors of “lively-elegant” and “natural-unique” play focal roles in application of color in design. These two factors have characterized single color sensibility in a more concrete manner than factors suggested by previous studies, and the extracted sensibility words are expected to render greater practical support for product design processes. Specific practical application for product design field and more detailed interpretation of the factors await further study.

REFERENCES

Wright, B., and Rainwater, L. 1962. The meaning of color. *J Gen Psychol* 67: 89-99.

Hogg, J., Goodmam S., Porter, T., Mikellides, B., and Preddy, DE. 1979. Dimensions and determinants of judgements of colour samples and a simulated interior space by architects and non-architects. *Br J Psychol* 70: 231-242.

Kobayashi, S. 1981. The aim and method of the Color Image Scale. *Color Res Appl* 6: 93-107.

Sato, T., Kajiwara, K., Hoshino, H., and Nakamura, T. 2000. Quantitative evaluation and categorizing of human emotion induced by colour. *Adv Colour Sci Technol* 3: 53-59.

Park, C. 2002. Sensibility factors of colored light. *Korean Journal of Cognitive Science* 13: 23-31.

Ou, L., Luo, MR., Woodcock, A., and Wright, A. 2004. A study of colour emotion and colour preference, part 1: colour emotions for single colours. *Color Res Appl* 29: 232-240.

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Psychophysical study on mesopic vision at different adaption levels and viewing conditions

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ABSTRACT

We investigated the spectral visual sensitivity in the mesopic vision rage wherein both rod- and cone-photoreceptors operate. Due to the different spatial distributions and operation ranges of the rods and cones, the spectral visual sensitivity in the mesopic vision range changes depending on the viewing conditions and adaptation levels. For experimental study, we measured spectral visual sensitivities by using a detection threshold method corresponding to a modified increment-threshold method. We obtained mesopic luminous efficiency functions for two subjects at three mesopic vision levels of 0.04 cd/m^2, 0.4 cd/m^2, and 1.8 cd/m^2 under viewing conditions of 2° and 10° centrally viewed fields and the (10-20)° peripherally viewed field. We observed that the spectral sensitivity data depend on background luminance and viewing angle condition. The observation was discussed in terms of the interaction between the rods and cones.

1. INTRODUCTION

We studied the effects of rods and cones in mesopic vision using a psychophysical method. The rods and cones are different in their properties of temporal and spatial responses. Moreover, they are differently distributed in a retina (Palmer (1999), Fairchild (2005)). Thus, the spectral visual sensitivity in the mesopic vision range changes depending on the adaptation levels and viewing conditions. We performed the spectral visual sensitivity experiments at three mesopic vision levels of 0.04 cd/m^2, 0.4 cd/m^2, and 1.8 cd/m^2 under viewing conditions of 2° and 10° centrally viewed fields and the (10-20)° peripherally viewed field.

To measure the spectral visual sensitivity, we used a a detection threshold method corresponding to a modified increment-threshold method (Wyszecki and Stiles (1982)). For the experiment, we developed a visual stimulator consisting of an integrating sphere source and a spectroradiometer. The stimulator provides a white background and a monochromatic test field.

Next, the experimental setup and method will be explained in experimental section. In the result section, we will present the results of a psychophysical visual sensitivity experiment.

2. EXPERIMENT

2.1 Experimental setup

A uniform integrating sphere source was employed as a Newtonian-view visual stimulator to superimpose a monochromatic target on a background field. Red, green, and blue LEDs attached on the integrating sphere offered a white background field with a correlated color temperature of 6500 K and a ratio of scotopic luminance to photopic luminance of 1.3. A tunable source consisting of a tungsten-halogen lamp and a monochromator produced a monochromatic test field with the spectral bandwidth of 6-8 nm (FWHM) depending on wavelength. In the experiments, a flickering monochromatic target light with a rate of 10 Hz was superimposed on a white background of adaptation field.

2.2 Method

In the experiments, we used a detection threshold method corresponding to a modified increment-threshold method (Wyszecki and Stiles (1982)). Two normal trichromatic subjects participated in the experiment. The power of the target field was adjusted until a subject perceived no flicker. The radiance of the target field at the psychophysically determined detection threshold was measured with a spectro-radiometer, the inverse of which corresponded to the visual sensitivity at the wavelength of the target. Repeating the measurement procedures with various monochromatic targets yielded a luminous efficiency function.

We performed spectral visual sensitivity experiments by varying viewing conditions and adaptation levels. The experimental data for 2° and 10° centrally viewed fields and the (10-20)° peripherally viewed field were measured at three mesopic vision levels of 0.04 cd/m^2, 0.4 cd/m^2, and 1.8 cd/m^2.

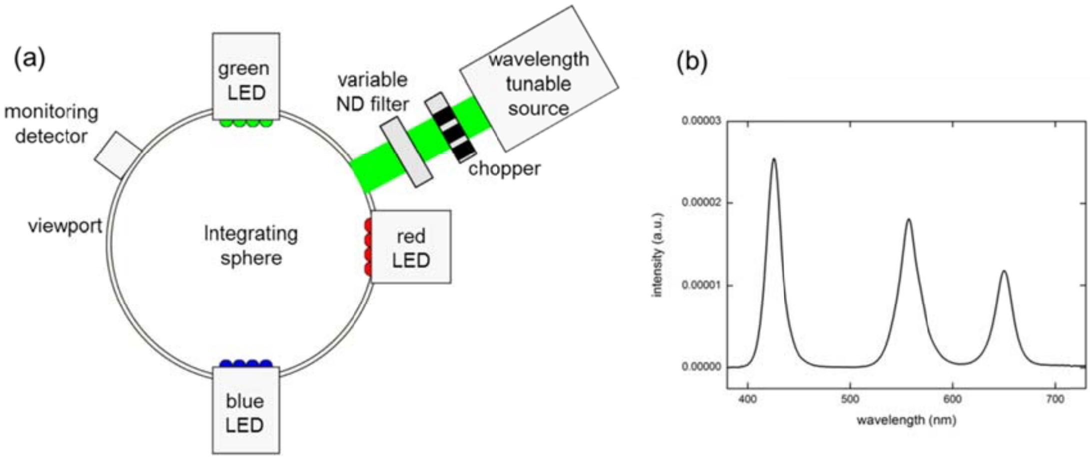

Figure 1 (a) A Newtonian-view visual stimulator using an integrating sphere source and (b) the spectral distribution of a white background used in experiment.

3. RESULT

We obtained mesopic luminous efficiency functions depending on a background luminance and a viewing angle. We observed a separation of rod- and cone-contributions for the measured data at different viewing conditions. We obtained a cone-dominant function for the data of 2° centrally viewed field, a rod-dominant function for the data of (10-20)° peripherally viewed field, and both rod- and cone-mediated function for the data of 10° centrally viewed field. Figure 2 shows the comparison between the obtained luminous efficiency functions and the Commission international de l'eclairage luminous efficiency functions.

Also, we observed that the visual sensitivity decreased depending on a viewing angle for the increasing background luminance. The detection threshold curves change depending on

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viewing angles. The detection threshold curves for (10-20)° viewing angle follows the deVries-Rose law. On the other hand, the 2° curve does not fit to a single mechanism on threshold-versus-intensity, which is interpreted as cone suppression due to the interactions of cones and rods (Goldberg, Frumkes, and Nygaard (1982), Coletta and Adams (1984)).

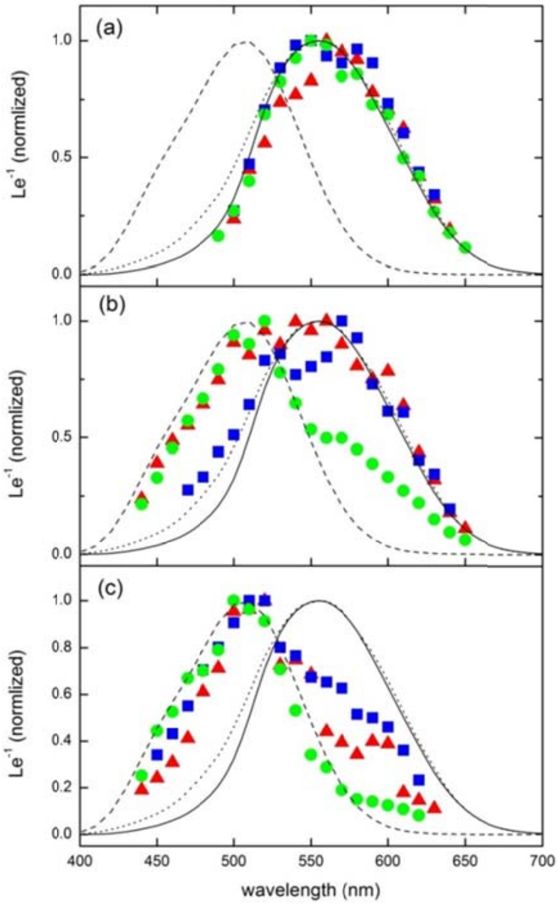

Figure 2 Normalized luminous efficiency functions under viewing angle conditions of (a) 2°, (b) 10°, and (c) (10-20) ° are plotted with the CIE V(λ)s. The solid, dotted, and dashed curves are CIE 1924 V(λ), the CIE 1964 V(λ) and the CIE 1951 V′(λ), respectively. Green circles, red triangles, and blue squares are data points for background luminance of 0.04 cd/m², 0.4 cd/m², and 1.8 cd/m², respectively.

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REFERENCES

Coletta, N. J., and A. J. Adams. 1984. Rod-cone interaction in flicker detection. *Vision Research* 24: 1333-1340.

Fairchid, M. D. 2005. *Color appearance models.* Chichester: John Wiley and Sons.

Goldberg, S. H., T. E. Frumkes, and R. W. Nygaard. 1982. Inhibitory influence of unstimulated rods in the human retina: Evidence provided by examining cone flicker. *Science* 221: 180-182.
Palmer, S. E. 1999. *Vision science: Photons to phenomenology.* Cambridge and London: Bradford Book.
Wyszecki, G., and W. S. Stiles. 1982. *Color science: Concepts and methods, quantitative data and formulars.* New York: John Wiley and Sons.

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Estimating object colors in outdoor scenes with same object region but different illuminants

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ABSTRACT

We propose a new approach to estimating the colors of objects in images of outdoor scenes. In color image analysis, it is useful to convert the colors of images taken under white or standard illuminants. However, most color images are not always taken under these illuminants and in fact the scene illuminants are unknown in most cases. In order to estimate colors of the objects in the scenes, we use images that include the same objects in outdoor scenes. This poses two restrictions: the colors of the objects appearing in the common images must be the same and the scene illuminants must be regarded as blackbody radiation, which varies with color temperature. Our approach extracts a set of object color candidates, which includes the correct one, from the colors in the object region of the image taken under a certain illuminant. The candidates are used to estimate the color of the object. Experiments using 100 kinds of object reflectance and three illuminants show that the estimated object colors are close to the correct ones with certain exceptions.

1. INTRODUCTION

These days, images captured by a large number of the general public are increasing and there are a lot of tools for image processing. In most cases, colors in images vary depending on the scene illuminants even for the same scene. The “white balance” function built in most digital cameras is useful to get the colors taken under a white illuminant; however, it sometimes does not function well in cases where the scene is dominated by certain colors.

Several methods have been proposed to estimate colors of the scene illuminants and/or objects in the scenes from the images. Estimating the colors of the illuminant makes it possible to estimate the colors of the object, and vice versa. The conventional methods can be mainly broken down into two types; one uses the gamut of colors in images taken under the possible illuminants (Forth (1990), Tominaga and Wandell (2002)) and the other uses physical or perceptual properties relating to illuminant or object colors. In the former, gamuts in a set overlap each other; this results in unstable estimation of illuminant colors in cases where most of the colors in an image have a low chroma value. In the latter, Klinker et al. (1987) use highlights, and Gershon and Jepson (1989) hypothesize that the average color of all of the objects in the scene is achromatic. However, estimation works well only when the target scene meets the above characteristics.

Our approach makes it possible to estimate the colors of objects in images with less restrictive constraints by using the colors of objects in images of outdoor scenes.

In the first part of the paper, we explain our approach. In the second part, we describe the experiments we conducted, and in the third part, we conclude the paper with a summary of key points.

2. OUR APPROACH

Our estimation scheme, which uses outdoor images having the same common object region, makes it possible to estimate the color of objects in the scene without strong restrictions.

The following equations show the relationship between image colors and surface reflectance. In equation (1), $X_{i,j}$, $Y_{i,j}$, and $Z_{i,j}$ are tristimulus values of the i-th object region in images under the j-th illuminant $E_j(\lambda)$, $\bar{x}(\lambda)$, $\bar{y}(\lambda)$ and $\bar{z}(\lambda)$ are color-matching functions, $\rho_i(\lambda)$ is the surface reflectance of the i-th object, and λ_k (k=1,2,…,n) is the wavelength in visible radiation from 400 to 700 nm at 10 nm intervals. Each reflectance comprises the product of the basis function $S_l(\lambda)$ derived by Cohen (1964) and its coefficient σ_{il} as shown in equation (2).

$$\begin{pmatrix} X_{i,j} \\ Y_{i,j} \\ Z_{i,j} \end{pmatrix} = \begin{pmatrix} \bar{x}(\lambda_1) & \bar{x}(\lambda_2) & \cdots \bar{x}(\lambda_n) \\ \bar{y}(\lambda_1) & \bar{y}(\lambda_2) & \cdots \bar{y}(\lambda_n) \\ \bar{z}(\lambda_1) & \bar{z}(\lambda_2) & \cdots \bar{z}(\lambda_n) \end{pmatrix} \cdot \begin{pmatrix} E_j(\lambda_1) & 0 & \cdots & 0 \\ 0 & E_j(\lambda_2) & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & E_j(\lambda_n) \end{pmatrix} \cdot \begin{pmatrix} \rho_i(\lambda_1) \\ \rho_i(\lambda_2) \\ \vdots \\ \rho_i(\lambda_n) \end{pmatrix} \quad \ldots\ldots\ldots\ldots (1)$$

$$\rho_i(\lambda_k) = \sum_{l=1}^{m} S_l(\lambda_k) \cdot \sigma_{il} \quad \ldots\ldots\ldots\ldots (2)$$

In the above equations, $E_j(\lambda)$ and $\rho_i(\lambda)$ are unknown; however, $E_j(\lambda)$ is expressed as blackbody radiation of a certain color temperature. If $E_j(\lambda)$ is once specified, the only unknown parameters are the coefficients σ_{il}. Therefore, the coefficients σ_{il} are derived using a pseudo-inverse matrix consisting of $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$, $E_j(\lambda)$, and $S_l(\lambda)$. By varying the color temperature of the black body as an illuminant, a set of surface reflectance candidates that includes the correct one is derived. Under different scene illuminants, candidate sets are similarly derived by using the colors of the same object region in the image. Each candidate is different from the others but each candidate set includes the correct one. The color of the object is estimated as the intersection of several sets of candidates.

3. EXPERIMENTS

We conducted experiments using 100 kinds of reflectance selected from the reflectance dataset ISO/TR 16066 (2003) and three illuminants simulated by blackbody radiation. Figure 1 (a) illustrates the surface reflectance samples, which are “flower&leaves #3” as the dotted line, “water #4” as the solid line, and “textile #9” as the dashed line, and (b) shows the spectral distribution of the illuminants corresponding to twilight (3000 K) as the dotted curve, sunlight at noon (6500 K) as the solid curve, and blue sky (10,000 K) as the dashed curve.

On the basis of equations (1) and (2), three sets of candidates representing the color of an object in the scene are derived; they are empirically expressed as approximate quadratic curves in an xy chromaticity diagram. The color relevant to the object is estimated as the intersection of three kinds of curves. Three curves derived using “flower&leaves #3” and three kinds of illuminants are shown in Fig. 2.

Table 1 shows the correct colors, the estimated ones expressed as u’v’ chromaticity, and the estimation errors calculated as the Euclidean distance between the estimated color and the correct one in a u’v’ chromaticity diagram. As the table shows, the estimated colors are close to the correct ones and the estimation errors are small. However, incorrect estimation occurred when the reflectance values were small in the range of visible radiation. In the cases shown here, one or two components of the XYZ tristimulus were near zero or very small, and therefore the candidates for the colors of objects derived by these tristimulus values are incorrect. High chroma colors tend to show these characteristics.

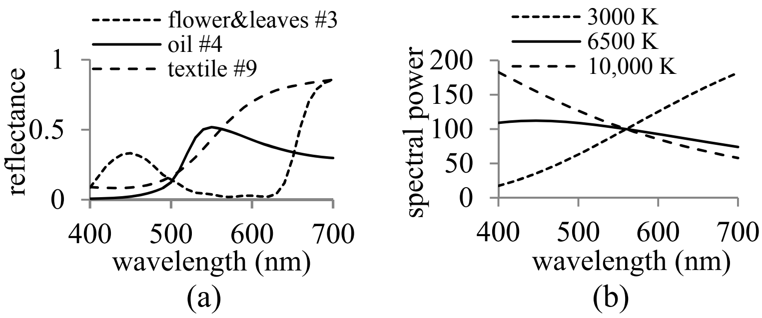

Fig. 1. Samples of surface reflectance (a) and spectral distribution of illuminant (b) used in the experiment.

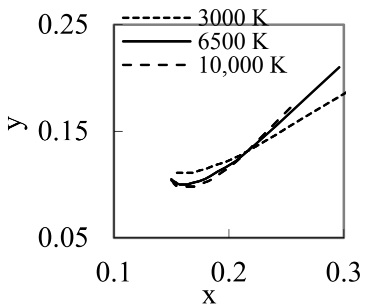

Fig. 2. Color candidates derived by simulated colors using “flower&leaves#3”.

Table 1. Samples of estimated results

reflectance	correct color	estimated color	estimation error
flower&leaves #3	0.216, 0.302	0.217, 0.301	0.001
oil #4	0.219, 0.556	0.185, 0.552	0.034
textile #9	0.278, 0.536	0.272, 0.534	0.006

4. CONCLUSION

We proposed a new approach to estimating the colors of objects in outdoor scenes. In the estimation, we used colors from the same object region common to the images under different scene illuminants. Experiments using simulated reflected colors from the objects showed that the estimated colors are close to the correct ones except in the case for ranges in which the reflectance value is near zero or extremely small.

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REFERENCES

Cohen J. 1964. Dependency of the spectral reflectance curves of the Munsell color chips. *Psychonomic Science* 1: 369-370.

Forsyth, D.A. 1990. A novel algorithm for color constancy. *International Journal of Computer Vision*5 (1) :5-36.

Gershon, R. and A.D. Jepson. 1989. The computation of color constant descriptors in chromatic images. *Color Research and Application*14 (6) : 325-334.

ISO/TR 16066. 2003. Standard object colour spectra database for colour reproduction evaluation (SOCS).

Klinker, G.J., S.A. Shafer and T. Kanade. 1987. Using a color reflection model to separate highlights from object color. In *Proceedings of the First ICCV*. London: 145-150.

Tominaga, S. and B.A. Wandell. 2002. Natural scene-illuminant estimation using the sensor correlation. In *Proceedings of the IEEE*90 (1): 42-56.

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Effect of differences in substrate white point on the acceptability of colour matches

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ABSTRACT

Acceptability and perceptibility thresholds were determined for uniform colour samples adjusted for differences in colour of paper, in three modes of proof-to-print comparison. The results show that for solid colours such adjustments are judged to produce acceptable reproductions, but for light tints the thresholds are considerably smaller and suggest that the difference in paper colour itself is the main factor determining acceptability.

1. INTRODUCTION

In graphic arts colour reproduction it is common for a final print to be produced on a paper that is not identical to that used for the proof, or which does not exactly match a target reference paper specified in the process control standard ISO DIS 12647-2 (ISO, 2012). To achieve an accurate colorimetric match on the new paper it would be necessary to generate characterization data for the printing process on the new paper. However, in many cases it is not practical to generate this data empirically by printing samples and measuring them. In addition, there will be some degree of adaptation to the new paper white point, so that a colorimetric match may not be a desirable reproduction goal. The goal is therefore to be able to compute new characterization data to take account of the change in paper colour in a way that preserves the appearance of the original when printed on the new paper.

Spectral reflection data are transformed to colorimetric values using a source spectral power distribution (SPD) which should ideally correspond to the SPD of the viewing illumination. The resulting measurements assume an adapted white point with the reflection characteristics of a perfect reflecting diffuser. However, when judging prints and proofs in a viewing booth it is common for the unprinted paper to be the lightest neutral in the field of view, and in this situation the observer will be at least partially adapted to the paper white.

Colour management using ICC profiles (ISO, 2010) provides a pathway to support either the perfect diffuser or the media white as the adapted white point (referred to as ICC-absolute and Media-relative Colorimetric rendering intents respectively). The MRC intent uses a form of 'wrong-Von Kries' conversion, based on tristimulus ratios instead of cone response ratios, matching the source white point to the destination white point regardless of differences in luminance or chromaticity.

For most colour reproduction tasks a media-relative conversion is preferred by users, especially when compared to the alternative ICC-absolute conversion which either clips the source white lightness or introduces a background tint, depending on whether the source medium lightness is higher or lower than that of the reproduction.

In the case of re-targeting, where a print targeted for one paper is reproduced on a different paper, the visual match of the reproduction can be critically important, as in the case of the proof-to-print match.

Previous work (Green and Oicherman, 2004) showed that the process of adaptation to different substrate colours under a single illumination source is analogous to adaptation to different illumination sources on a single substrate, and that for chromatic substrates observers were approximately 70% adapted to the substrate colour. This also relates to the finding that observers are approximately 60% adapted to the display peak white when viewing colours on a display (Katoh and Nakabayashi, 2001).

Thus two techniques that are available for adjusting characterization data for differences in media white point include the wrong-Von Kries media-relative colorimetry discussed above, and a chromatic adaptation transform (complete or incomplete). Previously Henley and Fairchild (2000) obtained good results using such a von Kries transform for cross-media colour matching, both with and without adjustment for mixed adaptation states.

The goal of the present research is to determine the acceptability of colour matches made on different substrates using these adjustment techniques, and in particular the range of acceptable colour differences between reference and re-targeted media. ISO DIS 12647-2 (ISO, 2012) specifies the colorimetry of a number of reference papers which form a range separated by a maximum of 5 CIELAB ΔE^*_{ab}, and if a difference of 2.5 ΔE^*_{ab} between target and reproduction were found to be acceptable when using an adjustment technique, the approach would be valid for most commercial papers by selecting the closest reference characterization data set and adjusting it accordingly.

2. EXPERIMENTAL

Three different use cases were considered in this work:

1. The observer judges a print against a proof on a different paper
2. The observer judges a print having previously viewed a proof on a different paper
3. The observer judges a print against a soft copy proof on screen.

These use cases are referred to as simultaneous, sequential and soft proof viewing. Three experimental phases were performed corresponding to these three viewing conditions.

2.1 Samples

CIELAB coordinates of a reference paper was selected from the ISO 12647 paper types, and 14 variants were generated which differ from the reference by 1-10 CIELAB ΔE^*_{ab}. The reference paper white point and the variants were simulated by printing on a non-optically brightened proofing paper.

Five colour centres in red, green, blue, orange and purple, similar to those used in Baah and Green, 2012, were selected, together with a light tint of each colour centre, and printed as a 25x25mm uniform patch with the simulated reference paper as a background. All colour centres were within the gamut of the printer used to prepare the samples, and the gamut of sRGB. A transform was applied to the 10 colour centres which shifted their colour coordinates in a similar direction to the difference between reference paper and variant. This shift approximated the media-relative correction for substrate, but in order to test the general approach rather than a specific adjustment technique the shift was larger and with some randomness. This resulted in a total of 10x14 samples in each experimental phase, varying by up to 10 ΔE^*_{ab} from the reference colour centre. The samples were printed on an HP Officejet 8600 printer and measured with a GretagMacbeth Spectrolino spectrophotometer.

For the soft proof phase, the reference papers and colour centres were simulated on an Eizo colour monitor with a 120cd m^{-2} peak white luminance. All colours on the display were measured using a Minolta CS-1000A telespectrophotometer, located at the observer position relative to the screen. The spectral radiance data was converted to tristimulus values normalized to the display peak white as L*=100.

Figure 1. Colour centres .

2.2 Psychophysical

Eight females and 13 males with good colour vision participated as observers in the psychophysical experiments. The observers were asked to rate the size of colour difference between reference and sample using a six-point scale where 1-2 are not perceptible or only barely perceptible, 3-4 are acceptable and 5-6 are unacceptable (Johnson and Green, 2001).

Hard copy samples were presented in a Verivide proof viewing cabinet with D50 simulating illumination at 500 lux against a surround with 20% reflectance. In the simultaneous viewing experiment, the simulated papers were presented adjacent to each other with 10mm margins separating the colour patches. In the sequential viewing experiment, reference and sample were presented with a 10-second interval. Finally, in the soft proof experiment, samples were presented simultaneously as in the hard copy experiment. The same 21 observers completed both simultaneous and soft proof experiments, and 16 of the observers had completed the sequential viewing experiment.

3. RESULTS

The threshold at which 75% of the observers judged the samples to be acceptable was determined using the 'instrumental wrong decisions' method, as described in Johnson and Green (2001). The threshold at which 50% of the observers judged the samples to be perceptibly different from the reference was determined by the same method, and the results for acceptability and perceptibility are shown in Table 3.

	Acceptability		**Perceptibility**	
	Solids	**Tints**	**Solids**	**Tints**
Simultaneous	9.52	2.27	1.24	0.56
Sequential	9.52	1.67	1.73	0.56
Soft proof	11.67	5.70	5.18	1.75

Table 1. Perceptibility and acceptability thresholds determined using instrumental wrong decisions method.

It can be seen that the acceptability thresholds for solid colours are considerably greater than the 2.5 ΔE^*_{ab} representing the maximum of substrate differences in standard characterization data sets. As the lighter tints are printed with a minimal dot and are close to paper white, the smaller acceptability thresholds strongly suggest that observers are considering the paper colour itself when determining acceptability.

3.1 Degree of adaptation

The degree of adaptation represented by the observer judgements was investigated using the following method. First, the geometric mean of the observer scale values was calculated for each sample (interpreting the scale categories as psychophysical magnitudes) to give a vector of visual differences ΔV. Next, the reference colours were transformed using the Bradford (Lam, 1985) chromatic adaptation transform (CAT), using the XYZ tristimulus values of the reference paper as source adapted white and tristimulus values of each variant as destination adapted white. The difference ΔS was calculated between the coordinates predicted by the CAT and the measured samples used in the experiment. The effect of varying the degree of adaptation, D, in the transform was then investigated by comparing the ΔV and ΔS values, assuming that where the CAT accurately predicts the visual match both ΔV and ΔS will be small. It was noted that this correlation was slightly improved when D=1 (i.e. under conditions of full adaptation) but the result was not significant. A different design of experiment will be required to investigate this further.

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5. CONCLUSIONS

The acceptability thresholds for solid colours on a reference paper modified by a media-relative type of adjustment were found to exceed the colour difference which would arise from re-targeting to a similar paper type, and confirms that some form of adaptation to paper white point does indeed take place. For the tints, the acceptability threshold is slightly smaller than the 2.5 DE difference which could arise from re-targeting, and this result suggests that the paper colour itself is the determining factor in the acceptability judgement for these lighter colours.

Presenting proof and print simultaneously or sequentially made little difference to the acceptability thresholds, while the thresholds resulting from the soft proof experiment were somewhat higher.

Further work is needed to evaluate specific models of incomplete visual adaptation to paper colour, using complex images as well as uniform colours.

REFERENCES

Baah, K. F., Green, P. J. and Pointer, M. R., 2012. Colour perception with changes in levels of illumination *Proc. SPIE Vol. 8292*

Green, P.J. and Oicherman, B., 2004 Reproduction of colored images on substrates with varying chromaticity, *Proc. SPIE Vol. 5293*

Henley, S. and Fairchild, M.,2000, Quantifying Mixed Adaptation in Cross-Media Color Reproduction, *Proc. IS&T/SID Col Imaging Conf*

ISO DIS 12647-2: 2012 *Graphic technology — Process control for the production of half-tone colour separations, proof and production prints — Part 2: Offset lithographic processes*

ISO 15076-1:2010 *Image technology colour management — Architecture, profile format, and data structure*

Johnson, A. J. and Green, P. J., 2001, The CIEDE2000 colour difference formula and its performance with a graphic arts data set *Proc. IARIGAI*

Katoh, N. and Nakabayashi, K., 2001, Applying Mixed Adaptation to Various Chromatic Adaptation Transformation (CAT) Models, *Proc IS&T PICS*

Lam, K. L., 1985, *Metamerism and Colour Constancy.* PhD thesis, University of Bradford

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Repeatability and reproducibility of a hyperspectral camera as a means of measuring color

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ABSTRACT

In this study we evaluate the repeatability and reproducibility of a hyperspectral system as a means of measuring color following the guidelines established in the ASTM E2214-08 standard. The system basically consists of a CCD digital camera, a spectrograph and a linear moving system, which allow sampling the scene both spectrally and spatially with a high resolution. The results highlight the usefulness of such systems to be used in industrial applications.

1. INTRODUCTION

Hyperspectral cameras, which allow measuring the complete spectrum for each pixel of an image, have appeared on the market in recent years (Chang 2009). Their main components are a digital camera, a spectrograph and an objective lens. An additional moving system allows scanning mechanically the complete scene, although sometimes the scan is performed optically. Using such systems, the scene is sampled spectrally but also spatially, creating a 3D cube of data (x, y, λ) with spectral information pixel by pixel. Therefore, the use of these systems can provide significant advantages in the fields of colorimetry and spectrometry, mainly in the characterization of non-uniform materials with complex spatial patterns. In this work we analyze the repeatability and reproducibility of a hyperspectral system following the guidelines specified in the ASTM E2214-08 standard, where the latest multidimensional procedures for characterizing the performance of color-measuring instruments have been established.

2. METHODS

The hyperspectral system analyzed consisted of a 16-bit digital CCD camera (AVT Pike F-210B), a spectrograph (ImSpector V10E), and an objective lens (Cinegon 1.8/16) (Figure 1). As stated before, throughout all the study we followed the guidelines specified in the ASTM E2214-08. It must be taken into account that since color is a multidimensional property of a material, repeatability and reproducibility must be reported in terms of multidimensional standard deviations, and not only using one color difference based metrics. Moreover, another problem usually arises when using color differences: they do not follow a Normal distribution but a curve related to the Chi-squared of F statistical distributions. This standard permits overcoming all these limitations.

To analyze repeatability we performed measurements on a calibrated white plate (BN-R98-SQ10C) and used univariate and multivariate metrics. 50 consecutive readings were taken to account for short-term repeatability, 50 in two consecutive days for medium-term repeatability, and 50 along 5 weeks for long-term repeatability.
To account for reproducibility we used two different sets of samples: 12 glossy ceramic tiles (BCRA CCS-II) and 24 matte patches (CCRC). The multivariate Hotelling and

inter-comparison tests were used to compare the readings of the hyperspectral system with those obtained by a conventional tele-spectracolorimeter (Photo Research PR-655). The reflectance factors from 400 to 700 nm ($\Delta\lambda$=10 nm) and a geometry of D/45 with a SpectraLight III overhead luminaire (Daylight configuration) were used in all measurements. Illuminant D65 and CIE 10º observer were used to compute the color data.

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Figure 1. Hypespectral system (camera, spectrograph and lens), illumination system (overhead luminaire) and linear scanning moving system.

3. RESULTS AND DISCUSSION

The results confirmed the good performance of the hyperspectral system in terms of short, medium and long term repeatability. As an example, Table 1 shows some of the metrics used for this purpose. Parameters $\Delta R_{\lambda,2\sigma}$ represents twice the standard deviation of the reflectance at the specified wavelength, ΔE_{00} is the CIEDE2000 color difference and RMSE (%) is the *Root Mean Square Error* (%).

Table 1. Results of short., medium and long term repeatability for some of the metrics proposed by the ASTM E2214-08.

Metrics	Short term	Medium term	Long term
$\Delta R_{440,2\sigma}$	0.0017	0.0105	0.0223
$\Delta R_{560,2\sigma}$	0.0011	0.0112	0.0246
$\Delta R_{650,2\sigma}$	0.0017	0.0146	0.0345
ΔE_{00}	0.031	0.130	0.399
RMSE (%)	0.1367	0.6631	1.8667

Another issue that should be considered in the analysis of repeatability is the drift shown by the instrument analyzed. This was investigated by studying the 50 consecutive readings obtained in the analysis of short term repeatability for some parameters. Figure 2 shows the L*, a* and b* data of these measurements. As it can be seen the instrument does not seem to be associated with a drift in the results.

In the study of repeatability done by Wyble and Rich (2007a) the repeatability of twelve commercial spectrophotometers was compared. The results found for these authors were similar to those obtained in our study. Therefore it can be concluded that the hyperspectral system shows a precision similar to the majority of instruments used for measuring color.

In the case of reproducibility, the two tests applied reported statistical significant differences between the hyperspectral system and the tele-spectracolorimeter PR-655 at 95% confidence level (P<0.001). However, it must be remarked that the statistical tolerance using the methodology proposed by the ASTM E2214-08 is strict as already reported by other authors (Wyble and Rich 2007b), who also found differences among 10 commercial spectrophotometers. Figure 3 shows specific examples of spectral reflectances measured by the hyperspectral system and the PR-655.

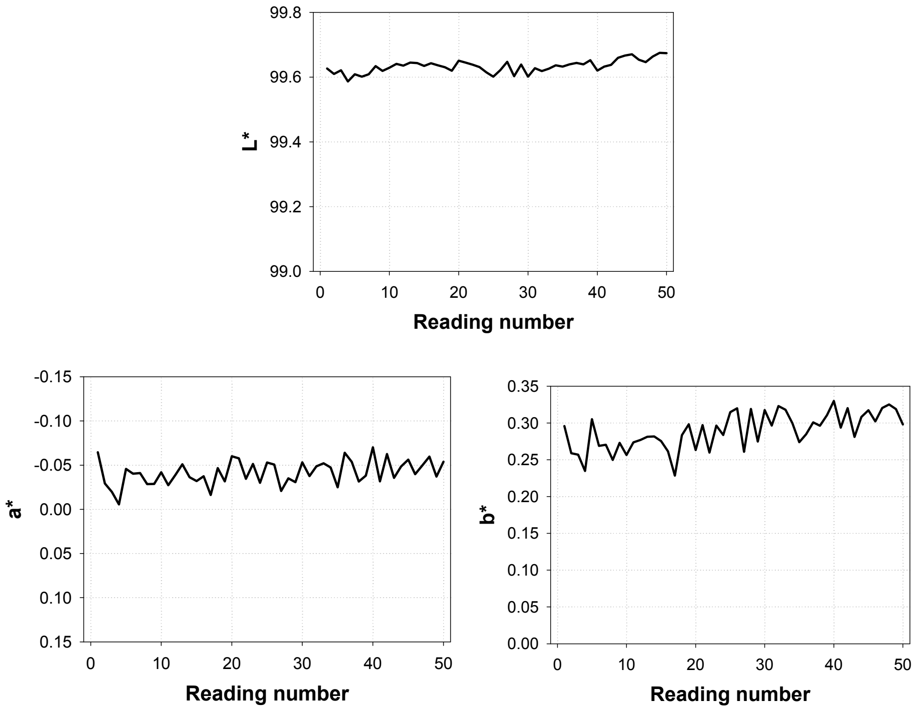

Figure 2. L, a* and b* vs. measurement number for the hyperspectral camera. The 50 consecutive readings obtained in the short-term analysis are considered.*

Table 2. Results of reproducibility in terms of mean color differences and RMSE (%)between the measurements provided by the hyperspectral and PR-655 tele-spectracolorimeter..

Set of samples (number)	ΔE_{00}	RMSE (%)
CCRC (24)	1.181	6.5422
BCRA (12)	4.339	23.0598

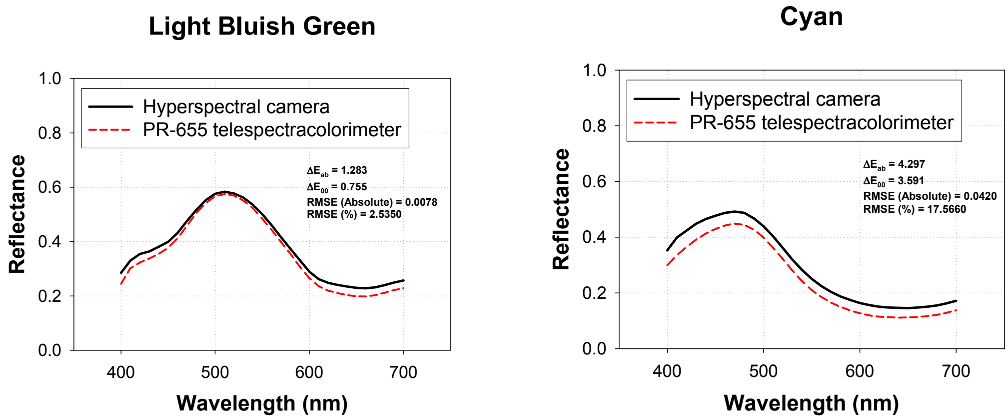

Figure 3. Spectral reflectances measured by the hyperspectral camera as well as the PR-655 tele-spectracolorimeter for the Light bluish green sample of the CCRC chart and the Cyan tile of the BCRA collection.

However, and taking into account the obtained results, it was concluded that the reproducibility was acceptable for matte CCRC samples while that corresponding to the glossy BCRA tiles was much lower. This might be explained by the gloss of the last set of samples and the geometry used (D/45), which could contribute to a higher variability among the results, i. e. the positioning of the sample with respect to the light source as well as the instrument would be more critical. Furthermore, one must have into account that geometrically speaking, both instruments do not actually have identical configurations, what can reinforce the former explanation and justify the larger differences found for the BCRA tiles. Hyperspectral cameras, allow measuring the complete spectrum for each pixel of an image, but this is done by measuring only one line on the scene. Later on, an additional mechanical moving system allows linearly scanning the desired part of the sample that is aimed to be analyzed. On the contrary, the PR-655 does not need the scanning system. It already has a viewing field of 1 degree. Having these differences in mind, the gloss could affect in a different way both instruments and for this reason worse results with the BCRA would be found.

On the other hand, non-uniformities of the illumination on the sample measured could also play an important role in the results. Even the overhead luminaire is designed to be perfectly uniform and incorporates a diffuser placed below the light bulbs, it does not provide a perfect uniform field of illumination.

4. CONCLUSIONS

In conclusion, it could be established that the hyperspectral system provided very good results in terms of repeatability and acceptable data in terms of reproducibility. Therefore, these systems are reliable and could be used in the industry providing advantages in the field of colorimetry and spectrometry, mainly in the characterization and identification of non-uniform materials with complex spatial patterns with a high spatial and spectral resolution.

ACKNOWLEDGEMENTS

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REFERENCES

Chang C. I. 2007. Hyperspectral data exploitation: theory and applications. 1a ed. New York: *John and Wiley and sons*.

ASTM E2214-08. 2008. Standard practice for specifying and verifying the performance of color-measuring instruments, *American Society for Testing and Materials*, United States.

Wyble D. R. and D. C. Rich. 2007a. Evaluation of methods for verifying the performance of color-measuring instruments. Part I: Repeatability, *Color Research and Application* 32: 166-175.

Wyble D. R.and D. C. Rich. 2007b. Evaluation of methods for verifying the performance of color-measuring instruments. Part II: Inter.instrument reproducibility, *Color Research and Application* 32: 176-194.

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Novel neural network application for printer characterization

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ABSTRACT

This study investigated a novel neural network architecture for a function approximation problem (colour transformation between printer device colour space and CIE XYZ space). The results revealed that the novel architecture did not outperform the standard multi-layer perceptron approach. The new method may be more effective for spectral transformations.

1. INTRODUCTION

The aim of printer characterization is that device coordinates (typically cyan, magenta, yellow and black) are converted into device-independent CIE *XYZ* values. The use of interpolation with 3-D look-up tables (LUTs) is commonly used in printer characterization (Hung, 1993). Kang (2006) notes that this requires three distinct phases: packing, extraction and interpolation. Packing is the process of populating the 3-D space with sample points that will constitute the LUT. Extraction is the process by which the closest points in the LUT are found with respect to a search point. Interpolation is where the extracted lattice points are used to calculate the required attributes for the search. Distance-weighted interpolation is unconstrained by the number of colour samples that constitute the LUT (Shepard, 1968) and is therefore appropriate for use in cases where the sample points are irregularly spaced. This approach is based on the principle that vectors near the point of interest should have a greater influence than vectors far away; so a weighting function inversely proportional to distance is used. A key to the success of any transform or interpolation method is the nature and quality of the data that are collected to optimize the transform or populate the LUT. Morovič *et al.* (2010) show that characterization performance (in terms of median color difference error) generally reduces as the number of samples in the training set increases set and only asymptotes when the number reaches several 1000s. Johnson (1996) suggested the use of 200 colour samples as an absolute minimum but approximately 4000 is more typical. Several attempts have been made to select the training samples wisely so that as few as possible can be used (e.g. Tastl *et al.*, 2009; Morovič *et al.* 2010).

The field of artificial neural networks (ANNs) defines a set of computational methods that were inspired from studies of how humans process information to solve problems. There are a great many different types of ANNs and an extensive literature available to explain the principles and algorithms of neural computing (e.g. Haykin, 1994). One of the most popular types of neural network is the multi-layer perceptron (MLP). An MLP consists of layers of processing units; each unit receives input and performs some function upon this input to produce an output. The function between input and output for any unit is known as the activation function or the transfer function and is normally non-linear. A typical non-linear transfer function is the sigmoid (S-shaped) function but linear transfer functions are sometimes used for the units in the output layer. The input for each unit is the weighted sum of the outputs from all of the units in the previous layer. The units in the first layer (known as the input layer) receive their input from an input vector and those in the last layer (known as the output layer) generate an output vector. Each unit in the hidden and output units also receives weighted input from a bias unit whose output is fixed at unity. The network as a whole can be thought of as a universal function approximater that attempts to find a mapping between input vectors and output vectors. Such networks are interesting because, in principle, they can perform any valid mapping to any arbitrary degree of accuracy. A valid mapping is one that is computable. The number of units in the input and output layers are determined from the nature of the problem being solved. If for example the network is being used to perform a mapping between a four-dimensional vector and a one-dimensional vector then the number of units in the input and output layers would be four and one respectively. However, the number of hidden layers and the number of units in each hidden layer must be determined empirically.

A comparison of neural networks and polynomial transforms to characterize a Kodak Color Proofer 9000A dye-sublimation printer was carried out (Westland and Ripamonti, 2004). Neural networks with various numbers of units in the hidden layer were evaluated but optimum generalization performance was found with 6 units in the hidden layer and the median CIELAB error on the test set was 3.16. For comparison, a third-order polynomial transform achieved a median test error of 4.01 CIELAB units. This was achieved with a training set of 729 samples. One of the difficulties of using ANNs for colour transformations is that they often require very large number of samples. For example, the number of free parameters (weights) in an MLP with a single hidden layer of 10 units that maps between an 4-d input vector of CMYK and a 31-d spectral output vector is 391. For a network to be adequately constrained during training there should be at least as many data samples as free parameters (one rule of thumb recommends a ration of 10:1 for data:weights). It has been suggested, however, that novel MLPs structures where the units between each layers are not fully connected could be useful for colour transformations (Iovine, 2005). This idea is tested in this paper.

2. EXPERIMENTAL

CIE *XYZ* data were measured for the patches of an IT8.7-3CMYK characterization chart printed on a HP Color LaserJet 5500n printer. This chart specifies colour at each pixel in CMYK terms. The colour patches from the IT8-7-3CMYK characterization were separated into 746 training patches and 104 test patches. The training samples were used to populate the LUT and distance-weighted interpolation was then used to estimate the CIE *XYZ* values of each of the 104 training samples. A standard MLP was trained using the 746 training samples with various numbers of units in the hidden layer. In addition, a partially connected MLP was also trained. The partially connected MLP can be thought of as three separate networks, each one transforming CMYK into either X, Y or Z. This allows the three networks to be smaller though each one still is constrained by 746 training samples. In all cases, the CIELAB colour differences were calculated (1964/D65) between the predicted and actual XYZ values. Each network was trained three times and the average performance of the three trials is considered.

4. RESULTS AND DISCUSSION

The distance-weighted interpolation method produced a mean CIELAB □E of 4.10 for the 104 training samples (with a maximum □E of 22.71). Figure 1 shows the mean CIELAB errors for the ANN with varying numbers of hidden units for the training and tests sets. As expected, the mean colour difference for the training set generally decreases as the number of hidden units is increased; however, the test error shows a minimum at around 23 hidden units (corresponding to 187 weights). For networks with greater than about 23 hidden units generalization error increases as the network is over-trained on the training data. The best performance of the network is a mean colour difference of 5.6 on the test set.

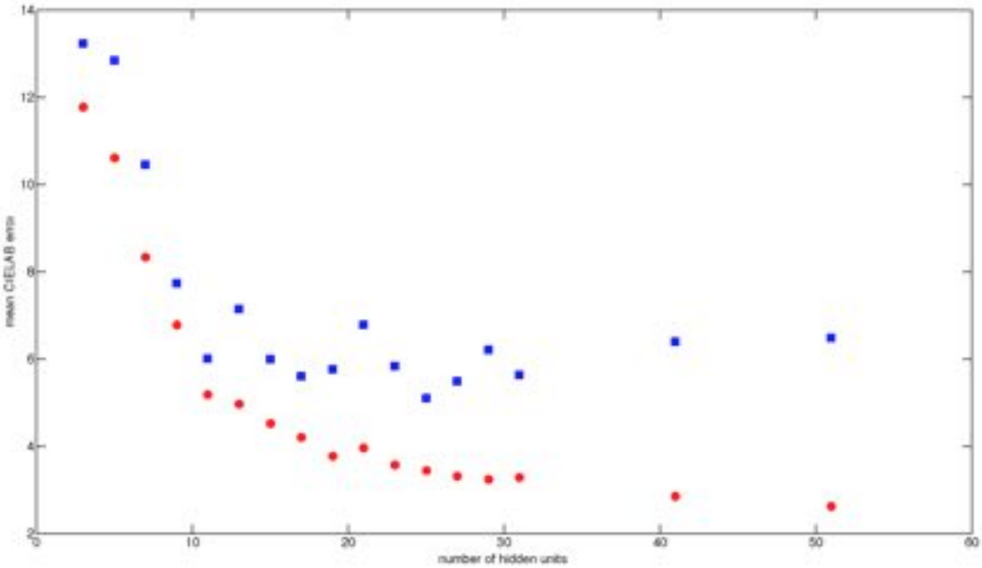

Figure 1: Training (red circles) and testing error (blue squares) for standard MLP with various numbers of hidden units.

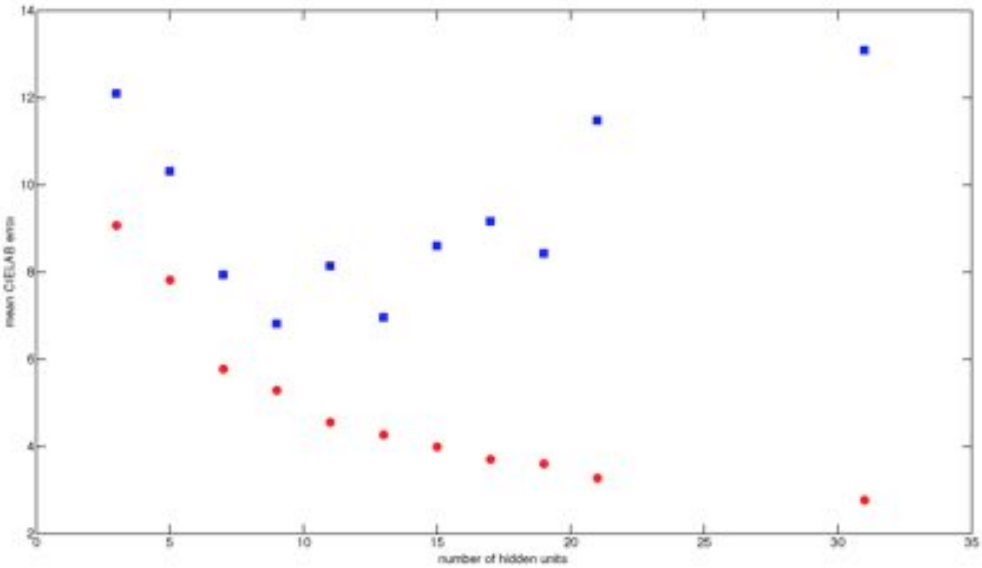

Figure 2: Training (red circles) and testing error (blue squares) for network that is not fully connected. The number of hidden units refer to the number of hidden units in each of the three networks.

Figure 2 shows the mean CIELAB errors for the ANN with varying numbers of hidden units for the training and tests sets. The test error shows a minimum at around 9 hidden units for each of the three networks (corresponding to 55 weights per network or 165 weights in total). The best performance of the network is a mean colour difference of 6.82 on the test set.

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5. CONCLUSIONS

The results of this study show that the neural networks do not outperform the distance-weighted interpolation colour transformation method. Previous studies (Iovine, 2006) had demonstrated that using a set of smaller networks (rather than one large network) for function approximation where the dimensions of the output vector are independent of each other outperform a standard MLP. However, that finding was not replicated in this study. One possible explanation is that the previous study used a spectral, rather colorimetric, output vector where the advantages of splitting a larger network into several smaller networks may be more significant.

REFERENCES

Haykin, S., 1994. *Neural Networks: A Comprehensive Foundation*, Macmillan.

Hung, P-C., 1993. Colorimetric calibration in electronic imaging devices using a look-up table method and interpolations, *Journal of Electronic Imaging*, **2** (1): 53-61.

Iovine, L., 2005. *Transformations between colour spaces*, PhD Thesis (University of Derby).

Johnson, A.J., 1996. Methods for characterizing colour printers, *Displays*, **16** (4): 193-202.

Kang, H.R., 2006. *Computational Color Technology*, International Society for Optical Engineering.

Morovič, J., Arnabat, J., Richard, Y., & Albarrán, Á., 2010. Sampling optimization for printer characterization by greedy search, *IEEE Transactions on Image Processing*, **19** (10): 2705-2711.

Shepard D., 1968. A two-dimensional interpolation function for irregularly spaced data, *Proceedings of the 23rd National Conference of the ACM*: 517-524.

Tastl, I., Recker, J.L., Zhang, Y., & Beretta, G., 2009. An efficient high quality color transformation, *Proceedings of the IS&T/SID's 17th Color Imaging Conference*: 111-116.

Westland, S., & Ripamonti, C., 2004. *Computational colour science using MATLAB*, John Wiley & Sons.

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Methods for Capturing and Analyzing Digital Images of Cultural Heritage

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ABSTRACT

Methods for capturing and analyzing digital images of cultural heritage are proposed. The requirements for 2D and 3D object are different. Both of them start from well-defined lighting and color correction. The reprehensive color swatches can be extracted from the digital image by a K-means based algorithm. The impacts of background, gloss and shadow must be removed before the color extraction. Various color spaces can be used for analyzing the data and generating accurate color swatches for industrial applications.

1. INTRODUCTION

Recent years, many museums and archives are engaged in direct digital image capture of cultural heritage. In Taiwan, National Palace Museum has a great number of ancient paintings and utensils including ceramics, bronzes and jades *et. al*. They are priceless, fragile and photosensitive, therefore the procedure of image capture should be standardized and carried out in very limited time. Painting needs a uniform lighting whereas utensils prefer uneven lighting to enhance the reflective highlights and shadows. The optimal setting is normally on a case-by-case basis. The color and surface property of the cultural heritage have great value for industrial design. However, the uncertainty of lighting setup makes the image-based color analysis more difficult. The present paper aims to recommend a SOP of digital image capture for painting and utensils and to propose methods to analyze the colors for further applications (e.g., industrial design).

2. COLOR ANALYSIS FOR A TWO-DIMENSIONAL OBJECT

2.1 Lighting

Based on the recommendation of American Institute for Conservation (Warda 2011), the light source can be fluorescent fixtures. If the flat object has pronounced texture, diffuse light sources are best in order to avoid creating confusing sets of double shadows. Lamps should be positioned approximately 25^o from the surface plane of the subject for minimizing surface glare. To achieve uniform illumination across the surface, the lamps should be placed as far from the subject as possible.

2.2 Image capturing

ICC-based color characterization (ISO 2010) is essential to digital photography. To analyze the color characteristics of a painting, it's better to calibrate the camera using a color management tool with reproduction (faithful) model first. However, most of the tools corrects hue while enhances image contrast with an S-shape tone curve. To estimate true colors of a painting, it's better to place a color target (e.g., Color Checker Mini or Kodak Q14) alongside the painting when taking the digital photos. To preserve the colorfulness of a painting, Adobe RGB is preferred to sRGB as the destination color space for image storage.

2.3 Uniformity correction

If the lighting of captured image was uneven but the background of the painting was uniform, bright and matte, one can take the following steps to correct the uniformity of illumination: (1) convert the image into XYZ space, (2) replace the foreground image by the nearest background color, (3) blur the processed background image intensively, (4) use the Y channel of blurred background as a luminance profile, (5) use the luminance profile to equalize XYZ values of the source image, and (6) convert the processed image back to RGB space.

2.4 Color correction

Color management tools are able to enhance the color accuracy of a digital camera to a certain level. However, photographers normally fine-tune the tone curve for preferred reproduction. It makes the RGB color not trustable. On the other hand, many ancient paintings in the National Palace Museum were not allowed to take new photos as they are nearly broken. Fortunately, the museum keeps old photos in hand and many of them containing Kodak Q14 target in the pictures. The color target can be used for estimating actual colors of the paintings (Figure 1). The colors can be corrected by the following steps: (1) take the RGB values of the grayscale in the target image with known colorimetric values (e.g., Adobe RGB values) to create gray-balance curves for RGB channel respectively, (2) smooth the curves, (3) use the color patches of the target to derive a 3x3 color correction matrix which connects gray-balanced RGB values to the corresponding colorimetric values, (4) process the source image using the smoothed gray balance curves, (5) correct the image colors using the 3x3 color correction matrix. The method is similar to common color correction approaches for digital cameras. Due to the correction would also bring right colors to wrong places, shift the source colors 50% towards the corrected colors is recommended.

Figure 1. Left: before color correction. Middle: after color correction (using the bottom Q14 target). Right: color correction with contrast enhancement.

2.5 Feature color extraction

The following steps are suggested to extract representative colors of a painting: (1) convert the RGB image to LAB space, (2) filter and downsize the source image to simulate vision blur under a typical viewing distance (Reinhard et al. 2008), (3) select a region of interest (ROI) to filter the edges and isolate points in the image content, (4) apply a modified K-means clustering algorithm in weighted LAB space where the weight for delta L* is a half to that of delta a* and b*, (5) remove very small clusters, (6) regard the centroid of each cluster as representative color swatches (Figure 2). Note that the number of cluster (K) is started at 20. An iterative approach is applied to reduce the K value automatically. The approach merges two nearest cluster centers below 6 weighted delta E. The iterative process stops when no cluster can be further merged. The final K value is image dependent.

2.6 Connect to different color order systems

The representative color swatches can be transferred to other color order systems (spaces) such as sRGB, HTML, ISO CMYK, NCS, Munsell, PCCS and Pantone using either ICC profiles (ISO 2010) or 3D look-up-table with interpolation (Trussell an Vrhel 2008) for industrial applications and further data analysis. The data can be summarized in many ways (Figure 2) such as color gamut, bubble plots (the size of bubble indicates the percentage of the feature color), pie charts and color tables (Figure 3). Color statistics can be made from the whole image or individual ROIs. Note that background color should be pointed out as it influences the statistic significantly. To compare color characteristics of different paintings, Earth Mover Distance (EMD) metric (Rubner, Tomasi, and Guibas 2000) is recommended. The metric enables to scale the dissimilarity of feature color histograms from any two images. Low EMD value implies that the color characteristics of the two images are very similar.

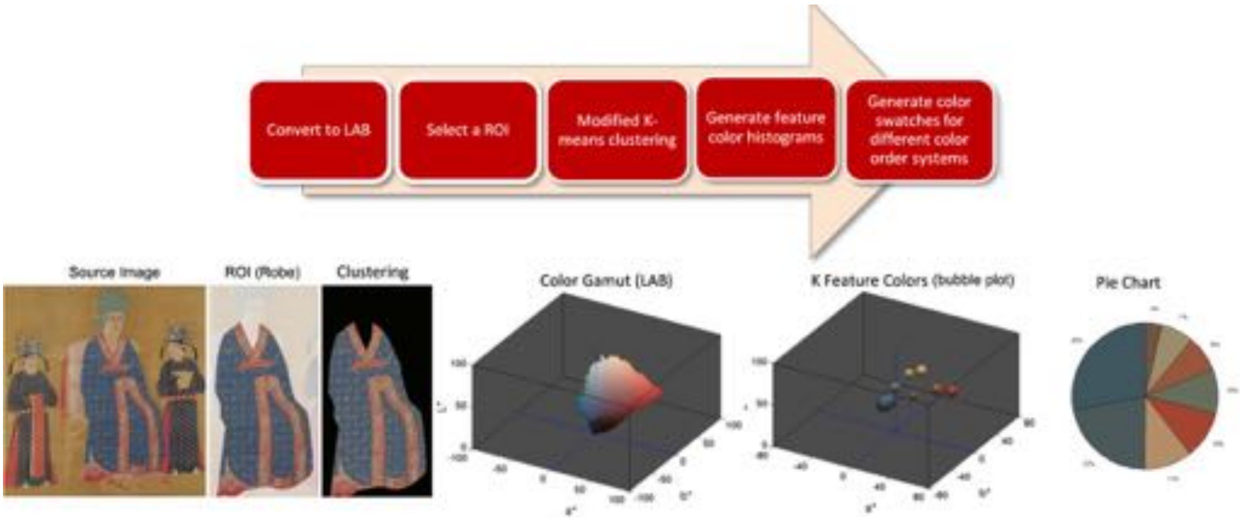

Figure 2. Color processing: from a color corrected image to various diagrams.

3. COLOR ANALYSIS FOR A THREE-DIMENSIONAL OBJECT

Two softboxes should be positioned close to the subject; one may be positioned slightly further back to introduce subtle shadows that define shape. To bring out surface details or to better separate the edge of the subject from the background, a single spot light can be added (Warda 2011).

To measure the gloss and diffuse components of a utensil more accurately, two exposures with different lighting geometries are recommended. The two components can be separated by comparing the image differences of the two images (Schuns and Teschner 1995). If the surface of the utensil is homogeneous, one image is enough to estimate the glossiness and shadows (Koschan and Abidi 2008). To extract reprehensive color swatches from the image, image background, gloss and shadow must be removed in advance. Gloss and shadow can be partly removed by scaling the vectors of gloss and diffuse components to 0 and 1 respectively in XYZ space. The other steps are similar to the description in Section 2 except the weight for delta L* is set as 1/3 of the others. The treatment will decrease the impact of highlight and shadow.

LAB	sRGB	ISO CMYK	Munsell	NCS	PCCS	Pantone		HTML	Perc.
35 -7 -8	64 86 95	49 24 22 57	5B 4/4	S-7010-B10G	16:gB-3.0-3s (dk)	445 C*	547 U	#40565F	28.1 %
37 -6 -2	74 89 89	41 22 29 59	10BG 4/2	S-7005-B70G	17:B-3.0-1s (g)	445 C*	5467 U	#4A5959	21.9 %
62 11 26	180 142 104	8 31 50 27	7.5YR 7/4	S-3520-Y30R	6:yO-6.0-3s (d)	4655 C*	873 U	#B48E68	10.6 %
42 39 33	164 69 48	9 78 74 32	7.5R 4/12	S-3060-Y75R	3:yR-4.0-6s (dp)	174 C	174 U*	#A44530	10.5 %
45 -6 9	102 110 92	31 18 41 50	7.5GY 5/2	S-6010-G40Y	11:yG-4.0-1s (g)	417 C*	5743 U*	#666E5C	9.9 %
44 26 27	152 87 61	11 62 64 36	2.5YR 4/8	S-4535-Y60R	5:O-4.0-4s (dk)	7516 C*	1685 U*	#98573D	8.1 %
59 2 20	156 141 107	12 20 44 36	2.5Y 6/2	S-4015-Y	8:Y-6.0-2s (d)	7503 C*	4505 U	#9C8D6B	7.3 %
39 11 13	113 84 70	20 45 48 54	2.5YR 4/2	S-6510-Y55R	5:O-3.5-2s (dk)	7518 C	4625 U	#715446	3.7 %

Figure 3. The LAB values of eight color swatches extracted from the robe in Figure 2. The corresponding values of 9 different color order systems also listed.

4. CONCLUSIONS

Methods for capturing and analyzing digital images of cultural heritage are proposed. The requirements for 2D and 3D object are different. Both of them start from well-defined lighting and color correction. The reprehensive color swatches can be extracted from the digital image by a K-means based algorithm. The impacts of background, gloss and shadow must be removed before the color extraction. Various color spaces can be used for analyzing the data and generating accurate color swatches for industrial applications.

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REFERENCES

International Organization for Standardization (ISO). 2010. 15076-1:2010: *Specification ICC.1:2010-12 Image technology colour management - Architecture, profile format, and data structure*

Koschan, A. and M. Abidi. 2008. *Digital Color Image Processing*, Wiley-Interscience, 186-194.

Reinhard, E., E. A. Khan, A. O. Akyüz, and G. M. Johnson. 2008. *Color Imaging: Fundamentals and Applications*, A K Peters, 605-620.

Rubner, Y., C. Tomasi, and L. J. Guibas. 2000. The earth mover's distance as a metric for image retrieval, *International Journal of Computer Vision*, 40(2):99-121.

Schuns, K. and M. Teschner. 1995. Analysis of 2d color spaces for highlight elimination in 3d shape reconstruction, *Proc. Asian Conf. on Computer Vision*, 2:801-805.

Trussell, H. J. and M. J. Vrhel. 2008. *Fundamentals of Digital Imaging*, Cambridge University Press, 486-494.

Warda J. 2011. *The AIC Guide to Digital Photography and Conservation Documentation*, 2nd ed., American Institute for Conservation, 113-130.

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Errors Involved in Profiles in Color Management Systems

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ABSTRACT

Scanning an image by a profiled scanner, can not easily be interpreted by other operating systems. Therefore, it is usually recommended to convert the image profile into a device-independent profile such as sRGB (for RGB images) in order to be able to accurately perceive the correct color image in all other operating systems. Several mathematical procedures must be performed on colored images, in order to convert the profile into a device independent profile which will obviously introduce errors in the results. The present paper, intends to calculate such errors for 2000 random samples in terms of calculated color differences by the aid of DE2000 color difference equation. Sometimes the errors are so large that the converting process causes to be a good technique. Therefore, it is recommended to use embedding profile to prevent color change.

1.INTRODUCTION

Color management systems means by which true color values of an image are visualized in various digital devices such as monitors, printers, scanners and etc. Color management systems are intended to actually visualize colors independent of devices (Sachs 2008).

The International Color Consortium was founded in 1992 under the auspices of the German research institute FOGRA. On board from the beginning were operating system manufacturers (Apple, SUN and Silicon Graphics), AGFA and Kodak with traditional knowledge of color and the PostScript inventor from Adobe. The large repro vendors Crosfield, Linotype- Hell, Scitex and Screen were not involved at this point in time. Microsoft maintained an equally low profile, only to join the ICC later under pressure from the competition (Homann 2009:117 -116).

All color management systems based on ICC have four components (Lukac 2007:chapter 1):

PCS: The profile connection space allows to give a color an unambiguous numerical value in CIE XYZ or CIE LAB that doesn't depend on the quirks of the various devices used to reproduce that color, but instead defines the color as we actually see it (2010).

Profiles: A profile describes the relationship between a device's RGB or CMYK control signals and the actual color that those signals produce. Specifically, it defines the CIEXYZ or CIE LAB values that correspond to a given set of RGB or CMYK numbers.

A profile can describe a single device, such as an individual scanner, monitor, printer or a class of devices, such as Apple Cinema Displays, Epson Stylus Photo 1280 printers, or SWOP presses; or an abstract color space, Such as Adobe RGB (1998) or CIE LAB. A profile is a lookup table, with one set of entries that contains device control signal values (RGB or CMYK numbers) and another set that contains the actual colors, expressed in the PCS, that those control signals produce or a matrix containing tags that describe the CIEXYZ values of the primaries, which form the matrix, plus tags that contain the tone reproduction characteristics of each colorant (Fraser 2005:79-98).

CMM: The CMM (Color Management Module), often called the engine, is the piece of software that performs all the calculations needed to convert the RGB or CMYK values. The CMM works with the color data contained in the profiles (Tapp 2009:Chapter 2, Adobe Photoshop 2009, SNMP 2007, Cisco ICM 2004).

Rendering intents: The ICC specification includes four different rendering intents, which are simply different ways of dealing with "out of gamut" colors that are present in the source space that the output device is physically incapable of reproducing (Sharma 2003: chapter 4).

Scanning an image by a profiled scanner, cannot easily be interpreted by other operating systems. Therefore, it is usually recommended to convert the image profile into a device-independent profile such as sRGB (for RGB images) in order to be able to accurately perceive the correct color image in all other operating systems. Several mathematical procedures must be performed on colored images, in order to convert the profile into a device independent profile which will obviously introduce errors in the results. The present paper, intends to calculate such errors in terms of color differences as calculated by the DE2000 color difference equation.

2. EXPERIMENTAL

2000 random color coordinates in the RGB color space with a 8 bit color depth in each channel which were used to compute errors involved in converting profiles. Figure 1 depicts 2 and 3 dimensional representation of these color coordinates in the RGB color space.

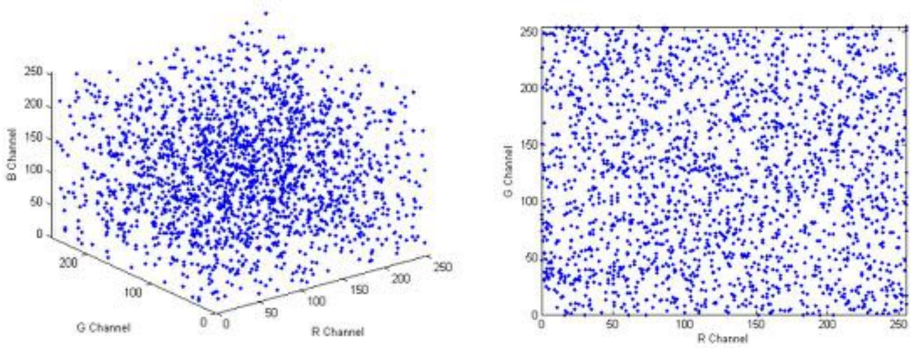

Figure 1- 2000 random color coordinates (left) in RGB color space (right) and their respective in RG coordinates

Three internal RGB color spaces, namely, WideGamut (Gamma=2.2), AdobeRGB (Gamma=2.2) and sRGB (Gamma=2.2) were used to compute errors involved in converting profiles in various conditions. It must be mentioned that the white point of sRGB and AdobeRGB is taken to be illuminant D65, however, in this article the white point is taken to be illuminant D50 in order to avoid problems of color constancy. Additionally, a prepared profile for an Epson Stylus photo P50 (printed on a super gloss 260 g/m^2 Lucky paper) at 25 grids and under D50 was used to check the errors involved converting to LUT profiles. Figure 2, illustrates color gamuts of 4 color spaces under D50 illuminant.

The printer profile was made by the Profile Maker 5.0 software (made by GretagMacBeth) and the eyeone-Io spectrophotometer to carry out the color management process.

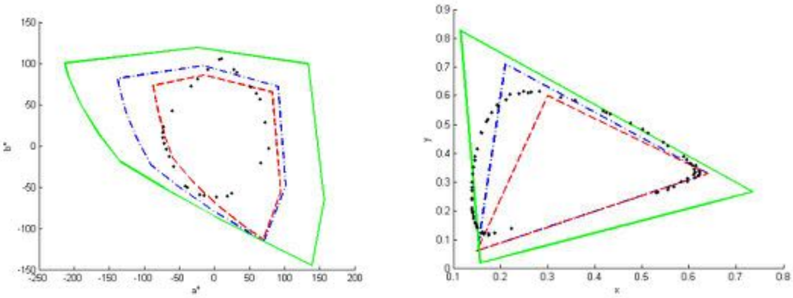

Figure 2- color gamut of sRGB (-), AdobeRGB (-.), WideGamut (_) and Epson P50 printer (.) xy coordinates in xyY color space (right) and a^*b^* coordinates in $L^*a^*b^*$ color space (left)

3. RESULT AND DISCUSSION

When a profile is converted to another profile, due to many arise errors the color coordinates of a device independent color in the destination profile will be different from the source profile. These errors may be as follows:

1- Errors arising from rounding off the decimal values
2- Errors arising from interpolating in tables of the LUT profiles
3- Errors arising from transferring "out of color gamut" colors

3.1. Errors arising from rounding off the decimal values

Since sRGB images were converted to AdobeRGB or WideGamut profiles, the RGB values would automatically be rounded off in the new profile and subsequently incorrect values will be displayed. This effect can easily be demonstrated by converting a color image from one profile to another and then reverting the process to re-obtain their original values. the results are shown in table 1.

Table 1- rounding off errors of decimal values in converting from sRGB to AdobeRGB or WideGamut and reconverting to their original values.

sRGB Convert To	DE2000 Mean	DE2000 Max	DE2000 STD
AdobeRGB	0.07	0.68	0.12
WideGamut	0.20	1.68	0.20

3.2. Errors arising from interpolating in tables of the LUT profiles

Interpolation procedures (either by a color management system and/or by an imaging software) is carried out in look up table profiles to predict unavailable values in such tables. Such interpolation procedures introduce errors in such predictions. For instance converting RGB values defined by a look up table profile to CIELAB values and the reverse process will produce different RGB values compared to the original RGB values. The errors in the created profile to be printed by an Epson P50 printer on gloss paper were converted from LAB to RGB and then reconverted by this profile are shown in table 2.

Table2- Interpolation errors of converting reconverting in LUT profiles

Rendering Intent	DE2000 Mean	DE2000 Max	DE2000 STD
Perceptual	0.9	3.19	0.49
Relative Colorimetric	1.19	3.37	0.54
Saturation	0.89	3.19	0.49
Absolute Colorimetric	0.86	3.32	0.50

3.3. Errors arising from transferring "out of color gamut" colors

In converting an image rendered using a profile having a bigger gamut to a new profile with a smaller gamut, several colors will be "out of gamut" in the new profile. Therefore, it is necessary to shift the "out of gamut" colors to be included in the new profile. This procedure, will undoubtedly introduced errors. In switching from AdobeRGB or WideGamut having a bigger color gamut to sRGB having a smaller color gamut and then reconverting to obtain original values, average errors shown in table 3 will be introduced.

Table 3- errors due to "out of gamut" colors for converting WideGamut to AdobeRGB or (sRGB) and then re-converting.

Convert WideGamut To	DE2000 Mean	DE2000 Max	DE2000 STD
AdobeRGB	3.33	17.3	4.08
sRGB	5.56	17.3	5.13

Such mentioned errors illustrate that embedding a profile for displaying an image for another operating system, introduces less errors than converting the original profile to a device independent profile.

It was shown that in this study that errors involved in converting an original profile to a device indepent profile involves various errors ranked to be out of color gamut errors> interpolation errors> rounding off decimal errors. These errors show that embedding a profile in order to display an image in a different operating system is generally preferable.

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REFERENCES

1- Sachs, J. 2008. Color Management. Digital Light & Color. Available online, ftp2. bmtmicro. com/dlc/ Color_Management.pdf
2- Homann, 2009. Digital Color Management .Berlin: Springer .
3- Lukac, R., K. N. Plataniotis. 2007. Color image processing (Methods and applications), University of Toronto.
4- 2010. Specification ICC.1:2010 (profile version 4.3.0.0). Available online, www.color.org.
5- Fraser, B., C. Murphy, F. Bunting .2005. Real World Color Management, Berkeley:peachpit press.
6- Tapp, E. 2009. Practical Color Management. Sebastopol: O'ReillyMedia.
7- Adobe Photoshop. 2009. Color Management Workflow in Adobe After Effects CS3.
8- SNMP. 2007. SNMP Guide for Cisco ICM/IPCC enterprise & hosted editions. Available Online, www.cisco.com
9- Cisco ICM- Windows 2000 planning. 2004. www.cisco.com
10- Sharma, G. 2003. Digital color imaging handbook, New York: CRS press.

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Methods for Assessing Blackness

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ABSTRACT

Thirty-nine untrained British and Korean observers took part in the assessment of blackness. The two observer groups showed good agreement in terms of blackness scaling. It was found that the new blackness model fitted quite well with the Natural Colour System (NCS) blackness. The observers tended to regard the bluish tint as the most blackish colour. On the basis of the experimental results, a new psychophysical model of blackness was developed.

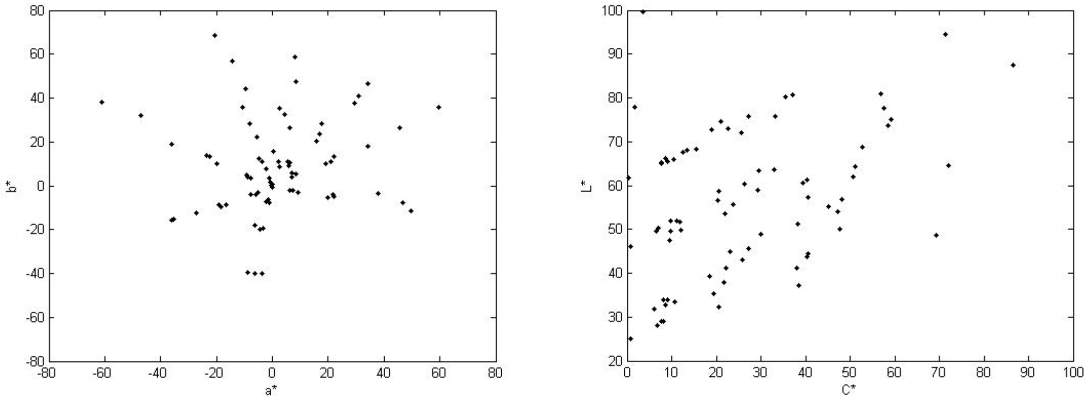
1. INTRODUCTION

Blackness is an appearance attribute defined as the perception as the closeness to an ideal black. It is included in the Natural Colour System (NCS) (Hard et al., 1981). It is also an important attribute in the graphic art applications such as grey component removal, black point set up and image contrast. Similarly, black level set up is equally important for displays. Hence, the darker the black point, the higher image quality of the reproduction system. Westland et al (Westland et al., 2006) developed a model based on CIELAB to predict blackness. At a later stage, the same research group (Tao et al., 2011) found that bluish blacks were regarded as darker than the other colours having the same lightness.

The leading author studied the attributes of vividness and saturation earlier (Cho et al., 2011). The present paper describes part of the studied into the scaling of blackness.

2. EXPERIMENTAL METHOD

A psychophysical experiment was carried out to assess blackness of colour stimuli using categorical judgement method (Torgerson, 1958). Nineteen British and 20 Korean observers participated in the experiment. All observers had normal colour vision, with little knowledge about colour science and naive to purpose of this study. Each observer rated 77 colour samples in terms of blackness using a six-point forced choice scale from 1(meaning low blackness) to 6 (high blackness). Figures 1 (a) and (b) show the 77 colours used in this experiment, as plotted in CIELAB a*b* and $L^*C^*_{ab}$ planes, respectively. The colours were selected from NCS atlas having 3×3 inch in size, of which 20 samples were assessed twice for testing repeatability. These samples covered a wide range of hue, chromaticness and blackness. Each colour was assessed under a D65 simulator in a VeriVide viewing cabinet with a grey background (X=160.01, Y=165.51, Z=187.82 (cd/m^2). The reference white of this study was X=479.05, Y=495.40, Z=548.94. Figure 2 illustrates the experimental conditions. The viewing distance between the observer and each colour sample was about 60 cm. The entire experiment was carried out in a darken room, i.e. the only light source came from the viewing cabinet.



(a) (b)

Figure 1 The 77 colour samples in (a) CIELAB a-b* and (b) L*-C^*_{ab} spaces*

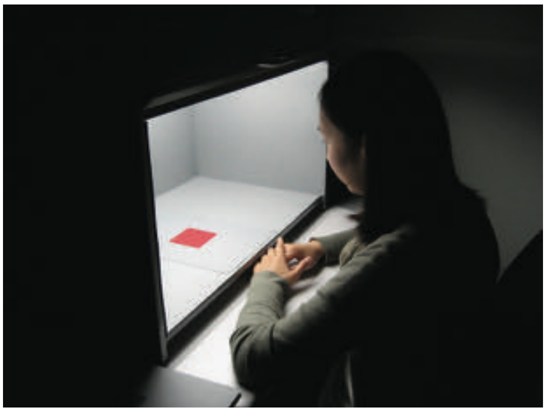


Figure 2 Experimental set-up

3. RESULTS

Intra- and inter- observer variability was calculated in terms of root mean square (RMS): 0.94 and 1.08, respectively. Comparing the values with test results for saturation and vividness obtained previously (1.19 and 1.46 RMS respectively), the scaling of blackness seemed to be more reliable and repeatable than scaling of the other two attributes.

High agreement was found between the British and Korean data, with a correlation coefficient of 0.94. Figure 3 shows the blackness results for the two groups of observers, illustrating high correlation between data of the two observer groups.

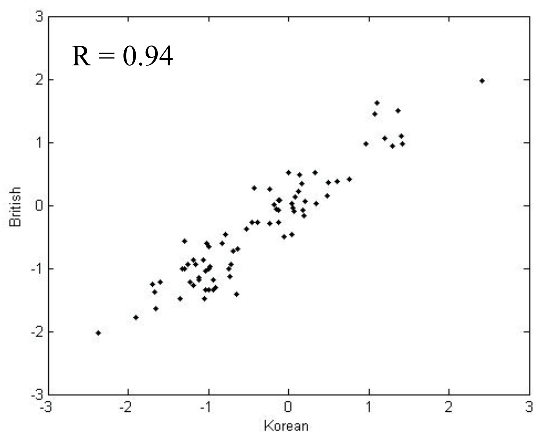


Figure 3 Data plot between Korean and British Blackness

The averaged Korean and British data were used to test three blackness formulae: NCS (Hard et al., 1981), Westland's model (Westland et al., 2006, see Equation 1) and the new formula developed here based on CIELAB, as given in Equation 2.

$$\text{Blackness (Westland)} = 8.6542 - 0.2583L^* - 0.0052a^{*2} + 0.0045b^{*2} \quad (1)$$

$$\text{Blackness} = 3.02 - 0.05\{(L^*)^2 + 0.89(a^*+2)^2 + 0.36(b^* - 33)^2\}^{1/2} \quad (2)$$

Here L*, a* and b* are CIE lightness and the CIELAB coordinates for the red-green and yellow-blue axes, respectively.

The results of the predictive performance are: 0.92 for NCS blackness, 0.36 for Westland's model (Equation 1) and 0.94 for the newly developed blackness formula (Equation 2), as also demonstrated in Figures 4 (a) to (c), respectively. The results indicate that both the NCS blackness and the new formula fit the experimental data quite well, whereas Westland's model does not seem to perform well here.

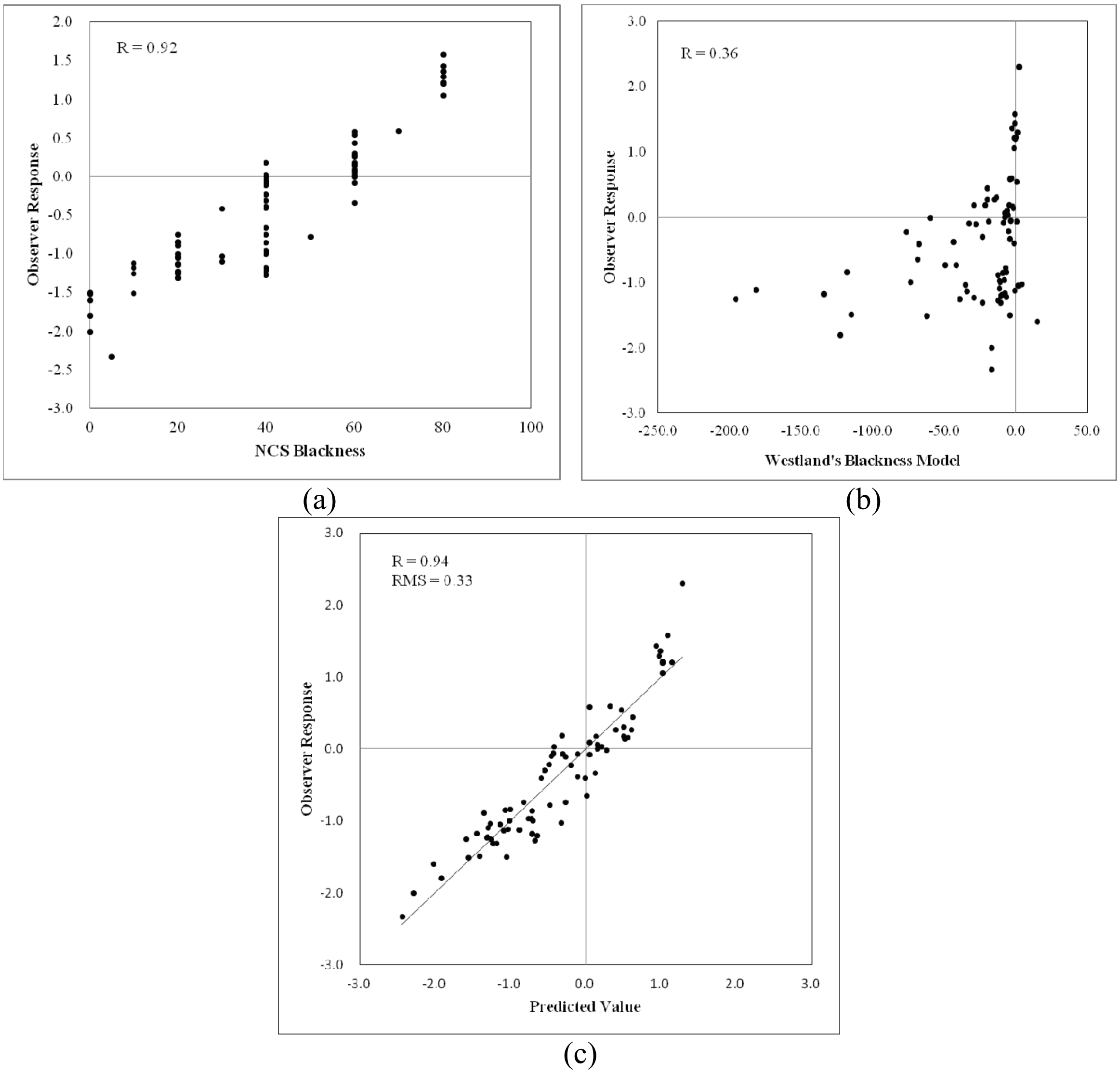


Figure 4 correlations between observer response and (a) NCS Blackness, (b) Westland's Blackness model and (c) a new blackness model proposed from the present study (Eq 2)

Equation 2 also suggests that the further away from a yellow black "black", (a*, b*) = (-2, 33), the lower the blackness value is, i.e. for colours of the same lightness level, those having a bluish tint tended to appear blacker than the other. This seems to agree with the finding of Tao et al. (Tao et al., 2011) which claimed that observers tend to regard a bluish black as being darker than other blacks.

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4. CONCLUSION

Good agreement was found between untrained, naive British and Korean observers, suggesting little effect of cultural backgrounds on the scaling of blackness between the two countries, using categorical judgement method. It was found that the NCS blackness fitted quite well with the new experimental data, with a correlation coefficient of 0.92. According to the experimental results, the observers, including both British and Korean, tended to regard the bluish blacks as being darker than other tints of blacks.

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REFERENCES

Hard, A, L. Sivik. 1981. NCS-Natural Color System: A Swedish standard for color notation. *Color Research and Application* 6 (3): 129-138.
Westland, S., T.L.V. Cheung and O.R. Lozman. 2006. A metric for predicting perceptual blackness, *Proceedings of the IS&T/SID's Color Imaging Conference*, Scottsdale, USA: 14-17.
Tao, L., S. Westland and V. Cheung, 2011. Blackness: preference and perception, *Proceedings of the IS&T/SID's Color Imaging Conference*, San Jose, USA: 270-275.
Cho, Y., L. Ou and M. R. Luo, 2011. Alternatives to the third dimension of colour appearance, *Proceedings of the IS&T/SID's Color Imaging Conference*, San Jose, USA: 88-93.
Torgerson , W.S., 1958. Theory and Methods of Scaling, New York: John Wiley & Sons

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Comparison of various whiteness formulae based on results of whiteness evaluation experiments

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ABSTRACT

The results of four systematically conducted experiments and their relationship with the predicted value of each type of whiteness formula, including the CIE whiteness formula, were examined, with the purpose of selecting the most superior whiteness formula. As a result of comparing the various formulae with respect to predicting performance, ease of calculation, and presence or absence of applicable scope, it became clear that the Grum whiteness formula is the most superior.

1. INTRODUCTION

As whiteness evaluation varies greatly between observers, it is desirable to compare experiment results with a large number of observers when assessing predicting performance of whiteness formulae. Accordingly, in this report, results from experiments systematically conducted by the Committee on Specification Method of Whiteness of the Color Science Association of Japan and the Special Interest Group on Whiteness of the Color Science Association of Japan (Katayama *et al*. 2011), and the relationship with the predicted value of each type of whiteness formula, including the CIE whiteness formula (CIE 2004), were examined, with the purpose of selecting the whiteness formula with the most superior predicting performance.

2. SUMMAY OF EXPERIMENTS CONDUCTED BY THE COMMITTEE ON SPECIFICATION METHOD OF WHITENESS

The Committee on Specification Method of Whiteness (CSMW) was set up with the purpose of accepting whiteness formula recommendations from the CIE and preparing standardization in Japan. This committee conducted the following three experiments in 1987. These were evaluations of 18 types of white cloth samples by 74 observers (CSMW-I), evaluations of 29 types of white paper samples by 74 observers (CSMW-II), and evaluations of 47 samples combining white cloth samples and white paper samples by 46 observers (CSMW-III). The observers of CSMW-I and CSMW-II were the same, some observers from CSMW-I and CSMW-II participated in CSMW-III. The observers all had normal color vision.

The chromaticity scope of the samples was established to encompass a range with a high likelihood of being treated as white cloth or white paper within Japan. Figure 1 shows the chromaticity distribution of the samples under Standard Illuminant D65. In Figure 1, the white paper samples are shown with circles, and the white cloth samples are shown with squares. Solid circles and squares are samples outside the CIE whiteness formula applicable scope. The tristimulus values of each sample were calculated from the spectral radiance factor, measured with a Xenon lamp as a light source.

For the visual evaluation of whiteness, D65 fluorescent lamps were used as a light source, and the luminance of the sample surface was roughly 1000 lx. Observers compared all the samples simultaneously, and conducted a ranking of whiteness. Whiteness interval scales were constructed from the ranking results by means of normalized ranking.

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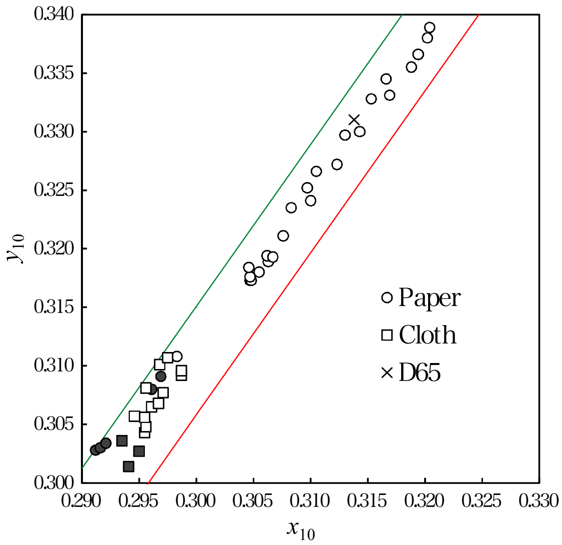

Figure 1. Chromaticity distribution of samples used in the CSMW experiments

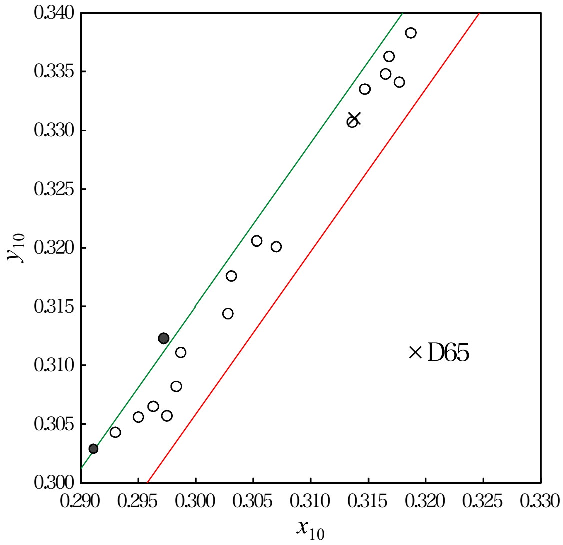

Figure 2. Chromaticity distribution of samples used in the SIGW experiment

3. SUMMAY OF EXPERIMENT CONDUCTED BY THE SPECIAL INTEREST GROUP ON WHITENESS

The Special Internet Group on Whiteness (SIGW), of which the authors are members, conducted evaluation experiments of white cloth samples from 2006 to 2007 at the Rochester Institute of Technology (RIT) in the U.S.A., Joshibi University of Art and Design (JUAD), and Kurashiki City College (KCC). A total of 69 observers participated in the experiment. The observers all had normal color vision.

In Figure 2 the chromaticity distribution of the samples under Standard Illuminant D65 is shown. Solid circles are samples outside the CIE whiteness formula applicable scope. The sample tristimulus values were calculated from ISO whiteness-adaptive spectrophotometer measurements.

For the visual evaluation of whiteness, D65 fluorescent lamps (JUAD, KCC) or tungsten halogen lamps with a filter to simulate the D65 (RIT) were used as a light source, and the luminance of the sample surface ranged from 1200 lx (JUAD) to 1600 lx (RIT). In the same way as with the CSMW experiments, whiteness interval scales were constructed.

4. EXPERIMENT RESULTS AND RELATIONSHIP WITH PREDICTED VALUES OF EACH WHITENESS FORMULA

No matter which experiment, the difference of the visual evaluation results among observers was large, but although, in this study we will discuss the average evaluation results only, in order to compare with the predicted values of whiteness formula.

Table 2. Predicting performance of the CIE whiteness formula

	all samples		samples inside the applicable scope	
CSMW I	- 0.788	**	- 0.263	n.s.
CSMW II	0.468	*	0.902	**
CSMW III	0.208	n.s.	0.787	**
SIGW	0.773	**	0.868	**

**: 1%, *: 5%

Whiteness formulae can be classified into the following five categories from their composition. Type 1, which is expressed with one tristimulus value; type 2, which is expressed through a combination of two or three tristimulus values; type 3, which is expressed as a function of lightness and chromaticness; type 4, which is expressed as a color difference from a reference white point; and type 5, which has all other compositions. A total of 16 whiteness formulae were selected corresponding to each type. In addition to whiteness formula, various psychometric values and their relationship with experiment results were also considered. Table 1 shows the evaluated whiteness formulae, psychometric values, *etc*.

The simple correlation coefficients between the predicted values of the CIE whiteness formula and each experiment result are shown in Table 2. If samples outside the applicable scope are excluded, the correlation coefficients with experiment results rise to a large degree, however the CSMW-I results are completely unpredictable by the formula.

The simple correlation coefficients between the measures which showed a positive correlation with all experiment results and the experiment results are shown in Table 3. The predicting performance rank among the measures obtained on the basis of Table 3 values, and their medians, are shown in table 4, respectively.

Table 3. Simple correlation coefficients between the measures which showed a positive correlation with all experiment results and the experiment results

	X_{10}	Y_{10}	Z_{10}	L^*_{10}	Hunter L_{10}	Stenius	Uchida	Grum
CSMW I	0.936	0.970	0.496	0.970	0.970	0.535	0.786	0.900
CSMW II	0.604	0.497	0.705	0.497	0.493	0.695	0.750	0.923
CSMW III	0.792	0.757	0.431	0.757	0.754	0.430	0.706	0.669
SIGW	0.713	0.598	0.793	0.598	0.597	0.796	0.818	0.827

Table 4. Predicting performance rank among the measures

	X_{10}	Y_{10}	Z_{10}	L^*_{10}	Hunter L_{10}	Stenius	Uchida	Grum
CSMW I	4	3	8	2	1	7	6	5
CSMW II	5	6	3	7	8	4	2	1
CSMW III	1	2	7	3	4	8	5	6
SIGW	5	7	4	6	8	3	2	1
median	4.5	4.5	5.5	4.5	6	5.5	3.5	3

From Tables 3 and 4 it can be seen that the predicting performance of the Grum whiteness formula (Grum *et al*. 1974), and subsequently the Uchida whiteness formula (Uchida 1998), are superior. The Grum whiteness formula differs from the CIE whiteness formula in that its applicable scope is not restricted, and it is easier to calculate compared to the Uchida whiteness formula.

5. CONCLUSION

The applicable scope of the CIE whiteness formula is narrow when compared to the chromaticity scope for that which is treated as white cloth and white paper within Japan, and it does not correlate at all with experiment results using samples with strong bluish tint.

The Grum whiteness formula is superior from any point of view including predicting performance, presence or absence of applicable scope, and ease of calculation.

Table 1. Whiteness formulae and psychometric values evaluated

Type	Formula	Identification Name	Note
1	$W_{10} = Y_{10}$	Y_{10}	ASTM Method E97-53T(1953)
	$W_{10} = Z_{10}$	Z_{10}	TAPPI Method T425m-48(1948)
2	$W_{10} = 0.333Y_{10} + 1.060Z_{10} - 1.277X_{10}$	Berger	
	$W_{10} = 3.67Z_{10} - 3Y_{10}$	Taube	
3	$W_{10} = L_{10} - 3b_{10}$	Hunter 1	L and b are Hunter coordinates.
	$W_{10} = Y_{10} - 13.2Y_{10}\left\{(\Delta u_{10})^2 + (\Delta v_{10})^2\right\}^{1/2}$	Croes	$\Delta u = u - u_0$, $\Delta v = v - v_0$, u and v are the chromaticity coordinates in the 1960 UCS diagram. u_0 and v_0 are the chromaticity coordinates of the perfect diffuser.
	$W_{10} = L_{10} + 3a_{10} - 3b_{10}$	Stensby	L, a, and b are Hunter coordinates.
	$W_{10} = \frac{100 + Y_{10}}{2} - 2000\beta_{10}$	Fukuda	β is a coordinate of Hunter UCS diagram.
4	$W_{10} = 100 - \left\{\left[\frac{220.2(Y_{10} - Z_{10})}{Y_{10} + 0.242Z_{10}}\right]^2 + \left[\frac{100 - Y_{10}}{2}\right]^2\right\}^{1/2}$	Hunter 2	
	$W_{10} = 100 - \left\{(100 - L_{10})^2 + 10b_{10}^{\ 2}\right\}^{1/2}$	Hunter 3	L and b are Hunter coordinates.
	$W_{10} = 100 - \left\{\left[3000\left((\alpha_{10} - \alpha_{n,10})^2 + (\beta_{10} - \beta_{n,10})^2\right)^{1/2}\right]^2 + \left(\frac{100 - Y_{10}}{200}\right)^2\right\}^{1/2}$	Hunter–Judd	α and β are coordinates of Hunter UCS diagram. α_n=−0.0051, β_n=0.0099.
	$W_{10} = 100 - \left\{(100 - Y_{10})^2 + 9.5\times10^5(\Delta S_{10})^2\right\}^{1/2}$	Selling	Δs is a distance on the CIE 1960 UCS diagram between the illuminant point and the test point.
5	$W_{10} = Y_{10} + 800(x_{n,10} - x_{10}) + 1700(y_{n,10} - y_{10})$	CIE	x_n and y_n are the chromaticity coordinates of the perfect diffuser under the CIE illuminant D65.
	$W_{10} = 9.53\left(0.9\times\frac{\frac{1 - x_{10} - y_{10}}{1.089y_{10}}Y_{10} - 100}{100}Y_{10} + 19.19\right)$	Stenius	
	$W_{10} = 3.8Z_{10} - 1201S_{10} - 270.1$	Grum	S is a distance on the CIE xy chromaticity diagram between the illuminant point and the test point. In the original formula, saturation is determined in MacAdam's geodesic chromaticity diagram.
	$W_{10} = W_{CIE,10} - 2(T_{W,10})^2 \quad [40 < W_{CIE,10} < 5Y_{10} - 275]$ $W_{10} = P_{CIE,10} - 2(T_{W,10})^2 \quad [W_{CIE,10} > 5Y_{10} - 275]$	Uchida	T_W is the CIE tint index. $P_{W,10}$=(5Y_{10}−275)−(800[0.2742+0.00127(100−Y_{10})−x_{10}]$^{0.82}$+1700[0.2762+0.00176(100−Y_{10})−y_{10}]$^{0.40}$)
Other metrics			
	X_{10}, L^*_{10}, Hunter L^*_{10}, a^*_{10}, b^*_{10}, $C^*_{10,ab}$		

REFERENCES

CIE. 2004. *Publication No. 15, Colorimetry*. Vienna: Central Bureau of the CIE: 26.

Grum, F., R. F. Witzel, P. Stensby. 1974. Evaluation of whiteness. *Journal of the Optical Society of America* 64(2): 210–215.

Katayama, I., H. Uchida, H. Sobagaki, G. Baba. 2011. Comparison of experimental results of whiteness evaluation by observers with different cultural backgrounds. *Journal of the Color Science Association of Japan* 35(1): 2-9.

Uchida, H. 1998. A new whiteness formula. *Color Research and Application* 23(4): 202–209.

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A fast and accurate algorithm for calculating the color gamut boundary of multi-primary device

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ABSTRACT

In recent years, the displays trend towards large size, light weight, super thin, and small smart-phones applications. At the same time, accurate color reproduction is also highly desired. Recently, multi-primary color displays is becoming a development trend. Multi-primary color device easily provides a larger color gamut than the one of three primary devices. Moreover the ability for truthful color reproduction is a major index to evaluate the quality of displays. So, in color mapping, we need to obtain the color gamut boundary (CGB) of displays. For the former technology of CGB, the data distribution for calculating the CGB of a reproduction device is not uniform, and then it causes some error in the implementation of color gamut mapping, CGB of a multi-primary additive color system based on color mixing theory. Then the uniform CGB in CIELAB color space can transformed from CIE xyY color space by inserting some color points between the extremes and adopting appropriate light sampling. This thesis provides a method to calculating the CGB of multi-primary device. By this method to determine the error of CGB in CIE xyY space is about 0.01, and in CIELAB space is about 5 because the impact of the extraneous light, stability of the projector, and color meter monitor.

1. INTRODUCTION

Color gamut of Multi-primary color (MPC) devices is presented as a polygon shape in CIE xyY chromaticity diagram, can to broaden the color gamut and more perceptible colors of display. An MPC lighting can provide not only incretion color gamut in an illumination area, but also high color rendering index to reproduce the colors of various objects faithfully in comparison with a natural light source. Many MPC applications need to know the color gamut boundary (CGB) of displays. The CGB is a device property representing the color range reproduced by the MPC device. The color gamut boundary is the shell of the color volume containing all displayed colors. The MPC system requires CGB to define color limitations. So, CGB can be provided a potent tool to solve the problems of MPC devices, and design a new MPC device.

Color mapping is transfer colors from one device to another device [1]. In color mapping, we need to obtain the CGB of displays. Obviously, the color gamut boundary of MPC is determined by additive color mixing theory [4]. It can determine the CGB by its apexes in CIE xyY space. When we obtain the xyY coordinates and their maximal brightness of the three or multiple primaries, the extremes of CGB in CIE xyY color space can be determined directly.

2. METHOD

In 1976, CIE proposed the CIELAB color space. The CIEXYZ system transfer to the CIE L*a*b* systems by the following equations (2- 1) to (2- 3):

$$L^* = 116\left[f(\frac{Y}{Y_n}) - \frac{16}{116} \right] \qquad (2\text{-}1)$$

$$a^* = 500\left[f(\frac{X}{X_n}) - f(\frac{Y}{Y_n}) \right] \qquad (2\text{-}2)$$

$$b^* = 200\left[f(\frac{Y}{Y_n}) - f(\frac{Z}{Z_n}) \right] \qquad (2\text{-}3)$$

If $Y/Y_n>0.008856$, $f(Y/Y_n)=(Y/Y_n)^{1/3}$,and if $Y/Y_n \leqq 0.008856$, $f(Y/Y_n) = 7.787(Y/Y_n)+16/116$, and the function $f(X/X_n)$ and $f(Z/Z_n)$ are defined similarly.

A real-time color volume construction of MPC device, whose samplings at lightness L* are uniform in CIELAB space, can be implemented by following the steps shown in Fig. 1,(a) First, each set of primary-color coordinates and their maximum color intensity of displays must be obtained. Second, the gamma value of the curve of color intensity versus sampling index is set at 3. Third, the amount of sampling at color intensity is considered with a tolerance for color volume accuracy. Fourth, the CGB apexes in CIE xyY can be computed by the color mixing theory [2] [3], where the curve and amount of color intensity sampling are set in the second and third step. Fifth, the amount of samplings inserted between the boundary neighbor apexes at equal boundary is considered with a tolerance for color volume accuracy. Sixth, the sampling coordinates inserted between the neighbor boundaries apexes in CIE xyY are computed by interpolation. Seventh, the sampling coordinates between the neighbor boundary apexes are transformed from CIE xyY into CIELAB space by (2-1) to (2-3). Finally, the color volume in CIELAB space based on the coordinates obtained from the last step is constructed [4]. Several papers have researched the process of constructing color volume from point to a close surface [5-6].

3. EXPERIMENT and RESULT

Two projectors (Projector I and Projector II are LCD projectors, professional EX-2700) and a color meter (BM-7A) are used as the color signal sources and the receiver, respectively. Fig. 1, (b) shows the experiment framework. Projector I provides red, green, and blue light using the digital information (α, β, γ), and Projector II provides yellow light by using a color filter in front of the projector lens, and by setting the digital information as (0,λ, λ) here α, β, γ, λ vary from 0 to 255. The screens of both projectors are fixed at the same location and display the same size color patches at full screen. The color analyzer (BM-7A) is located in the screen center of the color patches overlap by 1 meter in front of screen center. All possible extremes on the gamut boundary can be obtained by measuring the colors of the proposed digital information (α, β, γ, λ), where α, β, γ, λ vary from 0 to 255 with 16-step intervals in this experiment. The colors on the gamut boundary are measured and plotted in CIE xyY space as

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Fig. 2, (a). A blue point marks the gamut boundary data by color meter measurement. From this data, black lines are each primary-color coordinates with maximum and color intensity is selected for color volume simulation.

The four-primary coordinates of the four-primary color display, red, green, blue, and yellow are (0.5994, 0.3525), (0.0.3333, 0.6349), (0.1427, 0.0786), and (0.2257, 0.6639), respectively. The maximal luminous fluxes of red, green, blue and yellow are 60.75, 448.8, 50.89, and 245 lx, respectively. The CGB apexes sampled at color intensity with the gamma value of 3 in CIE xyY space are computed computed as proposed above. The apexes at the same color intensity are linked, producing polygonal boundaries which are marked with black lines, as Fig. 2, illustrates. The sampling amount of color intensity is 100 layers. The number of sampling points inserted between two neighbor CGB apexes is 20 points. The CGB apexes and these inserted points are transformed from CIE xyY space into CIELAB space by (2-1) to (2-3). The average color difference between the measuring points and CGB simulations in CIE xyY is about 0.01, and the one in CIELAB is about 5.

4. CONCLUSIONS

Clearly, from Fig 2, the simulations and actual measurements are seriously unmatched, where the backlight leakage coordinate that digital information is set as (0, 0, 0, 0) is (0.2375, 0.5153). Backlight leakage has a little impact on color volume in CIE xyY space for this monitor, but it has a large impact on the color volume in CIELAB, especially in low lightness region. And the poor stability of the projector also has impact over time. Backlight leakage, stability of the projector and color meter affects the accuracy of the color volume, and cannot be neglected. Therefore, the backlight leakage and the ambient light are called as extraneous light. Such extraneous light influences will cause the color of pictures less saturation and make color volume construction of display mismatched. Therefore, the future work will modifies the procedure of constructing the color volume while considering the impact of the extraneous light, stability of the projector, and color meter monitor.

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REFERENCES

[1] H. Zeng, Spring-primary mapping: *a fast color mapping method for primary adjustment and gamut mapping*, in Color Imaging XI: Processing, Hardcopy, and Applications, San Jose, CA, USA, 2006, pp. 605804-12.
[2] R. W. G. Hunt, *Measuring Colour second edition*, Ellis Horwood , London, 1991.
[3] R. S. Berns, *Principles of Color Technology*, 3rd Ed. New York: Wiley, 2000.
[4] T. W. Huang, *Methods for designing multi-primary additive color system*, Taiwan, 2011.

[5] P. Pellegri and R. Schettini, *Gamut boundary determination for a color printer using the Face Triangulation Method*, in Color Imaging VIII: Processing, Hardcopy, and Applications, Santa Clara, CA, USA, 2003, pp. 542-547.
[6] J. Morovič and M. R. Luo, *Calculating medium and image gamut boundaries for gamut mapping*, Color Research & Application, vol. 25, pp. 394-401, 2000.

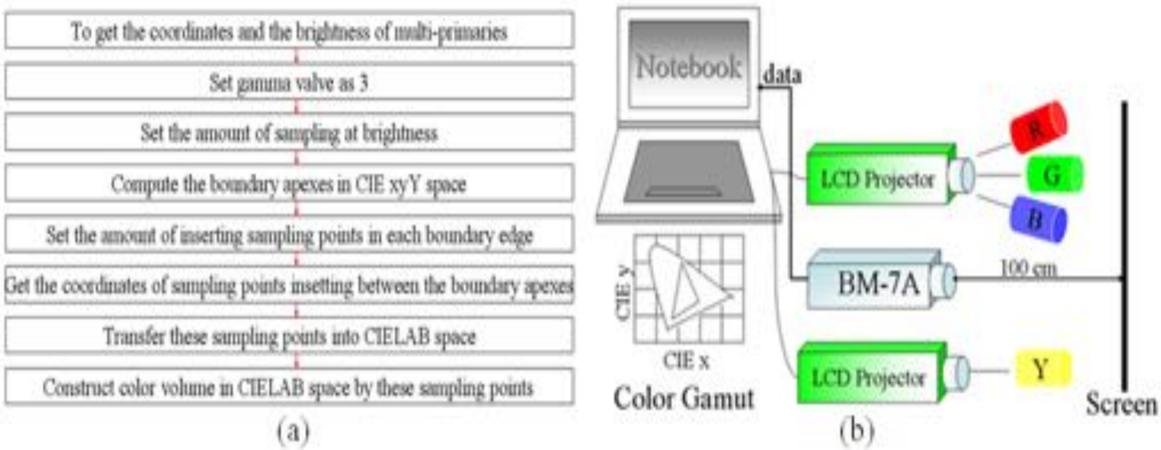

Figure 1, (a) the procedure of constructing the color volume is shown as a block diagram, and (b) Block diagram of experimental apparatus.

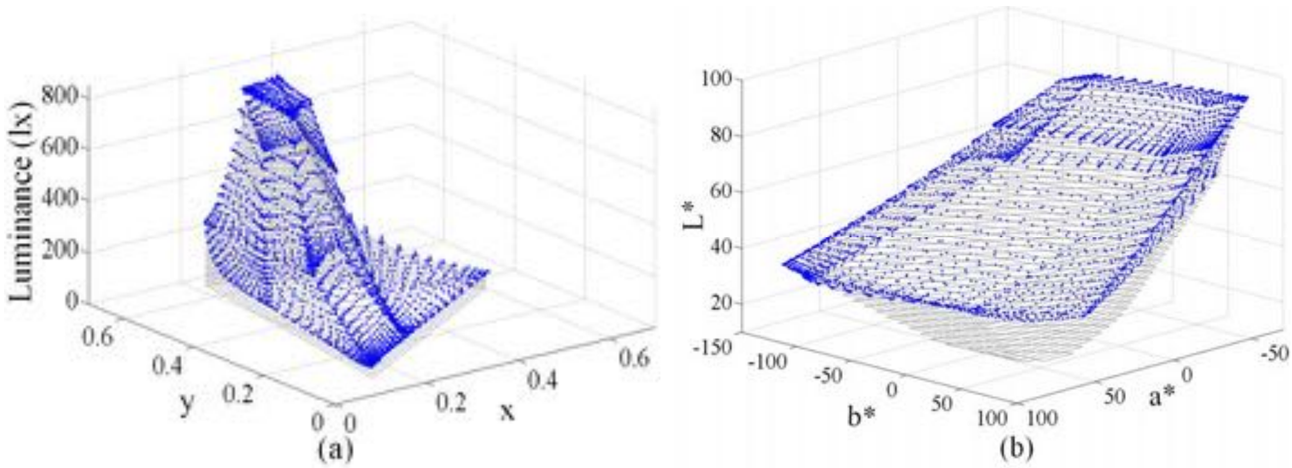

Figure 2, (a) CGB of simulations and experiments in CIE xyY space, and (b) CGB of simulations and experiments in CIELAB space

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Effects of Diffusers on Spectrophotometric Properties of Full Color LED Lightings

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ABSTRACT

In this work we measured and evaluated spectral characteristics of full color LED lighting sources with different diffusers and additional filtering materials to analyze effects of diffuser and other materials on the lighting spectrum. LED usually has narrow bandwidth of wave spectrum and causes discomfort glare unlike conventional lightings. Various diffusers are used to reduce glares and color filters are used to improve colorimetric characteristics of white LEDs. We propose an alternative method to improve colorimetric quality and visual comfort using diffusers and additional filtering materials called Hanji(韓紙), a traditional Korean paper which is made from mulberry. Experimental results show that spectrophotometric properties are modified not only by diffusers and but also by Hanji and the combination shows additive filtering effects. Hanji was very effective to modify spectrum. Especially, the unbalance of dominant wave length power spectral distribution in red, green, and blue lighting sources can be balanced better using Hanji than using diffusers. Human subject evaluation shows that the more balanced dominant wavelength power appears the more natural lights to human observers.

1. INTRODUCTION

Recently, LED lighting systems are frequently used for general lighting and artistic media façade because LED has not only high energy efficiency but also various lighting color. Color temperature can be tuned by mixing LED lighting sources with different color temperature. Chromaticity, an objective specification of the quality of a color regardless of its luminance(Stroebel et al., 1993), can be easily controlled by the mixture of red, green, and blue LEDs. In addition, LED light systems are environment friendly lighting sources since LED lights do not contain mercury and have longer life span compared with conventional lighting sources(Schubert, 2006).

LEDs, however, usually have narrow bandwidth of wave spectrum and cause discomfort glare unlike conventional lightings. Two or three lighting sources with different phosphors are used to develop white LED with high color-rendering index. Unified Glare Rating or UGR method is an international index presented by CIE(International Commission on Illumination) and is used to evaluate the psychological direct glare from luminaries. Diffusers are used to reduce glares or UGR in flat panel LED systems.

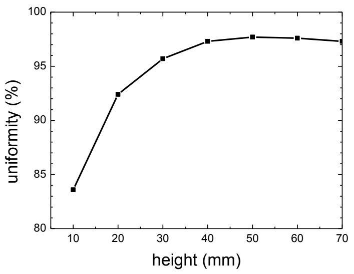
In a previous work, color filters were used to improve colorimetric characteristics of white LEDs(Perales et al., 2011). We propose an alternative method to improve colorimetric quality and visual comfort using diffusers and additional filtering materials called Hanji(韓紙), a traditional Korean paper which is made from mulberry trees and is now being used as a filter for emotional LED lighting systems in industry.

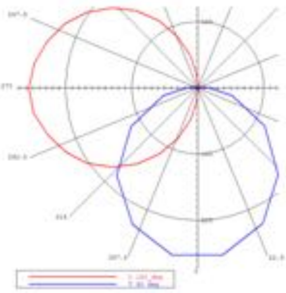
2. EXPERIMENT

We developed flat panel LED lights to investigate physical characteristics of full color LED lightings with red, green, and blue LEDs. In our preliminary experiment, two types of diffuser and four types of Hanji and their combinations were used. Physical characteristics were measured by a spectrometer and human subject evaluation was included.

2.1 Flat panel LED light design based on optical simulation and control unit

To achieve uniformity of light intensity in the flat panel LED lights, we first simulated the light intensity distribution according to different LED lamp structures. For LED chip in flat panel LED lights, we considered AlGaNInP/AlN & GaN/Al2O3 based-multi chips on single PKG from SAMSUM LED Co., Ltd. The total number of 10 by 10 LED PKGs were considered to be regularly arranged inside the plat panel whose dimension was 300 × 300 × *h* mm^3 where h is the height of plat panel. Figure 1 (a) shows the uniformity factor of the output light from the plat panel LED light unit with the various height, *h* of the plat panel. We choose the height of 60 mm for our plat panel LED light unit structure in terms of the uniformity factor of the output light. Figure 1 (b) is the radiation pattern from our plat panel LED lamp with the height of 60 mm, which shows the Lambertian patterns both in vertical and longitudinal directions.





(a) The uniformity factor of the output lights *(b)The radiation pattern from plat panel LED lights*

Figure 1. Uniformity factor and radiation pattern of the designed plat panel LED lights

Based on the simulation results, 100 (10 x 10) RGB LEDs are wired into serial-parallel arrays. The LED lighting unit is powered by 24V DC input. The lighting units are controlled by 3 Channel 8bit PWM(Pulse Width Modulation) using MCU(Micro Crotroller Unit). The PWM frequency used in the experiment was 488Hz. Each red, green, and blue color LEDs are controlled using DMX512 protocol.

(a) Developed flat panel LED lights without diffusers *(b) Developed controller unit*

Figure 2. Developed LED light unit and controller unit

2.2 Experiment procedures

To evaluate the effects of different diffusers on photometric properties, two state evaluation procedures are applied. At the first stage, a spectrometer is used to measure the photometric characteristics in different diffusers and filters for objective physical properties. A spectrometer, CAS-140CT with a 2-meter integrating sphere, is used to measure spectral transmission intensity from 380 to 780 nm in steps of 1nm. At the second stage, human subjects evaluate the naturalness and preference of the observed lightings since the emotional response of human subjects is very important.

Two types of diffusers are used, and four different filters are applied for each diffuser. Overall 10 different configurations are applied: 5 filters (including no filter as one additional case) x 2 different diffusers. Four 30 cm x 30 cm flat panel LED lighting units are used as a LED lighting system in each experiment. Experiment environment is shown in Figure 3, where two LED lighting systems are used side by side. For 10 subjects with normal eyes are participated in the evaluation of the naturalness and preference of the LED lamp.

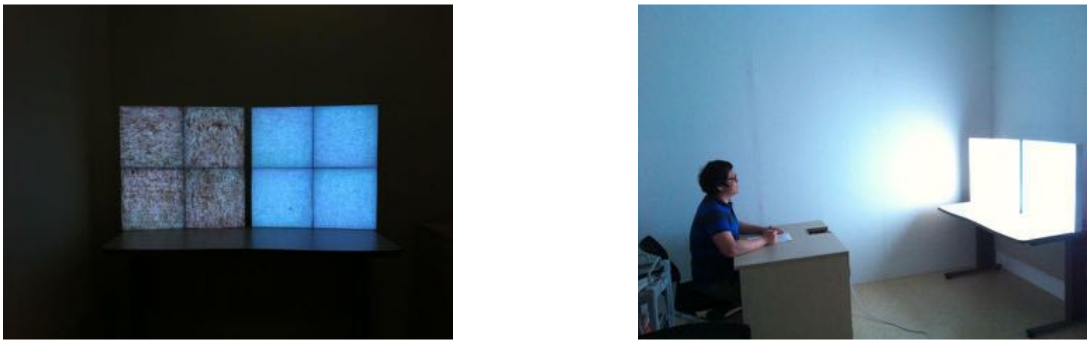
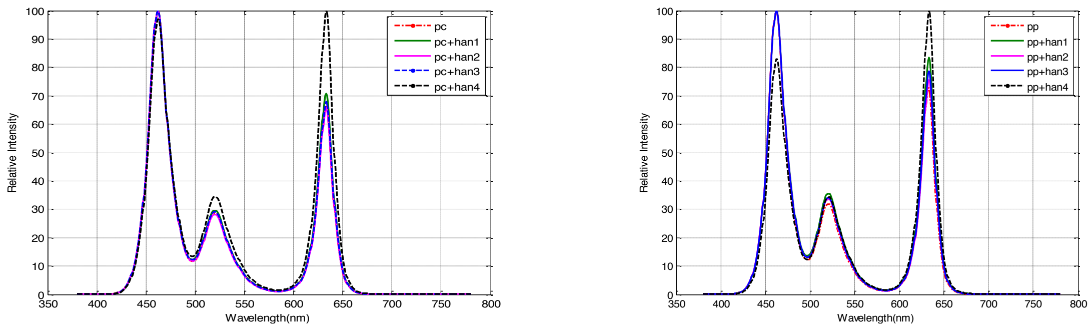


Figure 3. Experiment setup for human subject evaluation

3. RESULTS AND DISCUSSIONS

3.1 Experiment Results

In the first experiments, we measures spectrophotometric characteristics of each LED lamps with different diffusers and filters. Figure 4 shows normalized spectral power distributions of each LED lamps with different diffusers and Hanji filters. The normalization was performed by scaling the maximum in the peak wave length to be 1. Therefore, the graph shows change of wave length components by Hanji filter and diffusers. Especially Hanji type 4 absorbs wavelength around 460 nm and the peak wavelength changed to 633nm. The normalized graph shows that 460nm peak and 633nm peak are almost equal when Hanji type 4 is used. Hanji type 3 also decreases spectral power around 460nm and make power spectrum more balanced than without Hanji filter.



(a) Diffuser type A *(b) Diffuser type B*

Figure 4. Normalized spectral power distribution in different diffuser types & Hanji filters

Emotional response for the given LED lamp with a given diffuser and Hanji filter is evaluated by 7 points evaluation especially for naturalness of the observed light; 1 means most unlike natural light and 7 means most like natural light. Total score is a sum of *score value x number of response*, which gives overall score of naturalness of the light color. According to the human subject evaluation, the light using diffuser type B is more natural than the light using diffuser A.

In Hanji filter, Hanji type 4 shows most natural light in both type A and type B. Similarly, Hanji type 4 with diffuser type A shows most preferred LED lightings in the experiments.

Table 1. Human subject evaluation result for naturalness of the LED lightings

Diffuse Type	Hanji type	Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	Score 7	Total score
A	No	2	0	5	2	0	1	0	31
	H1	1	2	4	1	1	1	0	32
	H2	1	2	5	1	0	0	1	31
	H3	1	2	4	1	0	1	1	34
	H4	1	1	3	1	0	2	1	35
B	No	1	1	5	2	0	1	0	32
	H1	1	2	3	1	1	2	0	35
	H2	0	3	4	1	0	1	1	35
	H3	0	2	4	2	0	1	1	37
	H4	0	1	3	2	1	1	2	44

3.2 General discussions

Experimental results show that spectrophotometric properties are modified not only by diffusers and but also by Hanji and the combination shows additive filtering effects. Physical measurements using a spectrometer show different shift of primary colors in different diffusers. In addition, Hanji was very effective to modify power spectrum distribution. Especially, the unbalance of dominant wave length power spectrum in red, green, and blue lighting sources can be balanced better using Hanji than using diffusers. However, Hanji reduces overall energy efficiency as it reduces extracted light due to its semi-transparency. Human subject evaluation results show that the more balanced the dominant wavelength power is, the more natural and preferred lightings appear to human observers. Therefore, a new diffuser with energy efficient and balancing power spectrum diffuser may be required for emotional lighting applications.

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REFERENCES

Schubert, E. Fred, 2006. *Light-Emitting Diodes*. New York: Cambridge Press.

Stroebel, Leslie D., Richard D. Zakia, 1993. *The Focal Encyclopedia of Photography*. New York: Focal Press.

Perales, Esther, Elisabet Chorro, Valentin Viqueira, Francisco M. Martinez-Verdu, 2011. Color filtering of lighting systems based on wLEDs to improve their colormetric characteristics, In *AIC Midterm Meetings 2011, Proceedings*, ed. by Verena M. Schindler, Stephan Cuber, pp. 662-665.

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Makeup Color Representation Based on Spectral Characteristics

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ABSTRACT

Growing a technology for smart phone/pad, beauty applications which apply makeup effects to the images captured by smart phone appeared beyond simple correcting color, brightness and contrast, e.g. TAAZ, EZFace, Daily-makeover, etc. Thus, before making his/her face up or buying cosmetics, user can see the simulated their face by some commercial beauty applications. However, output images of these applications are different from the real face after making up with real cosmetics. It is caused by different color reproduction characteristics of digital camera and display. In addition, the makeup colors are similar to those of painting, so the colors must be decided by combinations of skin, cosmetics and lighting. Therefore it is hard to reproduce the makeup color with only RGB color data for skin and cosmetics from captured images. In this paper, a method to represent makeup colors using the estimated skin reflectance by spectrum-based camera characterization and the measured reflectance of cosmetic is proposed. Color characterization models for digital camera and display are generated based on the measured data for sampled input and output signal. The makeup colors are estimated by modeling the change of reflectance before and after makeup.

1. SPECTRAL CAMERA CHARACTERIZATION

The emitted light from an illuminant is firstly reflected to an object, and it reaches the CCD of CMOS in digital camera through an optical lens and a color filter as shown in figure 1. The characteristics of light, object, optical lens, and color filter are dependent on the wavelength. Thus the digital camera can be modeled by equation (1),

$$d_k = \int_{\lambda_{min}}^{\lambda_{max}} I(\lambda) r(\lambda) o(\lambda) f_k(\lambda) c(\lambda) d\lambda + \eta_k \quad (1)$$

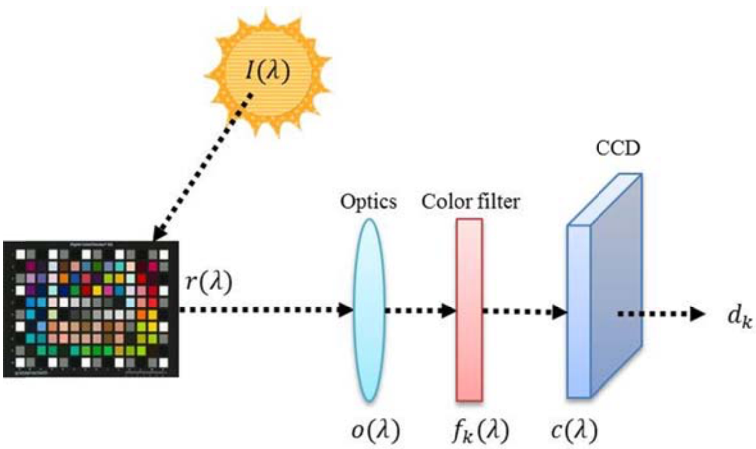


Figure 1. Digital camera model.

Where I is the light from illuminant, r is reflected light by object, o and f_k are spectral transmittance of optical lens and color filter each other, c is spectral sensitivity of CCD of CMOS in digital camera, d_k is the output RGB value of the digital camera, and η is the noise. If it is assumed that spectral characteristics of light and camera are fixed, the equation can be simplified by S_k, in equation (2).

$$d_k = \int_{\lambda_{min}}^{\lambda_{max}} S_k(\lambda) r(\lambda) d\lambda \quad (2)$$

Finally it is approximated by sampling wavelength as follows,

$$\boldsymbol{d}_k = \boldsymbol{S}_k^T \boldsymbol{r} \quad (3)$$

where S is the sensitivity of camera. If the input reflectance of object and output digital RGB value is known, The sensitivity can be estimated by using pseudo-inverse method, least square, neural network, etc. Figure 2 shows the spectral characterization process for digital camera. The reflectances of color patches on the color chart are measured by spectrophotometer. Then, the color chart is captured by a digital camera, and RGB data for each color patch from the captured image are obtained. The reflectance of color patch becomes input reflectance, r, and the corresponding RGB data become output value of digital camera. Using two color data(reflectance and RGB) for color patches, the camera sensitivity is estimated by applying pseudo-inverse method, least square, neural network, etc.

In equation (3), the wavelength is generally sampled at intervals of 5nm or 10nm in a visible light region rages from 400nm to 700nm. If it is assumed that the number of samples for the visible light region is 31 by 10nm interval, it is easy to find the output digital value with input reflectance. In contrast, if we know the digital value and want to find the reflectance, it should involve an estimation error because we cannot directly obtain an inverse matrix for the camera sensitivity, S. It means that 31-dimensional spectrum data is estimated with only three RGB data. Therefore, to reduce the estimation error, the color patches are constrained by a skin tone colors. Figure 3 shows the skin color patches used in the study. In other words, 16 skin patches in digital color checker SG are selected and used to characterize digital camera.

2. MAKEUP COLOR REPRESENTATION

By the use of spectrum camera characterization, the change of spectrum before and after makeup is measured to represent the skin color after makeup, and the results are shown in figure 4.

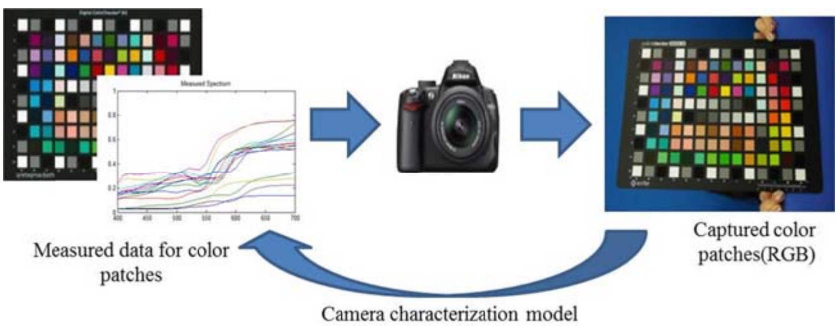


Figure 2. Spectral characterization process for digital camera.

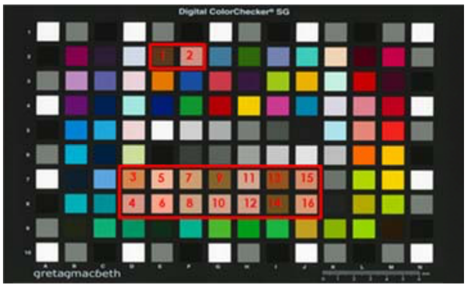
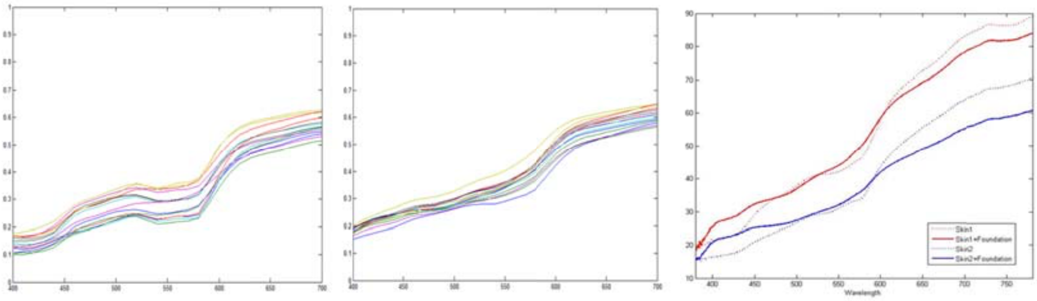


Figure 3. Selected skin tone patches on digital color checker SG.



(a) (b) (c)

Figure 4. Measured skin spectrum for (a)before and (b)after makeup, and (c)comparison.

The skins for ten subjects are measured before and after putting a foundation on them. The change of spectrum is similar with each other because all of subjects are Asian and same foundation is applied. The spectrum in a longer wavelength is decreased, whereas the spectrum in a shorter wavelength is increased. It means that the foundation reduces the reddish tone and exposes yellowish tone in the skin. Thus the transitions of spectrum for ten subjects are averaged and the linear transition model for each wavelength is generated based on the transitions.

3. DISPLAY CHARACTERIZATION

Through makeup color representation process, the spectrum of skin after makeup is estimated. Then, to reproduce the color on a display, conversion process of the spectrum data to RGB data reflecting the color characteristic of display is necessary. First of all, the spectrum data is converted into CIEXYZ values using color matching functions for CIE 1964 standard colorimetric observer. The CIEXYZ values are converted into RGB digital value by inverse characterization process. Figure 5 shows display characterization process. The relation between input RGB signal (d_r, d_g, d_b) and tristimulus values (X, Y, Z) of display is estimated by non-linear tone curve model and linear conversion with 3x3 matrix. Also R_Y, G_Y, and B_Y

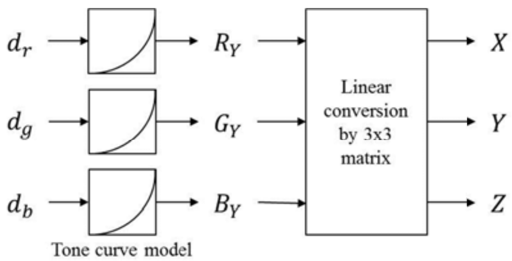


Figure 5. Display characterization process.

Figure 6. Makeup simulation program.

are linearized RGB signals by using the tone curve model. The makeup color is finally converted into RGB value by inverse process of the display characterization.

4. MAKEUP SIMULATION RESULTS

Figure 6 shows the makeup simulation results. The left image is extracted from raw image file without a color processing of digital camera. And the right image is a corrected one by proposed spectral characterization method. The skin tone of right image is more closed to the real skin color. The color patch in the right corner represents the color generated by display characterization using measured data for a real foundation. Also, it is applied to the right image. The patch's color and the applied color to the skin are little different because the spectrum of skin has an effect on the final appearance.

CONCLUSIONS

On a captured facial image by digital camera, to reproduce the makeup color exactly on a display, spectrum-based color correction process using measured data is a necessary. Thus, spectrum-based characterization of imaging devices and makeup color representation methods using measured spectrum data for skin and cosmetics are proposed. Comparing normal makeup color representation process without an additional color correction, the results by proposed method is more natural and closed to the real face after makeup.

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REFERENCES

Sharma G(2003), *Digital Color Imaging Handbook*, CRC Press.

Jang IS, Kyung WJ, Kim KM, and Ha YH (2011), User-Configured Monitor-to-Printer Color Reproduction, *Journal of Imaging Science and Technology*, **55**, 2, 1-10.

CIE (Commission Internationale de l´Eclairage), http://www.cie.co.at/.

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Influence of daylight illumination in principal components of natural images.

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ABSTRACT

It has been argued that the spatial color distribution in natural images can show statistic regularities in the color space. The distribution of luminance, color and other statistical descriptors in natural scenes has been quantitatively and qualitatively described elsewhere by Hyvarinen et al. (2009). The purpose of this work was to focus on the principal components and to study how changes in daylight illumination affect the Principal Components Analysis (PCA) of natural irradiance and reflectance spectra. A constant ratio approach is proposed to described the relationship between the eigenvalues for every illuminant an the 6490K reference one.

1. INTRODUCTION.

The color pixel values in a natural image are correlated rather than independent. It can be shown that there is a unique mathematically transformation that decorrelates the signal information and enables the best energy distribution among the transformed components (Gallager,1968). PCA can make this transformation and the principal components will be decorrelated containing as much of the variance of the input data as possible.

Geisler (2008) argued that the efficient information transmission in the Human Visual System (HVS) is achieved by a transformation of the response of the L-, M- and S-cones into achromatic and two opponent chromatic channels. The analysis Moorhead (1985) did of the spectral distribution of the sensitivities of the new channels showed that luminance channel is independent of the illuminant but chromatic channels have a clear dependence on the CCT of the illuminant. The opponent channel red-green has the strongest dependence and the results are emphasized when a previous von Kries chromatic adaptation like that of Buchsbaum and Gottschalk (1983) is considered.

2. METHOD AND RESULTS.

In this work the following sets of data have been used:

- The reflectances *R(λ)* of eight hyperspectral natural images obtained by Nascimento et al.(2002)
- Twenty-one Spectral Power Distribution (SPD) of daylight obtained by Hernandez-Andrés et al.(2001) E*(λ)*. They are characterized by their correlated color temperature (CCT) uniformly distributed in the range 5500K – 7500K between 400-700 nm.
- The spectral sensitivities of the three sensors *r(λ), g(λ)* and *b(λ)* of a commercial CCD color camera (Retiga 1300 C from QImaging)

2.1 PCA of color signals under different daylight.

The PCA was computed from the set of all the pixels of the eight hyperspectral images of natural scenes rendered with the SPD daylights of CCT from 5,500 K to 7,500 K.

Only four eigenvectors were needed to obtain more than 99'5 % of the information carried by those signals for the different illuminants. The different color signals were recovered using these four eigenvectors base. The Table 1 shows the Goodness-of-Fit Coefficients (GFC) to test the differences between the original and the recovered signals.

The Figure 1 shows the spectral distribution of the values of both signals for two different pixels of the Image 4 using the illuminants on the extreme of the range of working CCTs.

Table 1. Examples of the average, median and percentile 95 (P95) of the GFC obtained between the original and recovered color signal

GFC	Image 1	Image 4	Image 6	Image 8
Average	0,99867	0,99744	0,99718	0,99865
Median	0,99866	0,99743	0,99718	0,99865
P_{95}	0,99870	0,99757	0,99743	0,99874

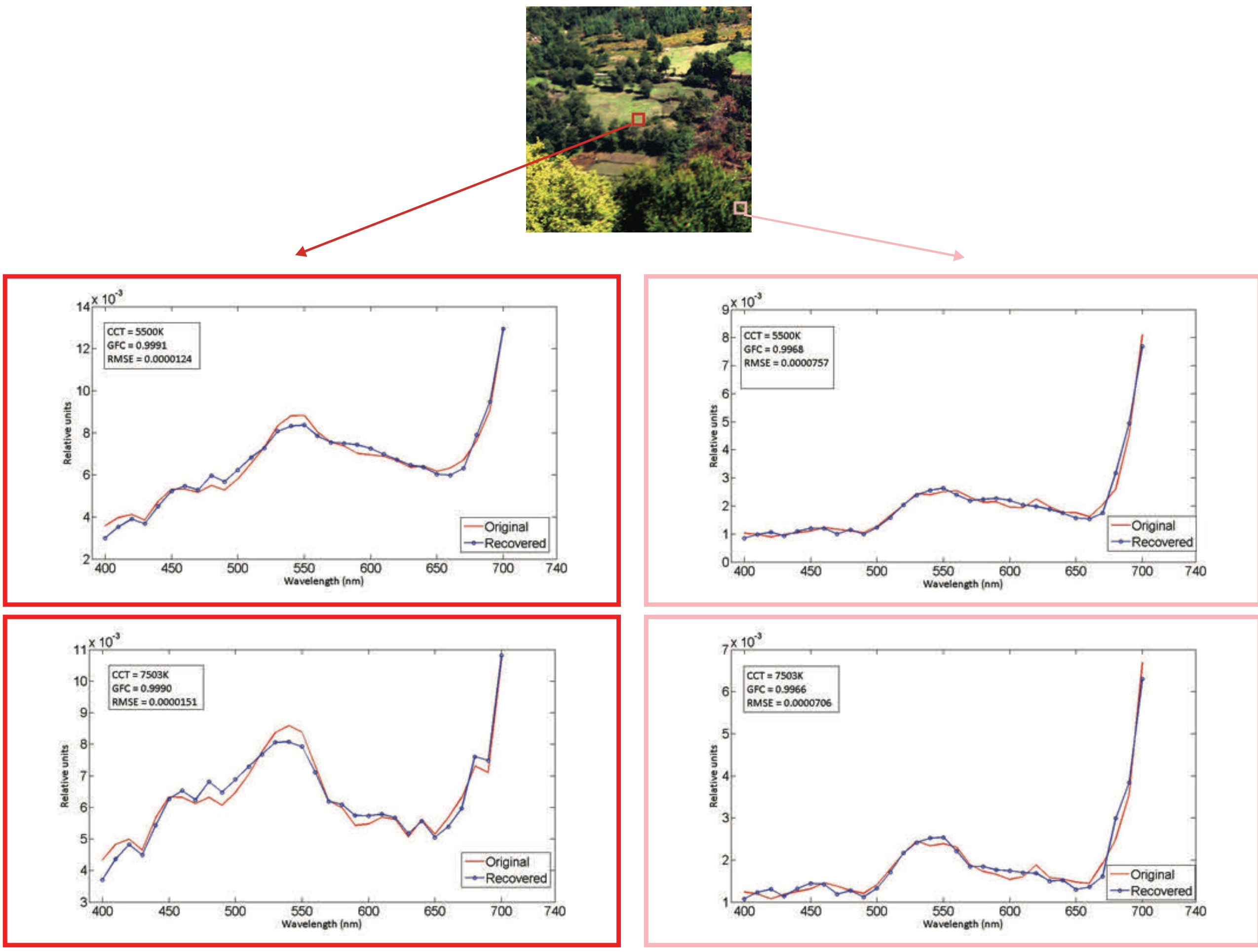

Figure 1. Examples of the Spectral distribution of the original and recovered color signals of two different pixels (denoted with boxes in the image) of the image 4 for illuminants of CCT 5500K and 7500K.

2.2 Computation of constant ratio of principal components eigenvalues.

An illuminant with CCT = 6490K was used as a reference to obtain linear relationships for the principal components of the color signal determined for each illuminant (Romero et al, 2007). Strong correlations for all CCTs were found for the first and the third components. The correlations of the coefficients for the second and the fourth components were significant in a reduced rank of CCTs (below 6,199K and above 6,699 K for the second and fourth components, respectively).

Figure 2 shows the plots of the slopes of the linear adjustments for illuminants with different CCTs. Only a linear fit was possible for the second principal component in the CCTs rank where the adjustment was significant.

Figure 2. Slopes of the linear adjustments between the response of each component for every illuminant and the 6490K reference one as a function of CCT.

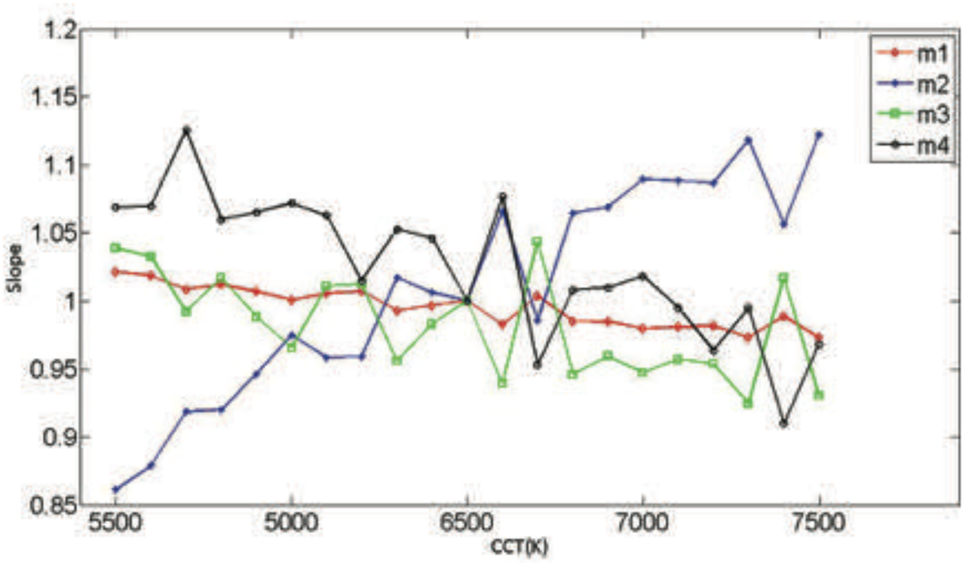

Table 2. Differences between the RGB original and recovered components of the Image 4 for different illuminants.

CCT	**RMSE**	**Average S-CIELAB color difference**	**Median S-CIELAB color difference**	**P95 S-CIELAB color difference**	**Percentage of number of pixels with S-CIELAB color difference < 3**
7503K	0,00230	0,0129	0,0095	0,0375	100
7286K	0,00244	0,0139	0,0104	0,0392	100
7089K	0,00180	0,0111	0,0080	0,0327	100
6920K	0,00155	0,0102	0,0072	0,0307	100
6699K	0,00098	0,0073	0,0047	0,0236	100
6287K	0,00137	0,0098	0,0069	0,0298	100
6098K	0,00084	0,0030	0,0013	0,0109	100
5895K	0,00107	0,0038	0,0019	0,0130	100
5699K	0,00123	0,0042	0,0022	0,0142	100
5500K	0,00255	0,0100	0,0071	0,0297	100

RGB images were recovered for the different illuminants using the principal components of the reference illuminant and a look-up table with the previous slopes. The differences between the original and the resulting RGB images were measured using the Root-Mean-Square-Error (RMSE) and S-CIELAB color difference (Zhang and Wandell, 1997). Table 2 shows that 100% of the pixels could be recovered with very good color quality (S-CIELAB < 3) for all daylights used.

3. DISCUSSION AND CONCLUSSIONS

In the range of working daylights used (CCT from 5,500 K to 7,500 K) PCA showed that only four eigenvectors were needed to obtain more than 99.5 % of the information carried by the color signals.

The linear relationship for the principal components of the color signal determined for each illuminant was thoroughly analyzed yet a linear model that fits the CCTs of the illuminants with the slopes of the adjustments of the four principal components of every illuminant with the reference one (with CCT=6490K) could not be found. Despite the lack of such a linear model, using the principal components of reference color signal and the slopes of those linear relationships, image color reproduction was quite good. It can be stated that this approach is an alternative to previous sensor-response-ratio (Romero et al, 2007) to generate color in computer graphic for different daylight illumination.

ACKNOWLEDGMENTS

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REFERENCES

Buchsbaum G. and A. Gottschalk. 1983. Trichromacy,opponent colours coding and optimum colour information transmission in the retina. *Proceedings of the Royal Society London*, B, 220: 89-113

Gallager R.G. 1968. *Information Theory and reliable communication.* New York:Wiley

Geisler W.S.2008. Visual Perception and the Statistical Properties of Natural Scenes. *Annual Review of Psychology* 59 : 167-192

Hernández-Andrés J., J. Romero, J.L. Nieves and R.L.Jr. Lee. 2001. Color and spectral analysis of daylight in southern Europe. *J. Opt. Soc. Am. A.* 18: 1325-1335.

Hyvärinen A.,J. Hurri and P.O.Hoyer. 2009. *Natural Image Statistics: A Probabilistic Approach to Early Computational Vision.* Springer.

Nascimento S.M.C., F.P. Ferreira and D.H. Foster. 2002. Statistics of spatial cone-excitation ratios in natural scenes. *J. Opt. Soc. Am. A.* 19: 1484-1490

Romero J., D. Partal, J.L. Nieves and J. Hernández-Andrés. 2007. Sensor-Response-Ratio Constancy under changes in natural and artificial illuminants. *Color Research and application* 32: 284-292.

Zhang X.and B. A. Wandell. 1997. A spatial extension of CIELAB for digital color-image reproduction. *Journal of Society for Information Display* 5: 61-63

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How Blue Is the Blue and White Porcelain? -A Study of the Color Characteristics on Blue and White Porcelain by Using Spectral Imaging Technology

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ABSTRACT

The popularity of blue and white porcelain spans for several centuries and regions. The shapes and patterns of the blue and white porcelain can be different from different regions. Even thought cobalt oxide pigment is mostly used for the blue color, the blue color appears differently among them. This research deploys spectral imaging technology to capture the color image of the blue and white porcelain. An achromatic CCD camera configured with a spectrograph element on an X-Y scan-bed is used to record the spectral color information in the visible bandwidth in 10nm increment, not in a regular RGB tri-chromatic format. A vector of principal component composition can then be derived as the spectral reflectance information on the material representing the color characteristics of the blue color which can be further computed into CIELAB values. The blue and white porcelains from different centuries collected by the Hwa-Kang Museum are the primary objects under investigation in this research. It is intended to establish a method to archive and analyze the color characteristics of the blue and white porcelain using a spectral imaging technology. The resulting analysis for the blue color characteristics of the collected blue and white porcelains are presented.

1. INTRODUCTION

It is common that one would use a key color to represent an object's color. For example, the color of a logo or the color of a new sedan can be described by a certain patch of color swatch. However for a color object with texture, not just a single solid color, it is difficult to represent the whole object's color by sampling randomly from the object's surface. One possibility is to take more samples and then compute the average as the mean color. However with colorful objects, this approach may result in the averaged color mostly as brown or gray. Furthermore, it is suggested that care should be used to distinguish between hue-names and color names by Bartleson (1976). It is not possible to depict how many key colors there are on the object, nor to find the color primaries of the colorants directly.

Chinese porcelains were mainly mono-chromatic until blue and white porcelain became popular (National Palace Museum 1981). It started in the Yuan dynasty (1271-1368) and flourished in the Ming dynasty (1368-1644) where blue gradation and patterns are delicately formed on the white surface of the blue and white porcelains. How to record and process the blue patterns on this kind of porcelains to extract a primary blue color that represents the spirit of the blue and white porcelains is an interesting subject.

A common practice in museum community is to archive objects by using digital camera with color management system (Li et al. 2011). The R, G and B signals captured can be tagged with ICC profiles to correlate the digital signals to CIE colorimetric values (ICC 2001). However, only three attributes (either R, G, and B signals, or CIELAB values) can be recorded in this manner. Besides, the image captured by a regular digital camera is a combination of the lighting characteristics and the object material as follows:

$$D_i = \int L(\lambda)\, R(\lambda)\, S_i(\lambda)\, d\lambda\,, \quad i = 1, n \qquad (1)$$

$L(\lambda)$ is the spectral power distribution of the illuminating light source

$R(\lambda)$ is the spectral reflectance of the object

$S(\lambda)$ is the sensor's responsivity in the imaging system

When a camera sensor is used as $S(\lambda)$, the output signal Di is not only influenced by the object's material characteristics $R(\lambda)$, but the variation in power distribution of the light source, $L(\lambda)$, can also change the value of the resulting signal, Di. In a way, the regular digital camera captures the image of an object as what the object appears to the camera under the illumination, not the object's surface characteristics themselves. For digital archive purpose in museum application, the recorded Di signal is not the color characteristics of the art work but what the art work would appear under that circumstance.

The same formula 1 can be used to represent the human vision. When the human visual system is used as $S(\lambda)$, for example the CIE color matching functions, the resulting signal is the tri-stimulus values as described in Colorimetry (Wyszecki and Stiles 1967). Therefore, if one can record the spectral reflectance of the object, $R(\lambda)$, it is possible to re-compute how the object would appear as formula 1 under any kind of illuminations accordingly. Based on this theory, this research deploys a spectral imaging system to capture the spectral reflectance characteristics of the blue and white porcelains and then performs color analysis to compute the key color characteristics of various blue and white wares collected by the Hwa-Kang Museum in Chinese Culture University. The resulting color characteristics are therefore the surface reflectance properties of the blue and white porcelains. Further computation can be performed to predict the color appearance of the object under various lighting conditions. It is intended to collect more data sets for the blue-and-white porcelains to establish a database for museum research in the future. The similar color analysis method can be used in other applicable color study.

2. SPECTRAL IMAGING CONFIGURATION AND COLOR ANALYSIS

Many prior researches had applied spectral imaging technology in digital archive of western art work (Berns et al. 2003; Ribes et al. 2005). Further spectral analysis and reproduction of the art work were performed (Tzeng and Berns 2005; Ribes et al. 2008). These prior researches mostly concentrated on Western art work and used multi-filter type spectral camera system. In this research, a new spectrograph device is integrated with a monochromatic CCD camera and lens on an X-Y scan bed with synchronized Xenon light source as shown in Figure 1. This spectrograph device is a grating-type instrument that can disperse the incoming ray into a line in spectral distribution. Therefore, a line of incoming pixels can be recorded on a 2-D monochromatic CCD camera as a line of spectral image. With an X-Y scan bed, a spectral scanner/camera system can be established.

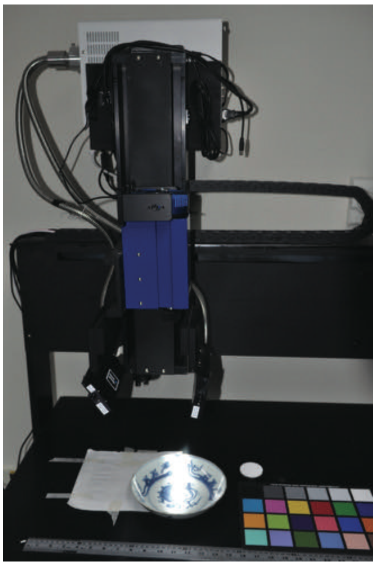

Figure 1. The spectral camera system used in this research.

A MATLAB program was developed to perform the calibration for relative reflectance factor and to compute the CIELAB values of the captured image. Principal component analysis (PCA) method is used to statistically analyze the captured spectral reflectance data. The primary spectral reflectance vector can be derived from this PCA analysis showing the maximum variance of the reflectance factors on the blue and white porcelains. Seven blue and white porcelains ranged from Ming dynasty, Ching dynasty and contemporary were taken as the test objects.

3. RESULTS AND ANALYSYS

Each of the blue and white porcelain was scanned by this spectral camera system. The collected spectral reflectance curves were processed by PCA method to find out the first component that explains the color variation the most. The resulting spectral reflectance vectors (curves) are shown in Figure 2. The corresponding CIELAB values in a*/b* under D65 illumination are computed and shown in Figure 3.

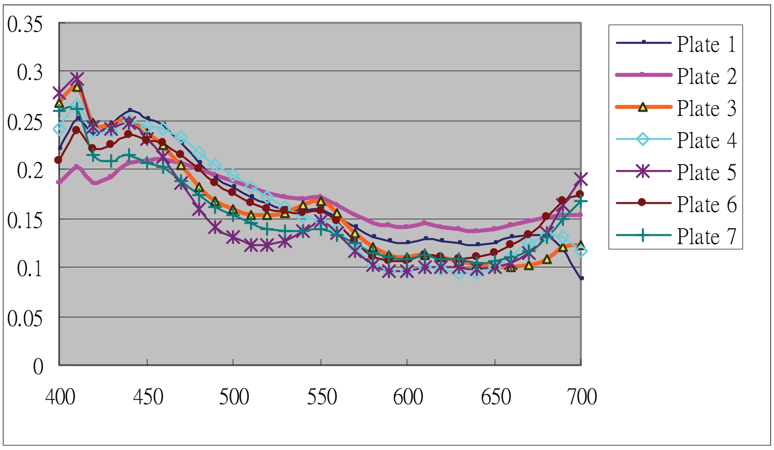

Figure 2. The resulting first principal components of the spectral reflectance vectors for all seven blue and white porcelains in visible bandwidth.

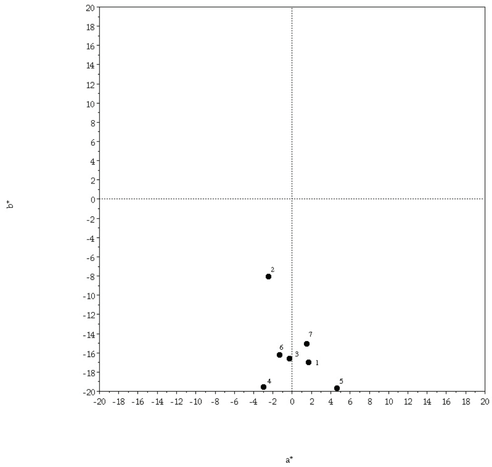

Figure 3. The resulting hues for the seven blue and white porcelains in CIELAB a*/b* plots.

4. CONCLUSIONS

This research intends to find out what are the color characteristics for blue and white porcelains by using spectral imaging technology. A new spectral camera system was built for this research. The spectral reflectance curves and their corresponding hue property are derived successfully to reveal the beauty of blue and white porcelains.

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REFERENCES

Bartleson, C. J. 1976. Brown. Color Research and Application, Vol. 1, 4, Winter 1976.

Berns, R. S., L. A Taplin, and F. H. Imai. 2003. Spectral imaging of Matisse's Pot of Geraniums: a case study. *11th Color Imaging Conference*, 149-153.

Li, P.-Y., Y.-P. Wang and L.H. Kao. 2011. *Digitization Procedures Guideline: Color Management*. Taiwan e-Learning and Digital Archives Program. Taipei, Taiwan, R. O. C.

ICC. 2001. File format for color profiles (Version 4.0.0), Specification ICC.1:2001-12. International Color Consortium.

National Palace Museum. 1981. *Catalogue of a Special Exhibition of CH'ING-Dynasty Monochrome Porcelains in the National Palace Museum*. National Palace Museum. Taipei, Taiwan, R. O. C.

Ribes, A., F. Schmitt, L. Christian. 2005. Calibration and spectral reconstruction for CRISTAL: an art painting multi-spectral acquisition system. *Journal of Imaging Science and Technology* 49, 6 (2005), 563–573.

Ribes, A. and R. S. F. Pillay. 2008. Studying that smile. *Signal Processing Magazine*. IEEE 25, 4, 14–26.

Tzeng, D.-Y. and R. S. Berns. 2005. A review of Principal Component Analysis and Its Applications to Color Technology. *Color Research and Application*, Vol. 30, No. 2.

Wyszecki, G., and W. S. Stiles. 1967. *Color science, concepts and methods, quantitative data and formulas*. New York: John Wiley and Sons.

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Correcting for non-uniform illumination when photographing the mural in the royal tomb of Amenophis III (IV) Applying huge mural images

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ABSTRACT

We have been attempting to digitize murals at the royal tomb of Amenophis III. When photographing the murals, two strobe lights, each of which has an umbrella, were used to provide uniform illumination. Nonetheless, the illumination was still somewhat non-uniform. This non-uniform illumination was corrected by applying an illumination model, which was evaluated using images of the simulated mural with and without white patches. The illumination model was then extended to two light sources and applied to images of the actual mural. The corrected images were observed to be more uniformly illuminated.

1. INTRODUCTION

The tomb of Amenophis III, one of the pharaohs of ancient Egypt, is located in the Valley of the Kings in Luxor, Egypt. The burial chamber is 8.2 m wide, 15.4 m long, and 3.1 m (partially 4.7 m) high. The Amduat is painted on the four walls. We have been attempting to create a full-size digital image of this mural, so that the mural can be displayed on a computer display, which can be observed by many researchers in the world without going to the location. Ninety nine images (small-size images) of each position of the mural were taken with a 21 mega pixel camera. These 99 small-size images were then stitched to produce a stitched image with approximately 500 mega pixels, which is referred to as a middle-size image. From these middle-size images, we are attempting to produce a full-scale large-size image corresponding to the entire area of each of four walls; north, south, east, and west.

To make the illumination to the murals uniform, we have been photographing the murals using two strobe lights, each of which has an umbrella. The strobes are placed on the right and left sides of the mural. However, due to columns in the room and a low power of the strobe, it is impossible to illuminate the mural from a distance, and therefore it is difficult to achieve uniformity of the illumination. We assume illumination from the strobe and umbrella as a point light source, and newly devised an illumination model based on the assumption. We showed that non-uniform illumination could be corrected using the model, and further attempted a method for correcting non-uniform illumination only with a photographed image.

2. ILLUMINATION MODEL

We assume illumination using a strobe with an umbrella as illumination from a point light source located at a longer distance as it is shown in Figure 1. Since illuminance from a point light source holds for an inverse-square law, the illuminance E at any point (x, y) on the mural is given by Equation (1):

$$E=\frac{p}{d^2}=\frac{p}{(x-x_0)^2+(y-y_0)^2+d_0^2} \quad (1)$$

where p is the luminous intensity of the virtual point light source, and as it is shown in Figure 2, d is the distance between the point light source and a point (x, y), x_0 and y_0 are the coordinates of the foot of a perpendicular of the point light source to the wall, and d_0 is the distance between the point light source and the mural. We named this model the Point Light Source (PLS) model.

It is difficult to directly measure the illuminance on the mural. The luminance from a point having a certain reflectance is proportional to the illuminance to the point. The digital values of an image taken by a digital camera are recorded as converted values from a tristimulus value Y which is proportional to the luminance. Therefore, the tristimulus value Y obtained from the digital values of a photographed pixel of a point having a certain reflectance is proportional to the illuminance. The illuminance used in this study is not necessarily an absolute value, and the relative value is enough. Therefore, the tristimulus value Y, which was obtained from digital values R, G, and B of a photographed image of a point having a certain reflectance, is used as the illuminance. As a coordinate (x, y), a position coordinate of a pixel in a digital image are used.

The illumination model was verified for images of a simulated mural with white patches and with uniform backgrounds instead of white patches: Inui et al. (2011).

On the other hand, the two-dimensional second-order polynomial expressed by Equation (2) is often used for illumination correction for a microscope image, etc.

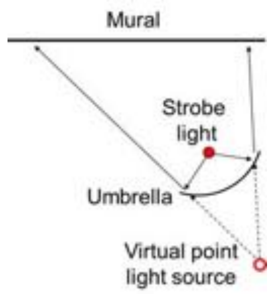

Fig.1 Illumination model in which illumination, provided by light from a strobe and reflected light from an umbrella, is assumed to act as a virtual point light source.

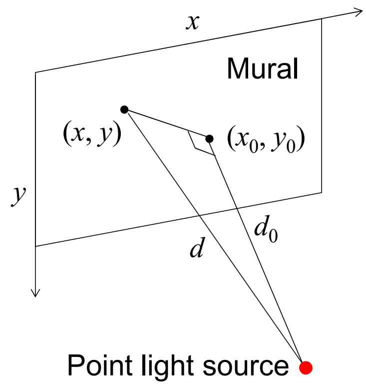

Fig.2 Geometric arrangement of a light source and a mural.

$$E = ax^2 + bxy + cy^2 + dx + ey + f \quad (2)$$

The above model is referred to as the second-order polynomial (SOP) model.

3. APPLICATION TO THE MURAL IMAGES

Since the photography was actually carried out using two strobes, each of which has an umbrella, from the right and the left sides, the proposed illumination model (PLS model) was extended to the following equation for two light sources:

$$E = \frac{p_1}{(x-x_1)^2+(y-y_1)^2+d_1^2} + \frac{p_2}{(x-x_2)^2+(y-y_2)^2+d_2^2} + a \quad (3)$$

where the subscripts 1 and 2 denote the light source number. On the supposition that a constant amount of light enters from the surrounding area, a constant a is introduced in Equation (3) as an ambient light.

On the other hand, in the second-order polynomial (SOP) model, even if the equation is extended to two light sources, the form of the equation is the same, and the number of constants remains six. Though the SOP model did not give a good result in the application to the simulated mural, an application to an actual image was tried in consideration of a case of multiple light sources in the future, since the equation of the model has the same form for the multiple light sources, which is convenient for use.

The middle-size image formed by stitching photographed images is a 16 bits TIFF image of about 500 mega pixels. The OpenCV 1.0, which we had used at that time, was not able to handle the above TIFF image. Therefore, an image of 20 mega pixels formed by stitching JPEG images, which were produced other than RAW images when pictures were taken, was used for the correction. The twelve images of East wall were corrected using both PLS and SOP models. As an example, four JPEG images of East wall are shown in Figure 3. Figure 3(a) is one of images which were most non-uniformly illuminated.

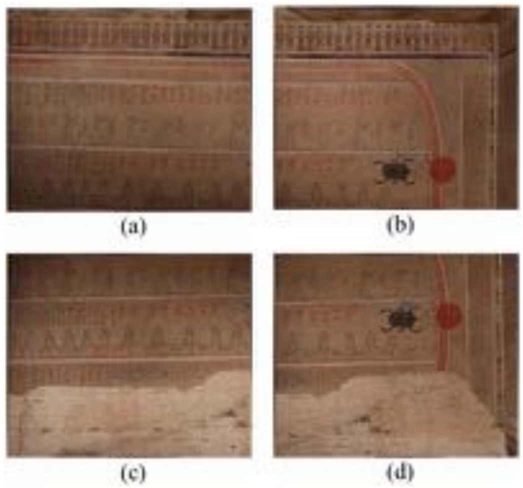

Figure 3 Four original images of East wall.

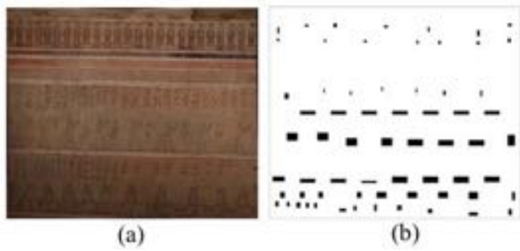

Figure 4 An example of extracted background which is assumed to have the same color. (a) is identical to the image of Figure 3 (a), and (b) shows extracted uniform backgrounds.

Uniform background portions were manually extracted. For an example, Figure 4 shows 65 background portions extracted from Figure 3(a). The constants used in illumination models were determined by the non-linear optimization as it was described above. The twelve images of East wall were corrected using these constants. The standard deviations of tristimulus values *Y* of the twelve images before and after the correction are shown in Figure 5. The mean of the standard deviation of the twelve images was 0.032 for the original images, but it was decreased to 0.012 and 0.014 for the PLS model and the SOP model, respectively. Of twelve images, two images (images e21 and e52) showed smaller standard deviation in the SOP model compared to the PLS model.

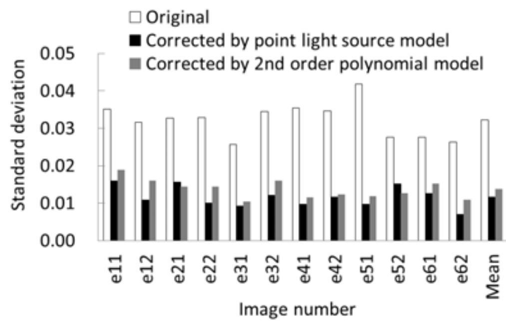

Figure 5 Standard deviations of tristimulus values Y of backgrounds of twelve original and corrected images.

Four original images shown in Figure 3 were corrected using the PLS model, which corrected images are shown in Figure 6. Though the lower part of Figure 3(a) is darker than the center area, the lower part of the corrected Figure 6(a) shows almost the same luminance as that of the center area. However, the left bottom part of Figure 6(a) shows slightly brighter than other area, which indicates an overcorrection.

The image of Figure 3(a), which is one of the most non-uniformly illuminated images, is designated by e51 in Figure 5. The tristimulus values *Y* of 65 background portions in the original image and the image corrected by the PLS model are shown in Figure 7. It is found that the tristimulus values *Y* of the original image, which are distributed in the range from 0.02 to 0.15,

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are decreased to the range from 0.06 to 0.11 in the corrected image. Further, the standard deviation of the tristimulus values Y of the corrected image is reduced to about 1/5 of that of the original image, that is, from 0.042 to 0.008.

Since a 16 bit TIFF image having approximately 500 mega pixels was not able to be handled with OpenCV 1.0, the TIFF image was converted into a RAW image, which was recorded after each line was read and processed. At that time, not only an illumination correction but also a color correction were performed. After that, it was intended to convert the RAW image into a 8 bit TIFF image and to carry out smoothing. However, it was found that the OpenCV 2.3 was able to handle a 16 bit TIFF image with approximately 500 mega pixels. Presently, the program has been transporting.

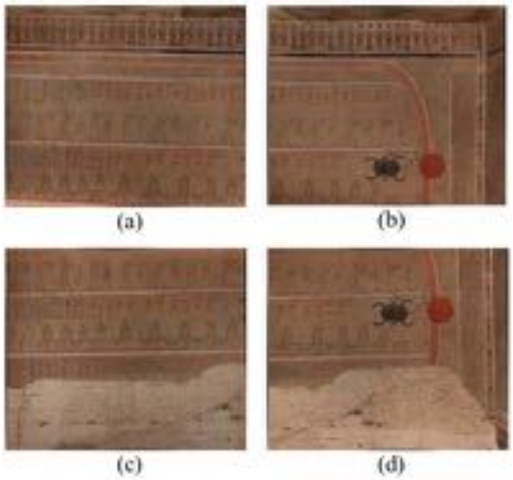

Figure 6 Corrected images of original images shown in Figure 7 by using PLS model.

4. SUMMARY

An illumination model was developed, in which an illumination with a combination of a strobe and an umbrella is assumed to be one from a point light source. By applying the model to an actual mural image, it was shown that an image taken with non-uniform illumination could be corrected into an image which looked like an image taken with uniform illumination.

From now on, we are going to apply the model to all photographed images and perform the illumination correction.

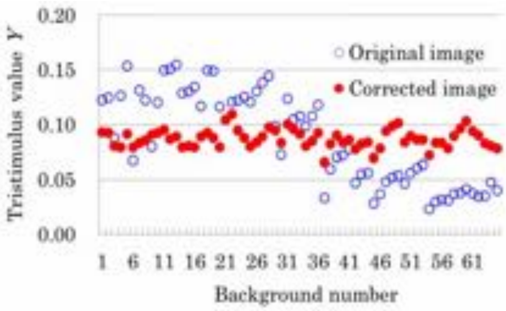

Figure 7 Tristimulus values Y of the backgrounds of Figure 3(a), the original image, and Figure 6(a), the corrected image, which correspond to the white and black bars of Image number e51 in Figure 5, respectively.

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REFERENCES

Inui, M., M. Kato, M. Sato, Y. Azuma, D. Saito, T. Mizuno, T. Kikuchi, S. Yoshimura. 2011, Correcting for Non-uniform Illumination When Photographing the Mural in the Royal Tomb of Amenophis III (I) Development of an Illumination Model and Its Verification, *Journal of The Society of Photographic Science and Technology of Japan* 74: 320-325

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The Synthesis and Properties of 3-(1'H-Benzimidazol-2'-yl)coumarin Fluorescent Dyes for Polyester Fabrics

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ABSTRACT

Fluorescent dyes based on 3-(1'H-benzimidazol-2'-yl)coumarin were synthesized by a simple reaction in this study. The chemical structures of synthesized compounds were subjected to FT-IR, Mass and UV/Vis analysis for color characteristics. Polyester fabrics dyed with the compounds were evaluated by color strength and color fastness to washing, perspiration and light of ISO. The results showed that synthesized compounds were identified by IR and Mass. And then they were used to the dyeing of polyester fabrics. It was clearly that color strength increased with the increasing of the amount of carbon in the seventh location of coumarin ring. The level of color fastness to washing and perspiration were 4-5 or more, while the level of color fastness to light decreased with an increase of carbon chain length.

Keywords: fluorescent dyes, 3-(1'H-benzimidazol-2'-yl)coumarin, polyester fabric, color strength, color fastness

INTRODUCTION

Coumarin compounds which are widely distributed in plants are good fluorescent materials hold excellent optical properties [1]. Coumarin was one of the materials that were the first found to contain fluorescence (Fig.1). Fluorescent dyes possess a very special structure that consist of double bond conjugate system and planar structure. Many coumarin dyes and their derivatives are of great practical interest; they are used widely as optical brighteners [2] and as fluorescent dyes [3] for textile materials. And introducing different types of substituted group in the 3- position or 7-position or both 3- or 7-position of coumarin ring will increase its fluorescence [4].

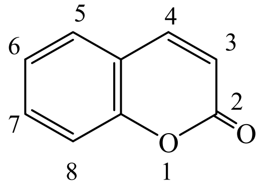

Fig.1 The Structural Formula of Coumarin

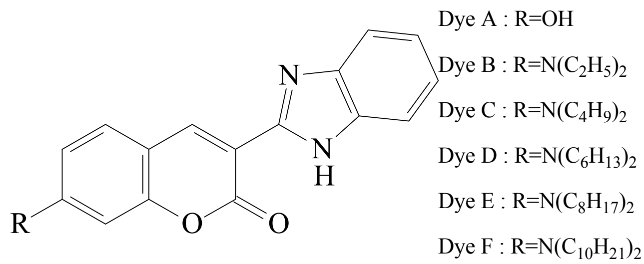

Fig.2 The Structural Formula of Synthesized Dyes

In this study, six dyes with different length of carbon chain were synthesized as the 3-(1'H-benzimidazol-2'-yl)coumarin fluorescent dyes (Fig.2). The structures of obtained compounds were characterized by FT-IR, ^{1}H-NMR, Mass and UV/Vis analysis for color characteristics. The properties of dyed polyester fabrics were determined by color strength and color fastness.

EXPERIMENTAL

Synthesis of Fluorescent Dyes

2-Benzimidazoleacetonitril and 2, 4-dihydroxybenzaldehyde, 4-N, N-diethylaminosalicylaldehyde, 4-N, N-dibutylaminosalicylaldehyde, 4-N, N-dihexylaminosalicylaldehyde, 4-N, N-dioctylamino--salicylaldehyde or 4-N, N-didecylaminosalicylaldehyde were dissolved in absolute ethanol. The mixture was then heated while stirring for 1 hour at 70~75℃ in the presence of piperidine. The product was converted into the coumarin derivative by dissolving it in 8% hydrochloric acid and heating the solution at 70~75℃ for 2 hour. Purification of these dyes was carried out by recrystallization with solvent.

Dyeing of Polyester Fabric

Polyester fabrics were dyed with the synthesized compounds in a liquor ratio of 1:30, at the same time; the leveling agents were added to keep dyeing evenness. Dyeing were carried out at room temperature and then heated to 130 ℃ in 30 minutes. After 30 minutes at this temperature, fabrics were removed and washed in a bath containing 32.5% sodium carbonate and 5g/L sodium dithionite for 20 minutes at 70 ℃ at a liquor ratio of 1:30. Finally, the dyed fabrics were dried.

RESULTS AND DISCUSSION

Structure Characterization of Synthesized Compounds

IR. Infrared spectra were recorded on a Jasco FT-IR 460PLUS spectrometer at 4 cm^{-1} resolution using KBr pellets that the data were represented in Fig.3. For compound A, stretching vibration of -OH bond at 3239 cm^{-1}, alkyl CH bond at 2952 cm^{-1}, For compound B, stretching vibration of $-NR_2$ bond at 3379 cm^{-1}, alkyl CH bond at 2927 cm^{-1}, The compound C, stretching vibration of $-NR_2$ bond at 3438 cm^{-1}, alkyl CH bond at 2924 cm^{-1},. The compound D, stretching vibration of $-NR_2$ bond at 3438 cm^{-1}, alkyl CH bond at 2924 cm^{-1}. The Compound E, stretching vibration of $-NR_2$ bond at 3438 cm^{-1}, alkyl CH bond at 2924 cm^{-1}. For Compound F, stretching vibration of $-NR_2$ bond at 3438 cm^{-1}, alkyl CH bond at 2924 cm^{-1}.

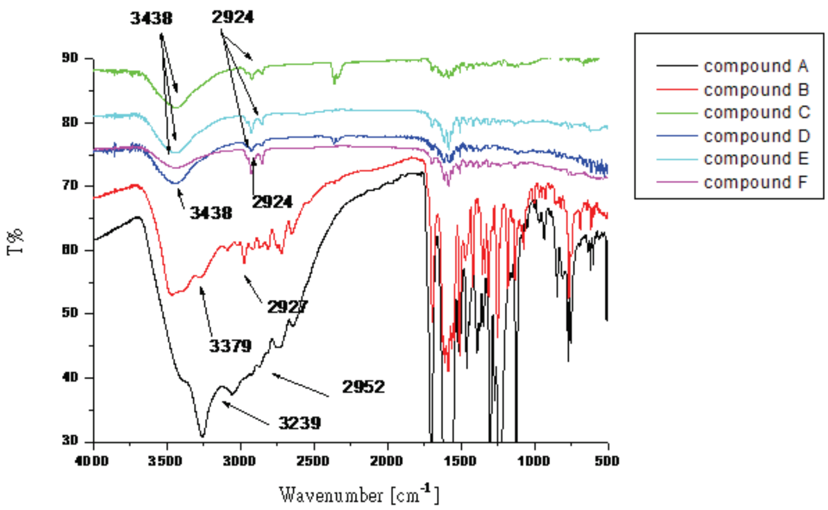

Fig.3 Infrared spectra of synthesized compounds

MS. Mass spectra were recorded on a Finnigan GC/LC/MS TSQ-700 spectrometer, operating at 50~800m/z. And the data were represented in Table 1.

Table 1 Mass spectra data of synthesized compounds

Compound	MS(EI): m/z
A	278(M+,100%)
B	333(M+,65%),318(100%)(M-CH_3)290(10%)(M-C_3H_7),261(10%),(M-$N(C_2H_5)_2$)
C	389(M+,81%),346(100%)(M-C_3H_7)304(84%)(M-C_3H_7-C_3H_6),290(32%),(M-C_4H_9-C_3H_6)
D	445(M+,100%),374(93%)(M-C_5H_{11})304(87%)(M-C_5H_{11}-C_5H_{10}),290(32%),(M-C_6H_{13}-C_5H_{10}), 261(3%),(M- $N(C_6H_{13})_2$)
E	501(M+,100%),402(64%)(M-C_7H_{15})304(91%)(M-C_7H_{15}-C_7H_{19}),290(22%),(M-C_8H_{17}-C_7H_{14}), 261(3%),(M- $N(C_8H_{17})_2$)
F	557(M+,100%),430(47%)(M-C_9H_{19})304(89%)(M-C_9H_{19}-C_9H_{18}),290(21%),(M-$C_{10}H_{21}$-C_9H_{18})

Optical Properties of Synthesized Dyes

Choose the wavelength with maximum absorptions as the excited wavelength to explore their fluorescent properties. The absorption and fluorescence spectra of the synthesized dyes were recorded in Fig.4. Clearly, dyes had characteristic absorptions in the range of 390~470 nm, while the emission fluorescence of dyes located in the range of 460~510 nm. And we can see from Fig.3a that the maximum wavelength of synthesized dyes increased with the length of carbon chain, whereas the increase would not happen that the carbon chain length was over six in ethyl alcohol. And the same phenomenon could be seen in dichloromethane. (Fig.3b)

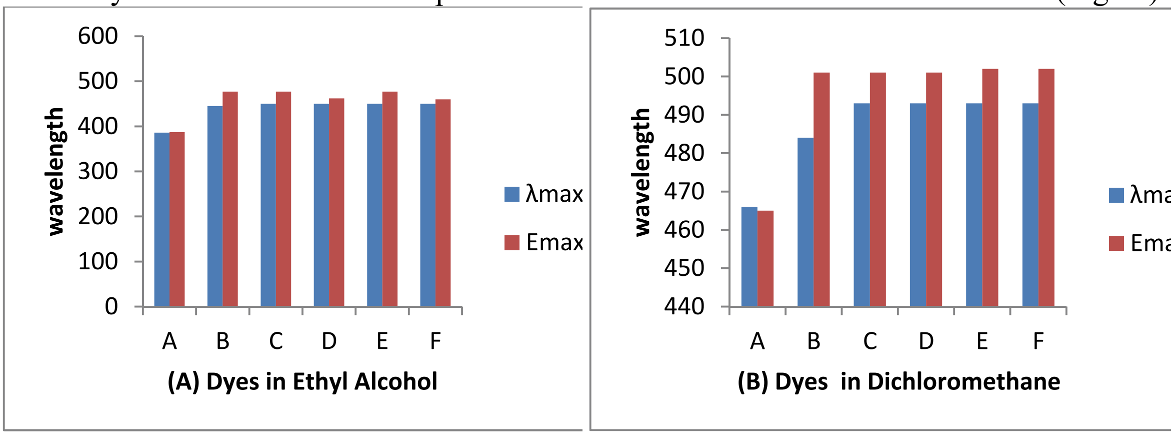

Fig.4 Maximum absorption wavelength (λ_{max}) and maximum emission wavelength (E_{max}) of synthesized dyes with the concentration of $2*10^{-6}$mol/L

Properties of Dyed Polyester Fabrics

Synthesized dyes of 1% (o.w.f.) were used to dye the polyester fabrics and the color strength of fabrics was measured by a color matching device (X-Rite SP62, Malvern, England) under illuminant D65 at 10° standard observers. As shown in Table 2, K/S value increased with the increasing of carbon chain length in the seventh location of coumarin ring and then decreased when the length of carbon chain was over six. This would probably because the reducing of dyeing ability.

Table 2 The color strength of dyed polyester fabrics

Dye	A	B	C	D	E	F
K/S value	2.662	14.077	10.516	6.857	9.771	8.132

The color fastness of dyed fabrics was evaluated according to ISO. The level of color fastness to both wash (Fig.5) and perspiration (Fig.7) are 4-5 or more no matter what the length of carbon chain. As shown in Fig.6, the longer the length of carbon chain in the seventh location of coumarin ring, the lower the level of color fastness to light which might due to the carbon chains break by daylight.

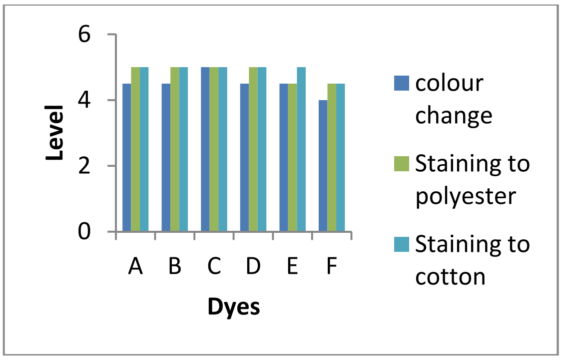

Fig.5 Color fastness of dyed polyester fabrics to wash

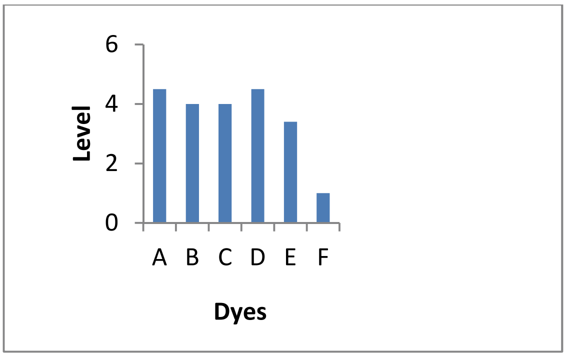

Fig.6 Color fastness of dyed polyester fabrics to light

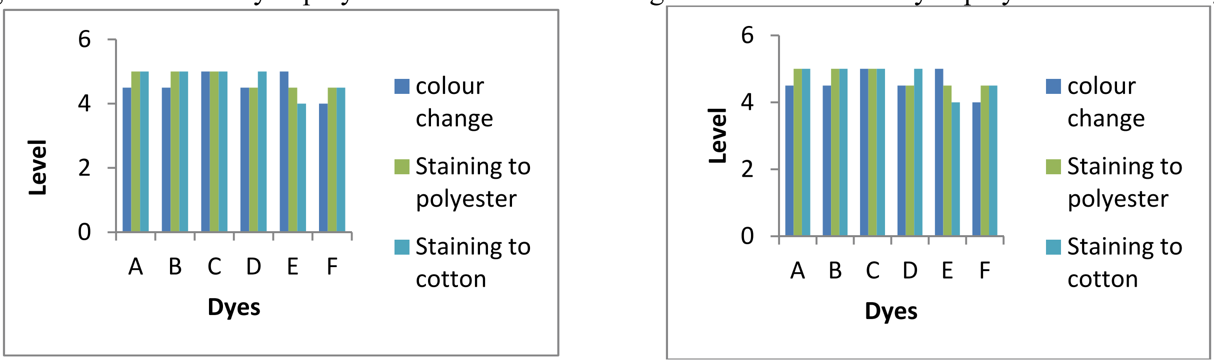

Fig.7 Color fastness of dyed polyester fabrics to perspiration (a) acid perspiration; (b) base perspiration

CONCLUSIONS

After identified by IR and Mass spectra shows all the structure of dyes are correct. Introduction of an electron-donating group into the 7-position of 3-(2′-benzothiazolyl)coumarin results in bathochromic shifts, the increased donor nature of the diethylamino group giving a larger shift than the hydroxy group. The color strength of synthesized compounds dyed on polyester fabric increased with the increasing of the amount of carbon in the seventh location of coumarin ring. The color fastness of synthesized compounds dyed on polyester fabric to wash and perspiration was well, while the color fastness to light decreased with the increasing of carbon chain length of the diethylamino group in the 7-position of coumarin ring, and when the carbon chain length were ten, the fastness level would reduce to only one.

ACKNOWLEDGEMENTS

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REFERENCE

[1] L.S. Zhu, X.H. Wang, G.X. Feng, Speciality Petrochemicals, Vol. 5, 14 (1991)
[2] Ciba-Geigy, British Paten 1,505,730 (1974)
[3] R.M. Christie, K.M. Morgan, M.S. Islam, Dyes and Pigments, Vol.76, 741-747 (2008)
[4] X. Luo, X. Naiyun, L. Cheng, D. Huang, Dyes and Pigments, Vol. 51, 153-159 (2001)

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Interaction of color-pigment and color-light for Set Design: studying a tool for CMYK and RGB color systems

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ABSTRACT

This research aims to study the interaction of color for set design. On stage, the set design surfaces are painted (pigment colors) and illuminated by artificial and colored light from projectors while the environment is dark. We are considering both RGB light and CMYK color systems to study a tool to simulate this interaction. The approach involves two key moments: (i) Color spectrum analysis of “apparent color” by the combination of the additive and subtractive color systems (RGB and CMYK); (ii) Creation of an application to simulate the apparent color resulting from the combination of the RGB and CMYK systems, graphical diagram and systematic observation, recording and analyzing the phenomenon on stage.

The main goal of this study is to clarify and understand the interaction of color (light and matter) as well as its relevance on stage. After testing and showing the relevance of these tools, the next step of the research should focus on their development as a support for the design thinking process. The lack of specific studies makes this research relevant.

INTRODUCTION

From the beginning I have always worked with light and color. In starting a new work that is the first thing I do. Without light there is no space. With light, there is color.[1]

Robert Wilson interview, Dec.2010

The study of the interaction of color through the systems of RGB and CMYK color aims to obtain a graphic diagram color as a useful tool for understanding the interaction of the light´s color with the color pigment of the Set Design.

Set design work is an ephemeral process, which implies a capacity for immediate response, intuitive and above all creative. For a designer, it is essential to know the potential of materials depending on the light´s color change to which they are exposed. With that meaning of apparent color is it easier for a set designer to work on the dramaturgy of the performance. The dramaturgy of the performance is a shared work between all areas and includes set designers, costume designers, lighting and sound designers, performers, and production (production executive, image and stage management). Color is one of the common links of this multidisciplinary nature of creation and requires a special focus on its interaction.

In the theoretical basis of color [1] [2] [3] [4] [5] we only can read color in ideal environments: color pigment is viewed in daylight, on a white surface and the light´s color ,

[1] Email interview with Robert Wilson Director (http://robertwilson.com). December 2010.

although presented by Newton in a light beam, viewed on a white surface. Why do we not create an ideal environment for interaction of color? Before recognizing the attributes of the interaction of light on objects studied by Kurnar and Choudhury [6] , it is necessary to understand the nature of color. Merleau-Ponty [7], Gibson [8], Fletcher [9] and Osborne [10] sensitize them to the issues of the phenomenon of color and the importance of the color interaction. Israel Pedrosa [11] deepens the phenomenon of controlling the color and color according to the location of the observer. And lastly Swirnoff [12] wonders about the fact that 150 years after Goethe had written his treatise on colors the issues of color and shape are still being studied separately.

In theater design issues, Max Keller [13] and Richard H. Palmer [14] provides us some analysis parameters for the design of light compared to each of the surrounding areas in a performance, where color is one of the common links of the elements of stage design in the area of performance. In the history of the theater and around the time of the emergence of electric lighting on stage, we found an article from 1920 published by the Journal Times [2] that acquainted us with the work of Adrian V. Saimoiloff, based on theories of physics which he used in his magic tricks.

DEVELOPMENT

Mathematical models developed by CIE that help predict change in color appearance given by the different viewing conditions, consist of various color spaces and serve to evaluate distinct color differences in light, pigment, imaging and computing. Just as there are diagrams showing additive and subtractive systems with the results given by mixtures in their ideal conditions we aim in this study to obtain a new graphic diagram which in a similar way can explain what the mathematical models can predict and finally compare whether these forecasts coincide with the reality of a theatrical stage. Like the graphic computational image these values will eventually simplify the matter of color reproduction and in this way convert different color spaces without major color changes, in this study we propose to compare the results of the color mixing of RGB and CMYK systems: first by studying the spectrum of the illuminant and obtaining a new scheme spectrum, and second, through the simulation of color resulting in an application/software for a mobile device and finally in a real environment through observation, recording, analysis, evaluation and comparing the results of these three situations.

After this we will draft a proposal for a graphic diagram which facilitates the understanding of this mixture.

We will need to go to the basic understanding of color, to develop a useful tool that simplifies and contributes to color literacy just as schematized additive and subtractive systems are and which relates the three-dimensionality, including key issues such as absorption, reflection, refraction without stimulating the understanding of a colored light on a colored surface.

In this context, the aim of this work is to contribute to the literacy of color through joining the RGB and CMYK systems.

Practical examples that explore the potential interaction of color can be found on the Philips Research [3] (Atmosphere Flipbook, 2007), in artistic projects of James Turrel [4]or the

[2] In http://query.nytimes.com/mem/archivefree/pdf?res=F40C13FC3B5A1B7A93C2AA178BD95F458285F9 (08/05/2012).

[3] http://www.research.philips.com/technologies/shoplight/atmosphere.html (10-02-2010)

experiences of chromatic variation of Tara Avery[5] of Department of Digital Media Arts Avery Caldwell.

METHODS AND RESULTS

In the first stage of the work will be employed the following methodologies will be employed: 1. Mathematical calculations and resulting graphs and description of the illuminant spectrum of the mixture of RGB to CMYK systems; 2. Measurement of the illuminant spectrum of a colored surface exposed to an RGB light (physics laboratory); 3. Simulation-mix additive and subtractive developed as an application for a mobile device as applied from the same mathematical models (CIE);
-observation of the interaction of color of painted surfaces illuminated by RGB spotlights on a stage in a theater .

The proposed methodology will to be develop quantitative and qualitative assessment and show the results still awaiting confirmation.This work will be offered in the form of a graphic diagram of the interaction of systems RGB and CMYK the results of which will be confirmed at a future date. In obtaining accurate results and confirmation of color this diagram will be completed with the results of apparent color:

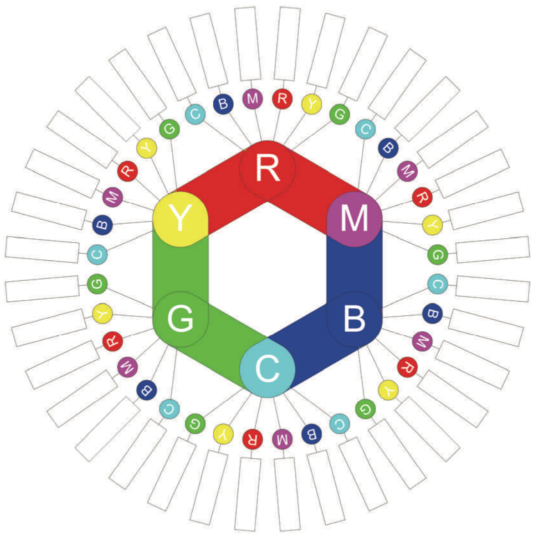

Fig. 1: Diagram of Interaction of two colors systems (RGB anda CMYK)

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[4] through his link: http://vimeo.com/5929848 can be viewed online a short documentary produced by BBC (10-02-2011)
[5] in this regard, see this link: http://www.youtube.com/watch?v = No6r5QjBq8Y (10-02-2011)

mobile application;I would also thank the Minho University (Physics Department), under co-supervision of Professor Sérgio Nascimento, for the analysis of the spectrum of the illuminant and finally the collaboration of the Polytechnic Institute of Porto (School of Music, and Performing Arts-Department of Theatre), for testing and experimentation on the stage at Teatro Helena Sá e Costa.

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CONCLUSION

We still have to finalize the study of the practical application of this diagram and apply the "calculator" color on a mobile device, to conclude whether or not this tool contributes to literacy of the interaction of color or even encourages learners to develop more complex scenographic compositions and thus contribute (through this interaction of color) to the dramaturgy of a performance. At present, this research is a work in progress and this proposal of laboratory experimentation is waiting for a confirmation.

REFERENCES

[1] Birren (1988) Light Color and Environment. NY: Schiffer Publishing.

[2] Birren F.(1987) Principles of Color, Atglen: Schiffer Publishing, Ltd.

[3] Goethe, J.W. (1973) Traité des Couleurs. Paris: Triades Editions.

[4] Arnheim, R.(1998). Arte e percepção visual – uma psicologia da visão criadora. (12ª ed.). S. Paulo: Livraria Editora

[5] Tournquist (2008). Color y Luz – Teoria e Prática. Barcelona: Editorial Gustavo Gilli, SL.

[6] Kurnar, A. And R. Choudhury, (2000). Modern. Concept of Color and Appearance. USA: Science. Publishers Inc. Berns

[7] Merleau-Ponty, M. (2002). O Olho e o Espírito. Lisboa: Vega.

[8] Gibson, J. J. (1986). The Ecological Approach to Visual Perception. London: Lawrence Erlbaum Associates, Publishers.

[9] Fletcher , A. (2003). The Art of Looking Sideways. London: Phaidon Press Limited.

[10] Osborne, Roy (2004), Color and form. USA: Universal Publishers.

[11] Pedrosa, Israel (1977) Da Cor a Cor Inexistente - 10ª Ed. S. Paulo, Editora Senac São Paulo.

[12] Swirnoff , L. (1986). Dimensional Color. New York: Van Nostrand Reinhold.

[13] Keller M. (2010) Light Fantastic: The Art and Design of Stage Lighting. Munich; London; New York: Prestel Verlag,

[14] Palmer H.R.(1993) The Lighting Art: the aesthetics of stage lighting design, Allyn & Bacon ISBN 10: 0135010810.

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Color absorption equation as instrumental tool of light research

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ABSTRACT

Nature of color is defined as the selective absorption of light. Light once generated, penetrate the peace undergoing the acts of absorption and reflection in air, to water, dust, and chemical conglomerations. Natural color structures are well known as the clouds of the atmosphere, oceanic water reflections, the wheel of rainbow. Chemical substances are responsible for the absorption of light. Important physical law of color absorption of the light: light partially reflected by pigment, partially absorption on the components of pigment. Pigment as chemical structure on the way of light is the mixture of separate substances. The general main physical specification of the spreading of the light through world is the acts of absorption and reflection. Since this is physical process, we can quantitatively describe and calculate the properties of one or other pigment or another selectively absorb and reflect light. Selective luminous absorption by the mixture of colored pigments is given by the system of three equations: 1. equal colored pigments absorb the equal parts of the light, 2. the brightness of reflected light equal to the superposition of the partial brightness's of the mixture of colored pigments, 3. selective color absorption is the result of the superposition of the luminous absorption of the partial components of colored mixture. The law of selective color absorption of color in question makes it possible to uniquely determine color and quantity of color pigments, the distribution of the substance being investigated as the distribution of colored pigment, in the comparison with the known standard pigments, as well as a natural color rainbow wheel. The surface of color mixing with the characteristic lines of color, brightness further adapts for mathematical computation of the spatial spreading of color pigment in the assigned substratum. Instrument task consists of the graphic measurement of the process of distributing the assigned substance. The extended task of investigating the industrial processes of the ejection of toxic substances into the natural landscape is examined.

K**eywords**: Color, physics, specification, optic, nature.

1. INTRODUCTION

The system equations of color selective luminous absorption by pigment mixture consists of three equations 1, 2, 3 where parameter E - light intensity incoming from the luminous source, parameter E (0)- light intensity after absorption on the pigment mixture. X, Y, Z are pigments quantities this type of the mixture, e (x), e (y), e (z) is brightness of the color light components X, Y, Z after acts of absorption on the pigment mixture Lev M Vozchikov(2002).

$$E=e(x)/X+e(y)/Y+e(z)/Z \quad (1)$$

$$E(0)=e(x)+e(y)+e(z) \quad (2)$$

$$E(0)/E=X+Y+Z \quad (3)$$

Characteristic lines of color surface Ch (X,Y), Ph(X,Y). Equal color line Ch (4):

$$Ch(X,Y)=X/Y \quad (4)$$

Line of equal brightness (5):

$$Ph(X,Y)=X+Y \quad (5)$$

The surface of color mixing pigments given equations (4), (5) consist superposition lines equal color and brightness of the aperture perception of light. Each pair of pigments always matches standard defined aperture perception of color, color surface the tool graphic study spreading pigment substance. Instrumental model of the mixture green and red pigments was built in the computer standard of the color gradations (**Figure 3). Figures 1** present the result calculating matrix specimen image instrumental lines equal color mixture green and red pigments. **Figure 2** are result calculation matrix image instrument lines equal brightness. **Figure 3** is image surface mixed green and red built in the gradations computer standard color 50 with the aperture perception 0-250. **Figure 4** reproduces result calculating 3D measured surface mixing pigments selective luminous absorption superposition lines equal color and brightness.

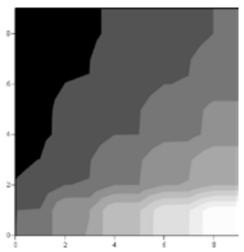
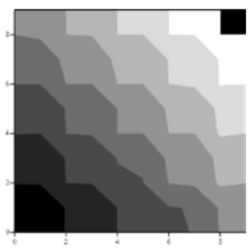



Figure 1: *Build equal color surface given in zones equal brightness Ph.* **Figure 2:** *Build equal color surface given in zones equal color Ch.* **Figure 3:** *Red, green mix yellow color image sample.* **Figure 4:** *3D surface of color mix.*

2. METHOD

Method preparation image specimen red green mixtures simulate 5x5 color ranged elements squares matrix mixture red and green. Each square 25 elements consists of 4x4 equal color elements matrix pigment. In sequence are mixed red and green pigments so that the aperture of acquiring it is equal 250 point's computer color standard gradations. Further image is mathematically isolated in the matrices red X and green Y. In the matrix form farther calculated matrix Ch, Ph image Ch (X, Y), Ph (X, Y) by calculation surface system equations 4, 5. Calculated matrices of color, brightness further used for constructing two-dimensionally image surface lines Ch, Ph equal color and brightness. Sequence algorithm procedures mathematically construct sample color surface is result color mixing process. Basic procedures color light study image color specimens paint sample, random scaled cluster 250 range given in this work.

3. EXPERIMENT

Has been analyzed several samples unique processes of the spreading one pigment substance in other. Learned examples, are specimens of the original process light color absorption with presence of the optically coloring substances. Nature substances: gas, liquid, self illuminated gas has been recorded photographically. The task graphic determination specification of the zones concentration substance has a goal to prognostic and to prevent presence random zones of concentration harmful substances. Method of selective light absorption works well and is effective for the processes different physical nature: turbulent gas emission, liquid dye injection into the liquid, atmosphere explosion of the luminous gas. Experiment uses an optical image recorded by digital photography. Consecutively calculating matrices X, Y image dyes spreading, applying algorithm of system equation surface color mixing 4, 5 as a result we find images of the specimens, in according to the method described above. Images presented are given by conversion color surface superposition cluster image lines equal color and intensity Lev M Vozchikov (1993, 2005).

4. RESULTS

4.1 Gas emission in environment

Turbulent diffusion is the most known emission example. The problem of the isolation zones limiting hazardous concentration this method is solved effectively with support optical monitoring scene of spreading gas that separate point source remotely. Pictography is the most advantageous technology fixation landscape field pollution. Investigating constructed algorithmic image of gas give us conclusion a constant chromatic structure is the presence indicator homogenous dye substance. Presence zones of color gradation are the characteristic feature of the structure gas concentration in the turbulent process of emission. The constructed image makes it possible to calculate dye concentration per unit of volume.

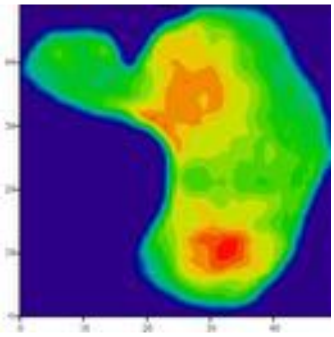
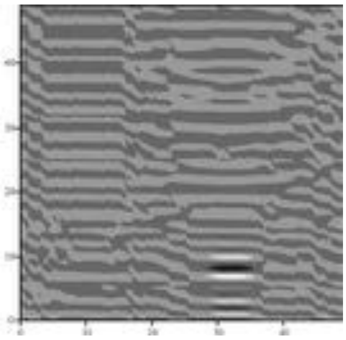




Figure 5: *Partial gas object recorded gas emission.* **Figure 6:** *Build color surface constant brightness Ph (X, Y).* **Figure 7:** *Build surface of color mix constant color Ch (X, Y).*

4.2 Liquid is injected in liquid

This specimen has characteristic mono-colored carrier the painting substance. Injection in liquid is the random process turbulent diffusion in limited volume. As can be seen from constructed images surface brightness and color diffusion structure is heterogeneous because of the super- position turbulent processes emission and diffusion. Accumulation coloring substance in this example more random responsible control appearance zones of the maximum permissible hazardous substance concentration. The constructed image makes it possible to calculate the structures zones concentration at the given moment of the process development.

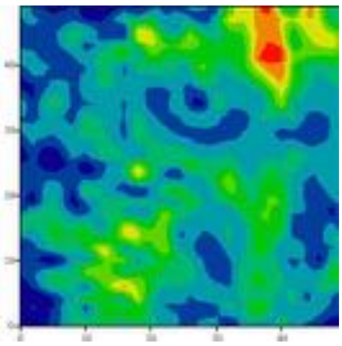
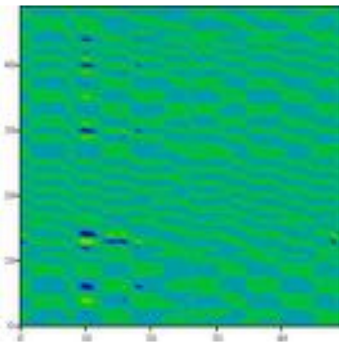
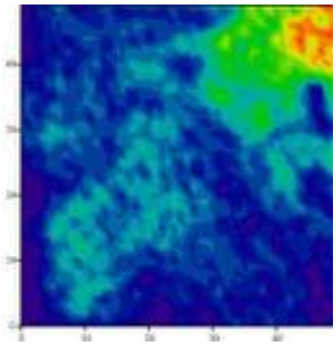




Figure 8: *Record of liquid substance magenta pigment, diffusion process.* **Figure 9:** *Build color surface constant brightness.* **Figure 10**: *Build color surface constant color.*

4.3 Self illuminated gas

Specimen is obtained telephoto graphically. Direct gas injection is caused luminous blast of high concentration with the high speed. Source of the gas ejection is moved along the trajectory. Zones diffusion are strictly isolated with the discrete nature combustion of the luminous gas. The source of dye in this specimen – point source, is located in the upper right corner intersection of the image coordinates. Constructed image makes it possible to calculate speed of the motion point source of gas and the residual concentration substance at the trajectory of the injection.



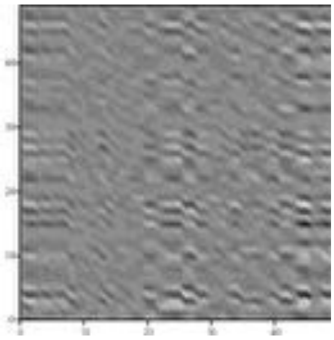


Figure11: *Original optical record of gas blast in air.* **Figure 12:** *Build superposition constant brightness clusters map*. **Figure 13:** *Build superposition constant color clusters map.*

5. CONCLUSION

Work demonstrates graphic mathematical method mapping control chemical substance spreading process in measurement of selective light color absorption. There are examined pigments examples emissions of the liquid, gas, luminous gas, computer screen standard color. Known pigment substances provided for obtaining the samples image of the physical process, process simulated in purposes of prognostication. Consecutively, on the basis the mathematical system equations of the color surface mixing pigments, shows efficiency of the mathematical apparatus for quantitative graphical analyses selective color absorption, pigment concentration. Surface model color light absorption standard color mixture is investigated for an isolation of the lines constant color, constant brightness pigment mixture. Method investigate optical model of the transposed pigment image clusters matrices by extrapolation spreading substance structure, measures hazardous concentration, describe industrial processes of gas emission, injecting liquid dye into liquid, explosion of the luminous gas. Work proves advantage, physics mathematic algorithm calculations spreading concentration dye substances in field as well in laboratory.

REFERENCES

Vozchikov L. To question about chromatic theory light record-transfer colour picture, in COLOUR 93: 7TH Congress: Papers and summaries. Nemcsics, Antal ED 1993 VOL ABC pt 7, pp P20-1, Lev Vozchikov, Technical University of Budapest, 0773 068670 96342030519(SET)

Vozchikov M Lev. To question about theory chromatic light pain, in 9th Congress of The International Color Association, proceedings of SPIE vol.4421, pages 379-383 (2002), ISSN 0277-786XISBN 0-8194-4128-7, SPIE-The International Society for Optical Engineering, Washington, USA, 2002.

Vozchikov M Lev. Image-color cluster structure superposition in air landscape emission observation by the color mix surface. In Proceedings of 10th Congress of the International Colour Association, Granada, Granada 2005, p.p. 1143-1145, Proceeding Book ISBN 84-609-5164-2

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A New Path to Introduce the Color Theory to Basic Design Studio: Impressionism as a Source

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ABSTRACT

As very well known, Basic Design is an introductory course offered in the first year of the curriculum in art and design education. As a course basically focusing on visual perception, principles of basic structures, form-function relationship, color theory and composition, it is an open ground for different approaches in introducing the color theory.

This study focuses on a specific method to introduce the color theory in Basic Design Studio. It is based on a series of exercises in 2011 Fall Semester that was conducted in Basic Design I in the Department of Industrial Product Design at Istanbul Technical University (ITU), Turkey. Impressionism, one of the influential 19^{th} century art movements, is the inspiring basis for these exercises because of its special attention to color and light not as objective facts, but relative and experimental issues.

Basically, the exercise has three stages; analysis of the color composition, re-interpretation of the composition and transformation to 3D. This paper includes stages of the formation, processing and the evaluation of the above mentioned exercise. Exercises are exemplified in a detailed way to help reveal the issue and process thoroughly.

1. BACKGROUND

1.1. Color in Basic Design Education

Basic Design is an introductory course offered in the first year of the curriculum in art and design education. Basic Design course is known as 'indispensable' by many instructors, and accepted as the most significant course of the first year (Özer, 2004). The establishment of the Basic Design concept is based on the human perception theories of Gestalt, which formed the educational curriculum of Bauhaus school (Denel, 1981). This course basically focuses on visual perception, principles of basic structures, form-function relationship, color theory and composition. These principles are mostly extracted from the early sources of Michael Graves (1951) and Rudolf Arnheim (1954). Therefore, they are widely accepted as the fundamentals for this course.

Color is accepted as one of the key elements in art, design and architecture (Samara 2007; Lidwell, et al. 2003). So, the Color Theory has been one of the major topics in Basic Design education. There are different approaches in introducing this theory in Basic Design studio.

One of the important color instructors in Bauhaus is Josef Albers. He clearly considers the searching process itself to be more crucial to learning than the end results in teaching the Color Theory. He believes that it is important for students to be aware of the basic color systems, to learn color terminology and to be introduced to the physics of light and color. The students have to experience in mixing colors and learn to apply it with skill. The students also have idea on how various artists or designers have used color in the past (Kelly, 2004). Thus, his approach is based on a self-education after being introduced with the theory.

According to an international survey on Basic Design education, it is said that for many instructors there are no major changes in terms of pedagogical approach or methodology of teaching Basic Design. In other words, the basic concepts of point, line, color etc. are still taught in the traditional segmented way or step-wise fashion (Boucharenc, 2006).

Güngör (1972) supports this traditional segmentation in design education, particularly in teaching the Color Theory. After teaching theory on a certain subject, an application is required supporting the theory. It is also stated that first studies are done in black and white; then black, white and gray and finally colored projects can be done (Güngör, 1972).

Briefly, there are different approaches in engaging color in design education. However criticized, color; -whether based on a strict methodology or model, or more experimental and speculative- is an issue to be studied especially in the field of design to assign or enhance meanings and functions. So, the methodology to teach the theory in design studio becomes crucial since the color is the one of the important tools in industrial design profession.

1.2. Impressionism

It can be said that**,** for Impressionism a search for a more exact analysis of color gets more importance. Instead of shadowing an object from its color just by adding some brown or black, the colors are enriched by the idea where the shadow of an object is broken up within the dashes of complementary colors.

The era when Impressionism evoked as an art moment was important since, "the nineteenth century was not concerned with just the explanation of nature itself, but with our way of apprehending it through the physical vision. This meant understanding the constitution of color and the structure of light and the psychology as well as the physiology of human vision. It is not surprising to find, therefore, that optical research was important in the scientific history of time, that many painters concerned themselves with contemporary theories and that the criticism and interpretation of art frequently turned upon the nature of vision (Taylor, 1953).

The organization of colors due to their ability to create compositional depth was another important topic for the Impressionist. Painters were able to create the illusion of an object's volume or flatten an area by using color. These spatial characteristics of color were fully developed by the French painter Paul Cézanne in the late century.

In the works of the Impressionists' line, value, shape and texture were greatly aided by the ability of color to create space and meaning. As Eugéne Delacroix, once stated; "Give me mud and I will make the skin of a Venus out of it, if you will allow me to surround it as I please."

2. PROPOSED METHOD TO INTRODUCE THE COLOR THEORY

2.1. Description of the Proposed Method and the Process

The exercise has three stages; which are namely analysis of the color composition, re-interpretation of the composition and transformation to 3D. In the first stage, students are expected to discover and learn what impressionism is and choose an Impressionist painting for next stages. They are required to analyze the painting by focusing on its color composition. They have to make an abstraction focusing on the dominant colors in the composition and the way they are structured on the surface of painting. Therefore, they are expected to divide 9 areas by considering color composition. This limitation compels the student to make abstraction and learn it by experiencing. Moreover, as a project constraint, they have to reach the intended hue only by mixing red, blue, yellow, white and black.

In the second stage of the exercise, students have to re-interpret the color combination in the light of color theory after they are briefly introduced with theoretical background. They may re-consider the combination and suggest a new one.

In the last stage, students are asked to transform the Impressionist painting into a self-standing 3D form by using tetrahedrons, considering the color combination is a volumetric understanding. This stage is where students have difficulties in transforming to 3D form since it is their one of the first exercises challenging the 2D and 3D relationship. This stage is the critical one since it is closer to Industrial Design education where students are mostly dealing with 3D objects.

2.2. Outcomes

In this section, 3 students' projects are revealed to discuss the outcomes of the project. Concerning the first stage –analysis of the color combination-, students are able to experience the certain hues by mixing red, blue and yellow. They can also add black and white to get the shades or tints of a hue. Therefore, it has been an experiential and informative stage while discovering the elements of a hue. Within these limitations, they try to reflect the color combination of the painting. In the re-interpretation stage, students mostly prefer to use the contrast colors and try to reverse the effect of the composition. In transformation stage, they often make abstraction of the dominant part of the painting.

In Project 1, the student endeavors to analyze, re-interpret and transform the painting of Claude Monet, one of the most famous Impressionist painters. The analysis of the color composition seems to be fairly successful since the student makes a "good" abstraction. In other words, the primary figures in the painting (the woman, the umbrella, the child and the shadow) is no more distinct/clear and dominant in the composition. Therefore, the analysis gains its own characteristics and it can be considered as a contribution to the exercise. In re-interpretation stage, cool colors are replaced with the warm ones. It is the student's aim to see/reflect what if a cool colored composition is re-interpreted with the warm colors.

Student Name: Cem Avci	**Painting by Claude Monet**	**Analysis of the color composition**	**Re-interpretation of the composition**	**Transformation to 3D**
				

Figure 1. Example Project 1

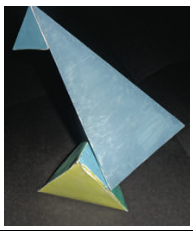
Student Name: Huseyin Ertit	**Painting by Claude Monet**	**Analysis of the color composition**	**Re-interpretation of the composition**	**Transformation to 3D**
				

Figure 2. Example Project 2

In Project 2, the painting is the same with Project 2. However, the analysis of the painting is quite different from the Project 2. It can be considered as a potential for this exercise to see different interpretations of the same painting.

In Project 3, especially the abstraction of the "sun" in the painting is noteworthy both in the analysis and the transformation part.

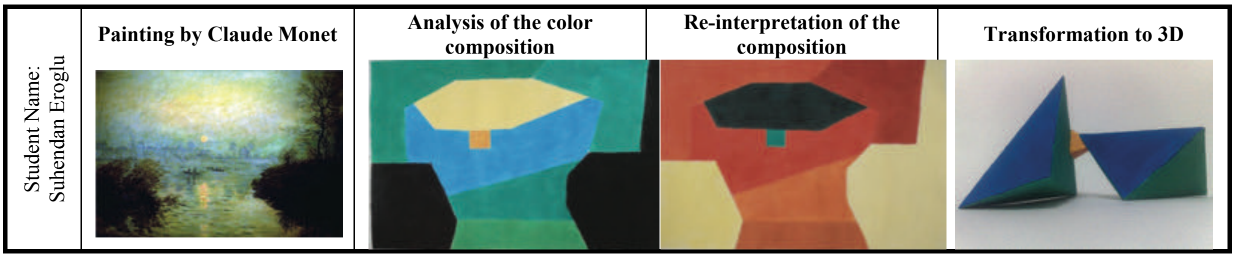


Figure 3. Example Project 3

3. CONCLUSION AND DISCUSSION

As color is a primary element in both art and design education in general, it is important to mention about the special position of it in terms of industrial design education. In classical understanding, color is regarded as connected to the aesthetics of an object. However, as this exercise suggests, the abstraction and transfer of the color into a self-standing 3D structure challenges a new transfer. That is of visual dynamics into a coherent physical function, which is the premature phase of form supporting utility in design. Abstraction is the source of alienation towards the form and function, in which new formulas can be created in terms of structure, utility and aesthetics.

For further studies there could be other design exercises such as; assigning a brand new function to the existing structure, analyzing the 3D form and transferring it into 2D again, creating variations or repeating the same exercise starting from a functional object into 2D to catch clues about brand identity etc.

REFERENCES

Arnheim, R. (1971). *Entropy and Art: An Essay on Disorder and Order*. USA: University of California Press

Boucharenc C.G. (2006), Research on Basic Design Education: An International Survey, *International Journal of Technology and Design Education*, 16:1-30

Denel, B. (1981), *Temel Tasarım ve Yaratıcılık (Basic Design and Creativity)*, ODTÜ Mimarlık Fakültesi Basım İşliği, Ankara

Graves, M. (1951) *The Art of Color and Design.* USA: McGraw-Hill Book Company

Güngör, H. (1972) *Temel Tasar (Basic Design).* Istanbul: Afa Matbaacılık.

Kelly, R. R., (2004) A Mini Course in Color the Collected Writings of Rob Roy Kelly. Retrieved from http://www.rit.edu/library/archives/rkelly/html/04_cou/cou_col1.html

Lidwell, W., K Holden, and J Butler. (2003). *Universal principles of design*. Beverly, MA: Rockport Publishers.

Özer, D. (2004) Origins, Aims and Methods of Basic Design Courses in Industrial Design Programs in Turkey, Msc. Thesis, METU. Department of Industrial Design, Ankara.

Samara, T. (2007). *Design elements: A graphic style manual*. Beverly, MA: Rockport Publishers.

Taylor, B. (1953). *The Impressionists and Their World*, Phoenix House LTD., London.

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Teaching aids about color mixture: Color by mixed spinning of dyed wool fiber

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ABSTRACT

This research examined the teaching aids which made various colors by mixing the dyed wool. The wool was dyed in three colors by using the acid dye solution (pH 4). The wool dyed in three colors was blended by carding, and the result of the changed color was considered. When the colors of the dyed wool were mixed by blending, the aggregate of the fiber was obtained where the wool fiber of each color before blending was distributed equally. Although it was difficult to make color of high chromatic saturation compared with the dyed wool before blending, various colors could be made by the blending of the dyed wool. The teaching aids that the learning students dye and blend the wool regarding the ratio of a color suggested it in the production process that it was also useful for study of other subjects such as the science and the fine arts.

1. INTRODUCTION

Our information from outside environment depends commonly on the vision. Especially color has played important role. When we product textiles as teaching aids, various expressions are attained by adopting various colors, and a student's volition is made high by it.

Although many textiles are used for our personal appearance, there are few opportunities for us to know the production process of textiles with the most ready-made articles. Homespun wool thread has processes such as washing, dyeing and spinning. The homespun wool thread is available to make textile goods, so the using such a thread for the teaching aids makes it possible to learn experience about the textile. However, it is difficult to prepare dyed wool of various colors at one school. Then, we tried to mix the dyed wool fiber by carding and to make various colors.

2. METHOD

2.1 Scouring and dyeing

In this research, we used Cori Dale's raw wool bred at Rokkousan Pasture of Kobe City in Japan. (Figure 1) We soaked the raw wool from which dung and straw was removed in the hot bath of about 40 degrees. The raw wool was rinsed with the hot bath about 2 hours afterward, was squeezed lightly, and water was removed. The raw wool after squeezing was soaked in the neutral detergent solution for laundry overnight. This condition in 0.2 % detergent solution for laundry was maintained overnight. We made the raw wool dry after

Figure 1. Raw wool of Cori Dale.

we rinsed it with a hot water on the following day. By the way, the yield of 1 kg of the raw wool was reduced to about 700g by washing treatment.

The wool was dyed in three colors by using the acid dye solution (pH 4). Names of those dyes are DERUKUSU red F-5G, DERUKUSU B. yellow S-GB, and DERUKUSU B. blue BG, respectively. All dyes were purchased in the "TANAKANAO, Inc. dye shop" in Japan. The dyeing effect of the wool fiber was very high, and the average degree of coloring power was about 98%. The experimental condition, the dyeing method and the dyeing result etc. were shown in Table 1, Figure 2 and Figure 3.

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Table 1. Dyeing conditions.

Wool fiber	10g
Acid dyes	2% o.w.f.*
80% CH_3COOH	6% o.w.f.*
Liquor ratio	1:60

* on the weight of fiber

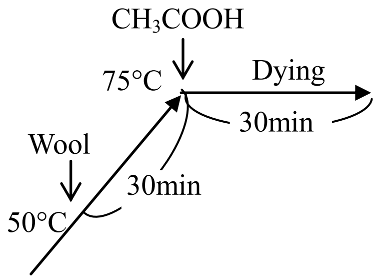

Figure 2. Dyeing method.

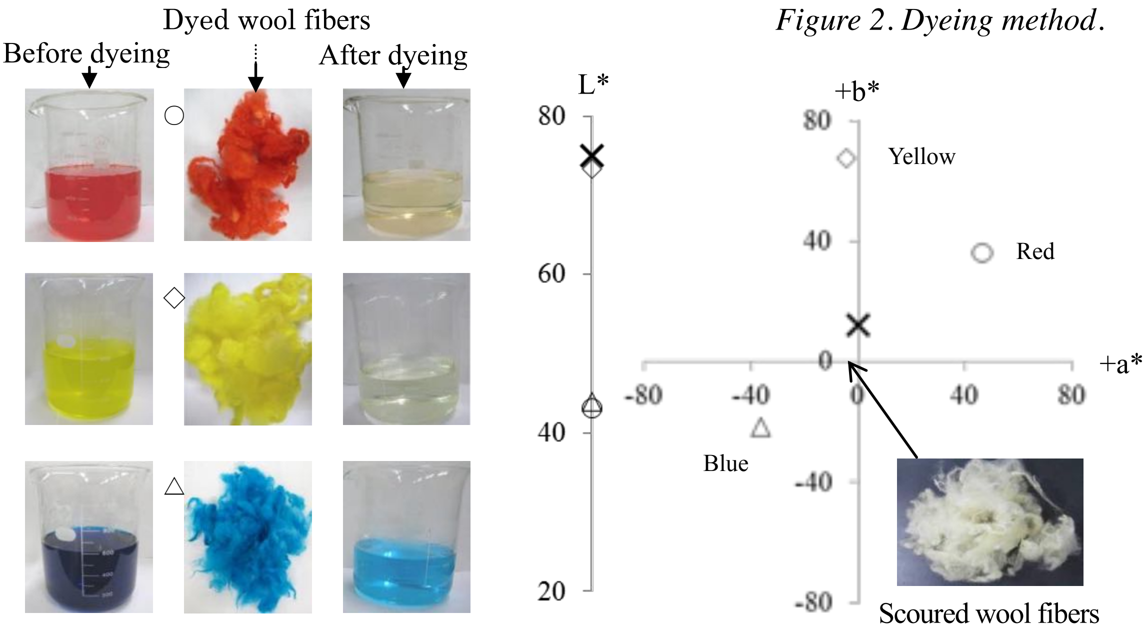

Figure3. Result of dyeing and chromaticity diagram.

2.2 Mixture of the dyed wool by handcards

We used a pair of handcards to mix dyed wool fiber. (Figure 4)

Three kinds of methods were adopted for carding. In the first method we mixed two chosen colors at a time from red, yellow and blue wool. Woolen weight of each color was changed to 1:3, 1:1 and 3:1. In the second method the wool of red, yellow, and blue was blended to 1:1:1. And then as the third method the each wool of three colors was blended with the wool before dyeing by 1:1.

Figure 4. handcards.

2.3 Measurements of colors

After mixing the dyed wool fiber, changes of the colors were measured by spectrophotometer (CM-2600d, KONICA MINOLTA). The measurement conditions of a color were shown in

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Table 2. In the specular component excluded (SCE) mode, the specular reflectance is excluded from the measurement and only the diffuse reflectance is measured. This way leads to a color evaluation which correlates the observer correct to the color object such as actually seeing. That is the reason why we measured in the SCE mode in this research.

Table 2. Measurement conditions of a color.

Light source	D65
Visual field	10°
Color space	L*a*b*
Optical System	SCE
Number of times	3

3. RESULTS AND DISCUSSION

3.1 Mixing of fibers and color change

When the colors of the dyed wool were mixed by carding, the aggregate of the fiber was obtained where the wool fibers of each color before blending were distributed equally.

The wool fibers dyed in three colors (red, yellow, and blue) were mixed with scoured wool at proportion of 1:1 in the each color. Those color changes were shown in Figure 5. It was difficult to make color of high chromatic saturation compared with the dyed wool before blending. However in the case of the a*, b* chromaticity diagram, values after mixed colors are on the line which connected each color to the point of scoured wool fibers. And high correlation was recognized between the mixing proportion and the chroma in the each color. On the other hand, the brightness became high when colored wool fibers and scoured wool fibers were mixed. This tendency appeared notably in red and blue.

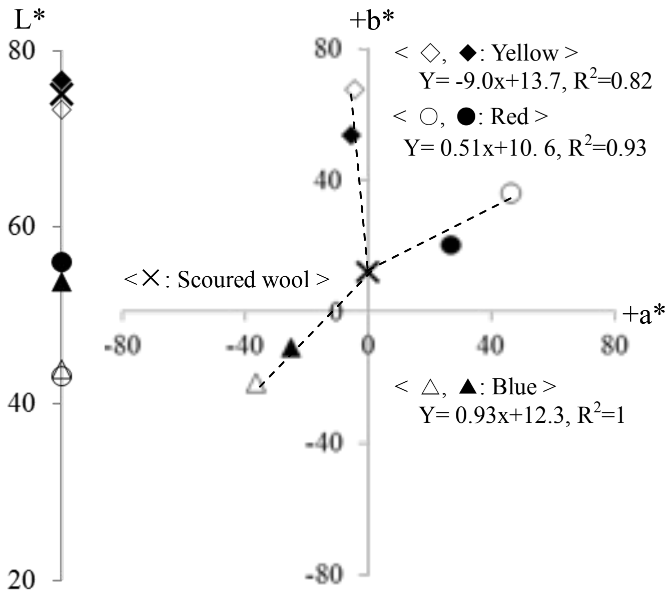

Figure 5. Distribution in chromaticity value of colored fibers (open marks) and color mixed fibers (closed marks).

3.2 Relation of color change and mixing proportion of fibers

The wool fibers dyed in red, blue and yellow were mixed in the experiment shown by 2.2. The distribution in chromaticity value of colored fibers and color mixed fibers were shown in Figure 6. Although it was difficult to make color of high chromatic saturation compared with the dyed wool before blending, various colors could be made by blending of dyed wool. The aggregate of this dyed wool is classified into the apposed color mixture. In a preceding research on color prediction of union fabrics, there was a report about the prediction model used apposed color mixture theory. Each equivalent amount dyed wool of red, yellow and blue was mixed finally. As for the result, the colorimetric of the wool after mixture, L*,a*,b*of color were 49.0, -7.93 and 19.23.This research considered making a teaching aids with introducing various colors of wool fibers that were made in the mixture of 3 fundamental colored fibers by carding. It became clear to be able to estimate change of color in the mixture of wool fibers by this method and to be applied to the teaching aids.

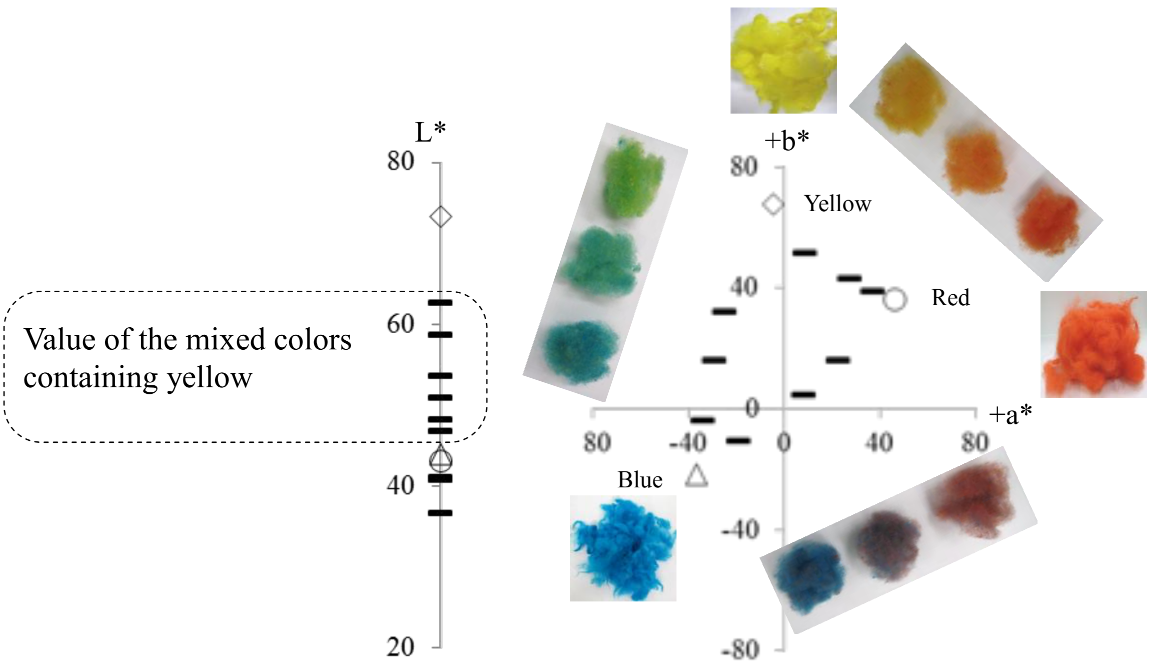

Figure 6. Distribution in chromaticity value of colored fibers (open marks) and color mixed fibers (closed bar).

4.CONCLUSION

The process of making teaching aids that learning students dye and blend wool fiber regarding the ratio of color makes clear that it is also useful for studying of other subjects such as the science and the fine arts.

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REFERENCES

KONICA MINOLTA SENSING, INC. 2007. SCE (specular component excluded) mode and SCI (specular component included) mode.
PRECISE COLOR COMMUNICATION. 41.

Kiyosawa T., Takatera M., Shimiza Y., and Yazaki Y. 2007. Color prediction of union fabrics considering mutual reflection between yarns, A new color prediction model using apposed color mixture theory.
SEN'I GAKKAISHI 63(5): 117-122.

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