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Color constancy depends on initial visual information

Chanprapha PHUANGSUWAN,[1] Mitsuo IKEDA,[1] Kanwara CHUVIJITRA,[2]
[1] Color Research Center, Rajamangala University of Technology Thanyaburi, Thailand
[2] Faculty of Mass Comm. Tech., Rajamangala University of Technology Thanyaburi

ABSTRACT

The concept of the recognized visual space of illumination RVSI asserts that the color appearance of objects is determiend by the adapted brain to the color of illumination of the space where the objects are placed and then the color constancy holds. Without any object in a space there should be no recognition of the space and no color constancy. The object necessary for the recognition of a space is called the initial visual information IVI. In this paper number of flowers was increased to increase the IVI complexity and the color appearance of a white board placed in the space was measured to see the effect of IVI for the color constancy. Only a small piece of a flower already gave a space recognition and the color constancy to some extent. With increase of complexity of IVI the white board became more white and many flowers surrounded by side walls gave almost perfect color constancy. As an additional experiment still smaller IVIs were investigated and it was found that even a pair of white petals already helped the brain to construct a space perception.

1. INTRODUCTION

The color constancy is a well known property of the visual system and many scientists studied on this phenomenon from two different approaches. One is to emphasize the cone adaptation at the retina and the other is to emphasize the brain adaptation. The former is expressed as the bottom up thinking and the latter the top down thinking. Ikeda's RVSI concept is one of the top down thinking and the present paper was carried out along the theory[1)]. The RVSI theory says that when a person enters a room he/she recognizes the space, understands the illumination filling the space, and adapts to the illumination[2)]. He sees objects in the space with the adapted brain and sees a white object as almost white whatever the illumination color may be, the phenomenon being called the color constancy. It was clearly shown by Pungrassamee et al.[3)] and Ikeda et al.[4)] that the color appearance of an achromatic patch returned achromatic when a subject could recognize the existence of the space where the patch was placed to confirm the RVSI concept. A question how much information or initial visual information IVI of the space is needed to recognize the existence of the space is an interesting question and Phuangsuwan et al.[5)] showed only a small information could construct the space recognition for the color constancy to take place. Their finding showed that the first smallest IVI that they employed was already enough to produce the color constancy. In the present paper several IVI, which were considered very small IVI, were employed to know IVI necessary to construct a space recognition and thus to produce the color constancy.

2. APPARATUS AND EXPERIMENT

The two rooms technique or the environment-stimulus independent illumination technique was employed to carry out the experiment. It was composed of two rooms as shown in Fig. 1, a subject room where a subject stayed and a test room where a test patch was placed. There was opened a large window W of the size 40 cm wide and 30 cm high on the separating wall through which a subject observed a test patch for judging the color of the patch by the elementary color naming method. The entire apparatus was of the size, 300 cm deep, 120 cm wide, and 200 cm high. The subject room was decorated by objects to simulate a normal room. At the viewing distance of 180 cm the window W was the size 13° x 10° arc of visual angle. At the back wall of the test room a white board WB of about L* = 94 was vertically placed, which served as a test patch. It is large enough to fill out the window W when a subject observed it.

The inside of the subject room was pasted by a white wall paper of about L* = 86. The room was illuminated by five fluorescent lamps of the daylight type Ls. The intensity of one of them was adjustable by a light controller. The lamps were covered by a color film to give a colored illumination for the subject room. Four color films, red, yellow, green, and blue were prepared and the illuminance was adjusted to 50 lx when measured on the front shelf. Figure 2 shows their chromaticity points by open circles. Diamond and square symbols indicate the white board WB and D65. The test room was illuminated by the same fluorescent lamps Lt as the subject room at one of four horizontal plane illuminances, 0.5, 1, 3 and 9 lx when measured just in front of WB and on a shelf at the height 85 cm from the floor.

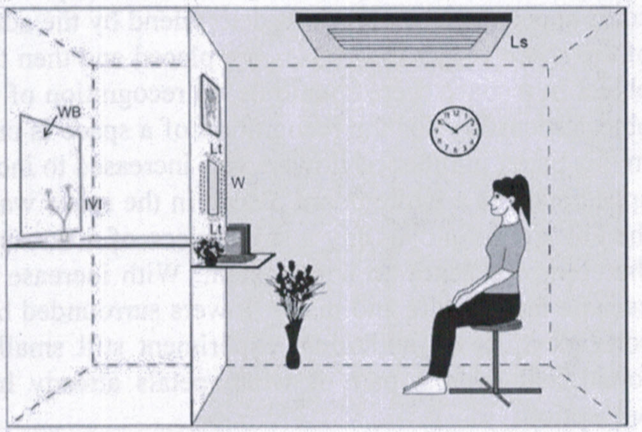

Fig. 1 A scheme of apparatus.

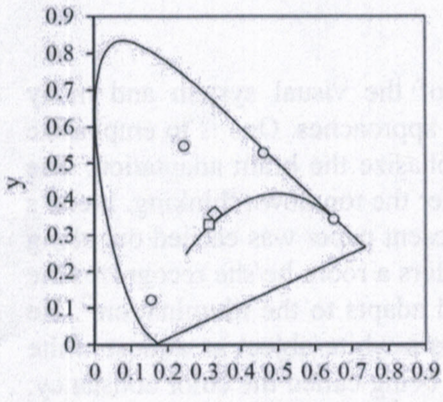

Fig. 2 Colors of illumination.

We first prepared seven initial visual information IVI, I_1 through I_7, as shown in Fig. 3. They were made of artificial flowers, white carnation, green leaves, red rose, and green fern. They were inserted into a white vase with blue line decoration.

Fig. 3 Initial visual information.

The IVI I_7 was the same flower as I_6 but with walls at both sides to help subjects to perceive a more complete space[6, 7]. The wall was a cardboard of pale yellow with some texture of very low contrast. The lightness was L* = 82. Beside these seven IVI we showed subjects no object at all, which was denoted as I_0. IVI I_1 could not be put in a vase and was hung by a thin string from the ceiling. Each IVI was placed near WB as shown in Fig. 1 and the flower(s) sometime touched WB. Subject could not see the bottom portion of the vase as indicated in Fig. 3.

The subject's task was to judge the color of the white board WB nearby the flowers but avoiding their shadow by using the elementary color naming method. Five repetitions were conducted for the measurement for each condition; IVI, illuminance level, and illumination color. Five subjects, MI, MK, CP, KC, and PL with normal color vision participated in the experiment.

3. RESULTS AND DISCUSSION

Without any object but the white board only in the test room, namely with the condition of I_0, subjects saw only uniform color over the window W and pasted on W. In other words the subjects recognized the color belonging to the subject room. With I_1 the subjects could notice the white board in the test room implying the perception of the space.

In Fig. 4 the amount of chromaticness perceived on WB is shown on the ordinate for IVI number on the abscissa. The data points from I_7 are plotted at 9. Those were obtained for 1 lx illuminance of the test room and for the red adapting color. Squares were from the subject MI and circles from KC. Short vertical bars show the standard deviation of five repetitions. In these cases the SD of MI is larger for almost every IVI than KC but in some other conditions (not shown) MI showed smaller SD than KC. Difference between the two subjects is not small but in both subjects showed a similar tendency of decrease of chromaticness for larger IVI. With I_0 subjects saw adapted color on the window W as if there was pasted a paper of that color. With I_1 or with one piece of carnation flower they suddenly recognized the existence of the space of the test room and could perceive the surface of white board, which eventually decreased the amount of chromaticness as seen in Fig. 4. The chromaticness of the white board continuously decreased and the whiteness increased for larger IVI. With I_7 the white board appeared almost white to imply the color constancy.

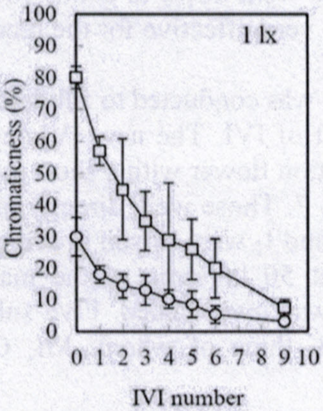

Fig. 4. Chromaticness plotted for IVI for red illumination. Squares, subject MI, and circles, KC.

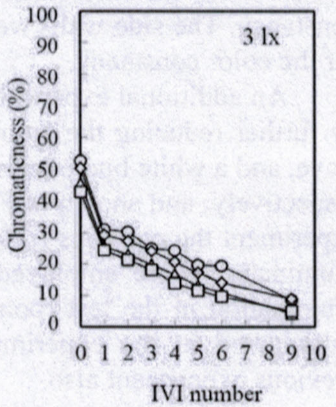

Fig. 5. Chromaticness plotted for IVI for red (circles), yellow (triangles), green (diamonds), and blue (squares).

Figure 5 shows the averaged amounts of chromaticness of five subjects for four illumination colors for different IVI, circles for red, triangles for yellow, diamonds for green, and squares for blue in the case of 3 lx test room illumination. Four curves showed very similar tendency. The drop of chromaticness at I_1 from I_0 was quite large. Amount of chromaticness of about 50% dropped down to about 30% with only one flower of carnation.

The average of four curves of Fig. 5 was taken and they are shown by circles in Fig. 6. In the figure the numbers of I_1 through I_6 were all increased by 6 so that the number of I_1 became I_7 (revised), for example. The number of original I_7 was also revised to become 14.3. The revision of the IVI number was conducted to approximate all the data points on a regression line as shown by a solid line, which can be written as Chr = - 2.9 × IVI + 47.9. In this way of plotting we can see that there remains a wide gap between I_0 and I_1 or I_7 (revised). It is amazing that even one piece of carnation flower already worked as initial visual information to construct an RVSI for the test room to some extent. With I_7 or $I_{14.3}$ (revised) the chromaticness went down to about 10% to show almost complete color constancy. The side walls were very effective for the recognition of a space and eventually for the color constancy.

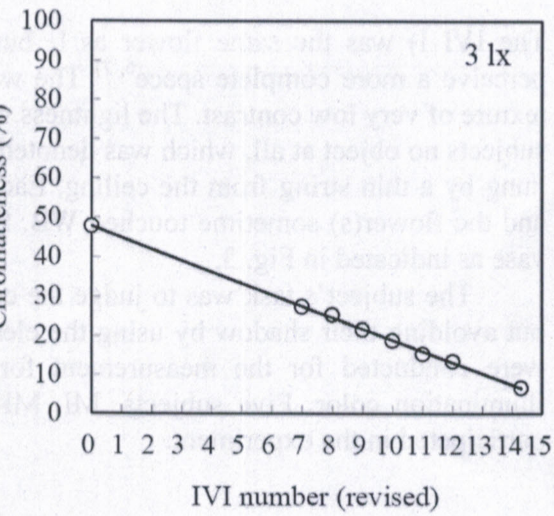

Fig. 6. Chromaticness plotted for the revised number of IVI.

An additional experiment was conducted to fill data points between I_0 and I_1 in Fig. 6 by further reducing the amount of IVI. The new IVIs are a pair of white petals, a green leave, and a white bud of carnation flower with a short green stalk as denoted I_A, I_B, and I_C, respectively, and shown in Fig. 7. Those were directly pasted on white boards WB. In the experiment the previous I_1, I_3, and I_5 were mixed proving 6 IVIs altogether. Four colors of illumination were employed at 50 lx same as the main experiment and only 3 lx of illumination in the test room was investigated. Five subjects, MI, TT, CP, KC, and KT participated in the experiment, three of whom, MI, CP, and KC participating in the previous experiment also.

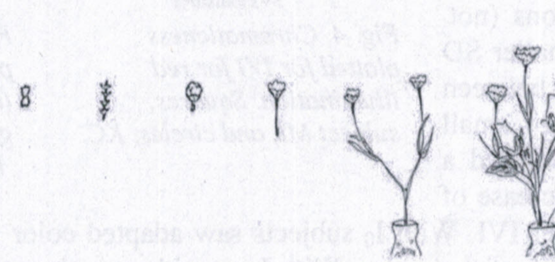

Fig. 7. Initial visual information in additional experiment.

IVI was randomly presented for one illumination color and the judgment was repeated 5 times for each IVI, and also for each illumination color.

Amount of chromaticness is shown in Fig. 8 for all the five subjects in the case of yellow illumination. The abscissa gives the IVI and the ordinate the chromaticness in percentage. With I_0 the chromaticness was very high and it gradually decreased for increasing IVI. There is a large individual variance but the property of a gradual decrease was held in common. The average of five subjects was taken for four colors of illumination, respectively, and is shown in Fig. 9 by different symbols. The property of gradual decrease of chromaticness for increase of IVI is seen commonly among the colors

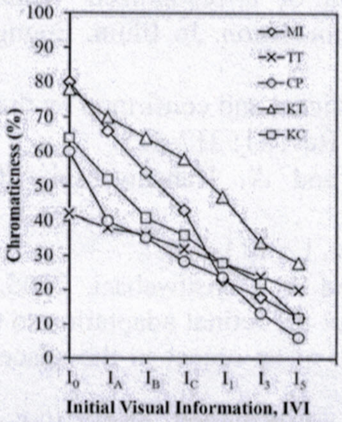

Fig. 8. Chromaticness plotted for IVI from 5 subjects.

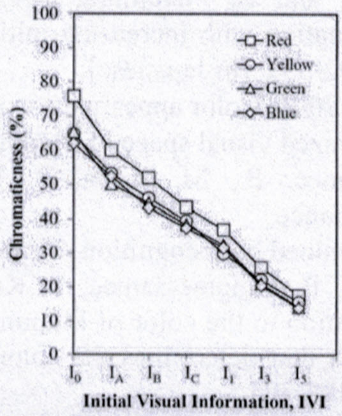

Fig. 9. Chromaticness plotted for IVI for illumination colors.

though the vertical positions of curves differ slightly. However, the vertical position should vary depending on the saturation of the illumination color and the relatively close vertical position of four curves is a coincidence by chance.

To fill the gap between I_0 and I_1 in Fig. 6 the results of three subjects who participated both in the main experiment and the additional experiment were averaged for all the colors in both cases. The results are shown in Fig.10 by open circles for the main experiment and filled circles for the additional experiment. They come very close with each other constructing one straight line of $Chr = -4.2 \times IVI + 61.3$ when the IVI number was slightly revised, I_A to 2, I_B to 4, and I_C to 5.5. The dashed line was obtained by this formulae.

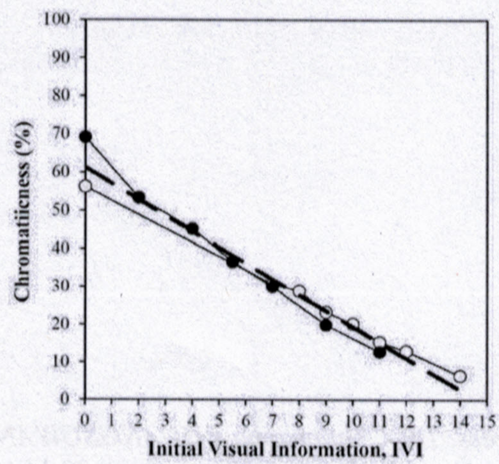

Fig. 10. Chromaticness for revised IVI. The average of three subjects.
○, *the main experiment;* ●, *the additional experiment*; — — —, regression line.

To conclude only a pair of white petals already worked as meaningful initial visual information to construct a space perception and the color constancy.

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Address: Dr. Chanprapha PHUANGSUWAN, Color Research Center,
Rajamangala University of Technology Thanyaburi, 39 Moo 1 Klonghok Thanyaburi,
Patumthani, 12110, Thailand
E-mails: karamennn@gmail.com