Color Constancy Demonstrated in a Photographic Picture by Means of a D-up Viewer

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According to the recognized visual space of illumination concept, space perception is essential for color constancy. It should be possible to experience the color constancy in a picture if we perceive a three-dimensional space in the picture. A dimension-up (D-up) viewer was constructed to perceive a space for a picture. An experimental room illuminated by various color lights was used as the reference scene and the subject determined a picture in which the color impression was matched to that of the room by selecting from 13 different colored pictures of the room. The picture with the color nearest to the color of the room was selected with the D-up viewer implying the existence of color constancy in the picture. When subjects observed a picture in a normal way the picture of the room illuminated in white was selected regardless of the actual room illumination color, confirming no color constancy in the picture.

Keywords: color constancy, color appearance; photograph, 2D and 3D, space perception, illumination color, recognized space of illumination

1. Introduction

The recognized visual space of illumination (RVSI) concept was introduced by Ikeda and colleagues[1–4] to explain the color appearance of objects and lights. When a person looks at, comes into, or stays in a space they understand the illumination in the space and adapt to the brightness and color of the illumination. The concept asserts two points; the recognition of a space and the adaptation to the illumination in the space. It is natural for a person to recognize a three-dimensional (3D) space in whatever they see since they always live in a visual 3D space and so must always visually perceive a 3D space. When the person recognizes a space they understand the illumination filling in the space. The adaptation is neither to the light coming from the objects nor to the color of the objects but to the illumination filling the entire space including the empty spaces. In other words, it is the adaptation within the brain ("teki-oh" in Japanese) that is a positive action and not a form of retinal adaptation ("jun-noh" in Japanese), which is a passive action, as the adaptation takes place only when a person recognizes the existence of the space.[5–8] The adapted brain state is expressed as the brain constructed a RVSI for the space. The apparent lightness and apparent color of anything in the space are then determined based on the RVSI. The concept asserts that a RVSI is always constructed in a person whatever they see and the color perception is gained accordingly. It must be pointed out that two-dimensional (2D) RVSI does not exist. In this respect the words 2D and 3D must be used with care. 2D perception exists in a RVSI but it is a 2D plane perception in a 3D space perception. A 2D stimulus can be used,[9,10] but the stimulus may be perceived as a 2D object in a 3D space perception that is constructed by the entire surrounding including the stimulus. In addition, the RVSI concept does not discuss a mechanism as to how a person understands the illumination but starts from a point they understands by any means, although the concept defines objects and other cues in the space that they first see as the initial visual information and the RVSI becomes more complete with as more initial visual information is acquired.[2,3,11]

The RVSI concept was applied to some apparent lightness phenomena,[12] such as the White effect,[13] the simultaneous contrast demonstrated by Heinemann,[14] the Kofka ring, the Kanisza pattern and the Gilchrist experiment,[15] so as to show the importance of space recognition. Most of these researchers used 2D patterns as a stimulus, except for Gilchrist,[15] but the patterns were interpreted to produce RVSI to some extent to explain their results successfully. A new stimulus pattern that consisted of gratings was then introduced to strengthen the idea of RVSI.[12]

The importance of space recognition was also shown for the color constancy. Pungrassamee et al.[16] employed a two rooms technique, where a subject stayed in one room illuminated by color light and observed, through a window opened between the two rooms, the stimulus placed in another room that was illuminated by a daylight type lamp. When the subject room was illuminated with a red ceiling light and the stimulus was achromatic, and when the window was small so that only the stimulus was seen to the subject, the stimulus appeared as a vivid bluish green patch pasted on the window. When the window was enlarged the stimulus returned to its original achromatic color indicating color constancy was obtained. Color constancy took place immediately when only a small part of the surrounding stimulus room was seen around the stimulus patch, that is, the color constancy took place when the subject recognized

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the existence of the stimulus room. Space recognition is the obligatory factor for the color constancy. Many researchers have investigated color constancy by various approaches, but it seems important to employ a real room or real objects in carrying out the experiment, as has been done by some researchers.[9–11,17–19]

It is a common understanding that color constancy does not hold in a photographic picture.[20] A picture taken under an incandescent lamp appears very orange when the picture is observed under a white lamp. A white object in the picture is no longer white but pale orange. The RVSI concept can explain this fact and suggest a way to demonstrate the color constancy in a photographic picture, which is reported in the present paper. The reason for the failure of the color ...es in the failure of perceiving a 3D ..., therefore, we can perceive a 3D space in a photographic picture the color constancy should take place according to the RVSI concept. The question then is how can the viewer do this? Any retinal image of the outside scene is a 2D image, yet we appear to perceive it as a 3D scene. This fact indicates that our brain changes the 2D image to a 3D scene. That is, our brain has a dimension-up (D-up) function. When we see a photographic picture placed in a room we see a mere 2D picture because the D-up function of the brain is already used for the 3D room. If, however, we input only the picture to the eye such that the retinal image contains only the image of the picture and nothing else, then the D-up function of the brain should be used for the retinal image of the picture and we should perceive a 3D scene for the picture. The color constancy is expected to take place for the picture. Mizokami et al.[21] employed this logic and did an experiment to obtain an achromatic perception for a small test patch in a photographic picture observed with a D-up viewing box. Two pictures were investigated, which were taken under the daylight type and the incandescent type fluorescent lamp, respectively. The results showed good color constancy with some subjects but poor or no color constancy with other subjects. We suppose that a large variance among subjects and the failure to obtain the color constancy with some subjects were because of the difficult task of the subject to judge absolutely the achromaticness on a small test patch without reference. Foster[22] pointed out interpretational difficulties in the achromatic adjustment that depends on the criterion used by subjects. Hurlbert[23] also wrote that the achromatic setting reveals the observer's internal assessment of the light source color. In the present paper we employ the same logic of 3D perception of a photographic picture as Mizokami et al. but different experimental method. The subjects compare colors of a real room illuminated by a colored light and of photographic pictures taken under various colors, and choose a photographic picture that gives the same color impression as for the real room. This is a kind of symmetric matching experiment as subjects are presented with a same scene of the real room and should be easier for the subjects in their judgment. We will cover wider color range of the room illumination to know systematically the effect of the room color for the color constancy.

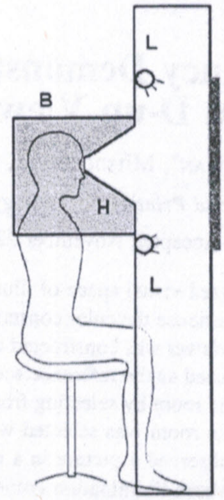

Fig. 1. Schematic diagram of the D-up viewer. P, a picture stimulus; L, lamps; H, a hood to limit the visual field; B, a box to eliminate stray light.

2. Apparatus

2.1 *D-up viewer*

A D-up viewer was built to get a 3D perception on a photographic picture as shown schematically in Fig. 1. The essential point of the apparatus is to present the subject with a view of only the picture without any other images or light. A subject saw a picture P (38 cm wide by 25 cm high) through a hood H at the distance 27 cm from his/her eye which was pressed to the opening of the hood of the size 5 cm wide and 3 cm high with a good contact. The subject head was covered by a box B opened to the back of the head to eliminate stray light coming into the eye from surrounding. The view angle for the picture was 70° wide and 50° high. Inside the hood there were several black strips attached to the surround to cutoff the reflection from the inside surfaces of the hood. There were two 3-bands daylight type fluorescent lamps L of $x = 0.312$, $y = 0.343$ and the color temperature 6,500 K, one above and one below to illuminate the picture uniformly. The picture was placed on the back wall from behind so that it could be quickly changed to another picture by the experimenter.

2.2 *Experimental room*

The experimental room (100 cm wide, 200 cm deep, and 216 cm high) was built to simulate a normal room including some decorations, such as a painting, books, dolls, artificial flowers, and others, and is schematically shown in Fig. 2. The walls, covered by a white wall paper with a slight texture, had a Munsell Value of about N9. Three fluorescent lamps (L_{w1} and two L_c) were attached at the ceiling to illuminate the room. L_{w1} was a 3-band daylight type fluorescent lamp with chromaticity coordinates of $x = 0.320$, $y = 0.340$ and the color temperature 6,100 K. The two L_c lamps were the same type of daylight lamps as L_{w1} but were covered by orange films giving an emitted light

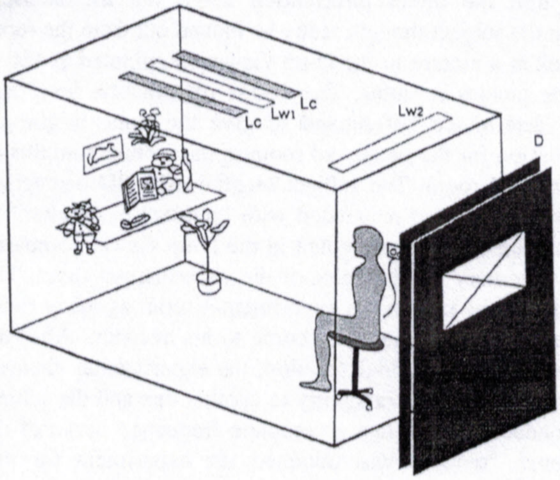

Fig. 2. Schematic diagram of the experimental room and the D-up viewer D.

with chromaticity coordinates of $x = 0.571$, $y = 0.400$ and the color temperature 1,610 K. The films had a monotonic spectral transmittance but increasing rapidly at around 560 nm to reach the maximum 91% at 620 nm. Their intensities were controllable independently with light controllers, shown at the right hand of the subject in the schematic Fig. 2. By mixing the white (L_{w1}) and orange lights (L_c) the room illumination of any color connecting the two points on the CIE xy diagram was obtainable. The subject sat down on a chair about 180 cm from the front wall to observe the room without a chin rest allowing free movement of the subject's head as well as their eyes. There was another ceiling lamp (L_{w2}) of the same daylight type near the entrance of the room. Just outside the room the D-up viewer D was placed and the subject inside the room could move out from the room to observe a picture in the D-up viewer.

Thirteen colors of illumination were prepared for the experimental room by adjusting the ratio of intensities of white and orange lights but keeping the total illuminance at 80 lx, as shown by circles in the xy chromaticity diagram in Fig. 3. The colors were measured with a color luminometer pointing to the front white wall. For these thirteen illuminations color photographs were taken from the position of the subject's eyes. One example of the picture stimuli is shown on the left of Fig. 4. The color of the front white wall in the picture was measured by the same color luminometer, with the results shown by symbol x in Fig. 3. All the color shifted towards the left implying that the color reproduction is not exact. It is, however, evident that the shift is mostly along the x-axis in the xy diagram and so the x value was used hereafter to specify the color of illumination and of the picture stimuli.

2.3 *Apparatus to confirm 3D perception*

It was obvious to any subject that they perceived a 3D scene when they observed any of the thirteen photographs

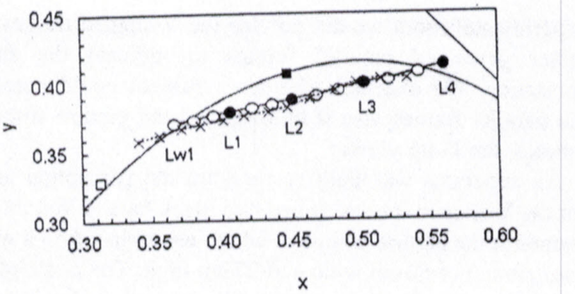

Fig. 3. The color of the (○) illumination in the experimental room prepared for picture stimuli and (×) the picture stimuli. L1, L2, L3, L4 indicate the illumination employed in the experiment, (□) the D65; (■), illuminant A light source; and (solid curve) the black body locus.

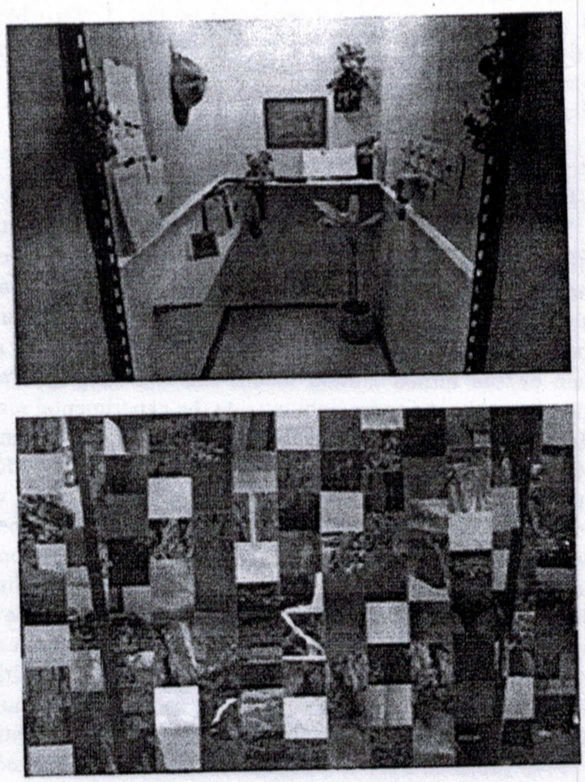

Fig. 4. Two different stimuli used for the experimental confirmation of 3D perception.

with the D-up viewer but we decided to confirm the perception experimentally by examining the visual property of the objects in terms of the shape constancy.[24–27)] The retinal image of an object does not reproduce the exact shape of an object, yet we perceive the object in its original shape. The picture stimulus that we used in the present experiment had two angle frames at both sides which were not parallel but made a V-shape, as seen on the left section in Fig. 4. The angle of the apex of the V was 15.5° when measured from the outer edges of the frames. When we saw the real experimental room we did not see the V-shaped frames but rather perceived parallel frames to indicate the shape constancy. We checked whether a subject could perceive the parallel frames also if he observed the picture stimulus through the D-up viewer.

An apparatus was built to measure the perceptual angle for the V-shaped frames. It had two black bars to imitate two frames in the picture stimulus, which were placed on a white background of 60 cm wide and 27 cm high. The angle of the two bars was adjusted by manually changing the distance between the bottom sides of the two bars by pulling either one of two attached strings.

An additional pattern stimulus was made to evaluate the difference between a 3D and 2D perception. A color picture of an arbitral scene of the same size as the picture stimulus was cut into about 120 pieces and they were randomly put together to make a mosaic pattern to remove the perspective of the scene, as shown on the right in Fig. 4. Two black stripes were pasted on the mosaic stimulus at the same positions and with almost the same angle as the frames in the picture stimulus (15.6° vs 15.5°).

3. Procedure

3.1 *Confirmation of 3D perception*

There were two stimuli, as shown in Fig. 4, and two different viewing conditions, normal and D-up. In the case of the normal viewing condition, the subject first looked at a stimulus placed on a table vertically inside the experimental room and illuminated by the L_{w2} ceiling light at 80 lx, and then he/she turned around to see the two bars apparatus illuminated by the room light outside the experimental room. He then adjusted the angle of the bars to match to the angle of frames perceived for the stimulus. The subject could look at the stimulus as many times as he wished until he was confident of the bar adjustment. Three or four judgments were typically required. Then the subject proceeded on to another stimulus. In the case of the D-up viewing condition the subject looked at the stimulus through the D-up viewer by one eye and then turned to the two bars apparatus to adjust the bar angle, as per the normal viewing condition. The same adjustment was carried out for another stimulus. The measurement was repeated ten times for each condition.

Five subjects, PW, JP, ET, BW, and MI, participated in the experiment. Each had a good visual acuity.

3.2 *Color constancy*

In the main experiment to investigate the color constancy, four different illuminations of increasing red spectra but at the same illuminance of 80 lx (L_1–L_4 in Fig. 3) were used, with illumination L_4 representing illumination with only the L_c orange lamps. There were two viewing conditions, the D-up and the normal. In the D-up viewing condition, after the experimenter had adjusted the light of the experimental room to one of the four colors at 80 lx the subject was asked to enter the experimental room and to look around the room to remember the color of the room as a whole, presumably based on the various objects placed in the room. He/she was asked to wear a cap to avoid seeing the ceiling lamps, which give him the direct information about the illumination. When the subject thought ready he moved out from the room to look at a picture in the D-up viewer illuminated at 160 lx on the picture stimulus. The 160 lx illumination level had been determined beforehand to give the same brightness impression for the perceived room in the picture stimulus as for the real room. The subject ascertained a 3D perception for the picture and responded with "redder" or "whiter" to the picture stimulus presented in the D-up viewer compared to his memory for the color of the experimental room. The subject could look at the experimental room as many times as he wished until he could come to his decision. After the subject made their final decision, the experimenter changed the picture stimulus randomly to another one and the subject responded again. When a complete frequency curve of the response "redder" was obtained the experiment for that room illumination was over, and a redder frequency curve was obtained for another illumination. These processes were repeated until all the four illumination colors were investigated, when one session was over. Ten such sessions were obtained for each subject.

In the normal viewing condition the first step of observing the room was same as for the D-up condition above. When the subject was ready for the next step he switched off the ceiling lamps, turned around, and switched on lamp L_{w2}. He was handed a picture stimulus by the experimenter and observed it binocularly by putting the picture on a table right ahead of his at the distance of about 60 cm. He was asked not to gaze at the picture stimulus to avoid yielding any 3D perception on it. He observed the color of the picture stimulus and responded "redder" or "whiter" as before. To see the room again the subject switched off the L_{w2} daylight lamp and switched on the L_{w1} and L_c lights. When the subject gave the final response the experimenter handed another picture stimulus to the subject. Again the judgment was repeated until a frequency-of-redder curve was obtained.

Five subjects, SS, JP, PK, TK, and MI, who all had normal color vision, as tested with the 100 hue test, participated in the experiment. The subjects JP and MI also participated in the 3D confirmation experiment.

4. Results

4.1 *3D confirmation*

The mean results of the perceived angles of V-shaped frames of five subjects are shown in Table 1 with the standard deviation based on 10 responses. For the jumbled mosaic stimulus the perceived angle was about 12 or 13° regardless of the viewing condition, which is close to the physical value of the stimulus. For the picture stimulus, the value differed depending on the viewing condition. It was large, as with the mosaic stimulus when the stimulus was observed in a normal way but it became very small with the D-up viewer, only 1.6°, almost zero. Subjects perceived the frames as parallel with each other indicating a 3D space perception with the D-up viewer. A space perception was confirmed for a picture when the D-up viewer was employed.

Table 1. Angle of V-shaped frames and standard deviation in degrees.

	Picture	Sd	Mosaic	Sd
Physical value	15.5		15.6	
Normal viewing	12.5	1.5	12.3	0.9
D-up viewing	1.6	0.4	13.4	2.0

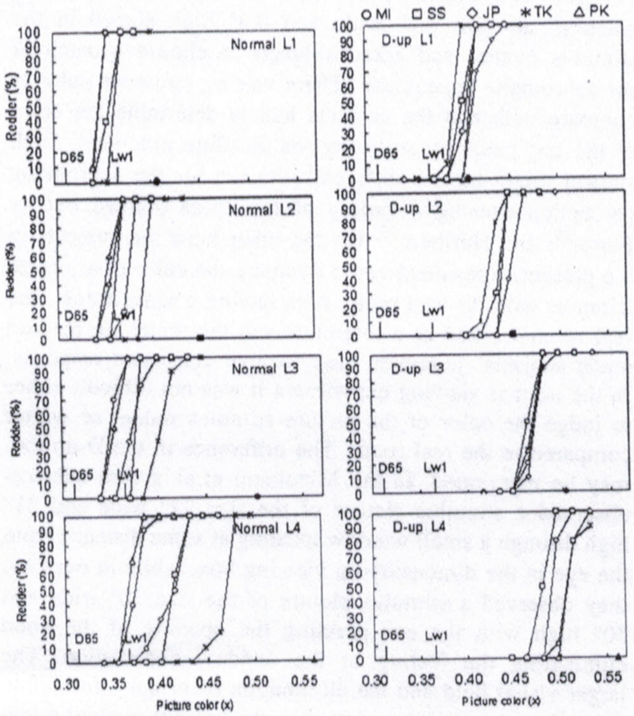

Fig. 5. Frequency of redder response curves obtained by five subjects. The experimental conditions are shown in each section.

4.2 *Color constancy*

Examples of the frequency of redder response curves are shown in Fig. 5. The abscissa gives the chromaticity coordinate x of the picture stimuli and the illumination color, and the ordinate the redder percentage of the response. The experimental conditions, as normal viewing or the D-up view, and with L_1, L_2, L_3, or L_4 illumination, are shown in each section. The x values are shown by filled circles, filled squares, filled diamonds and filled triangles for the illuminations, respectively, whilst the color of the ceiling light L_{w1} and that of D65 are shown by short vertical bars. The five curves correspond to the five subjects, as indicated at the top right, and each data point is the average of ten responses. The slopes of the curves are sharp in most cases, indicating the easiness of the judgment "redder" or "whiter" for the picture stimulus presented to the subjects. The variance among five subjects was small for all the illuminations in the D-up views but it increased gradually for more orange illumination in the normal viewing. In the latter viewing condition subjects should compare the color

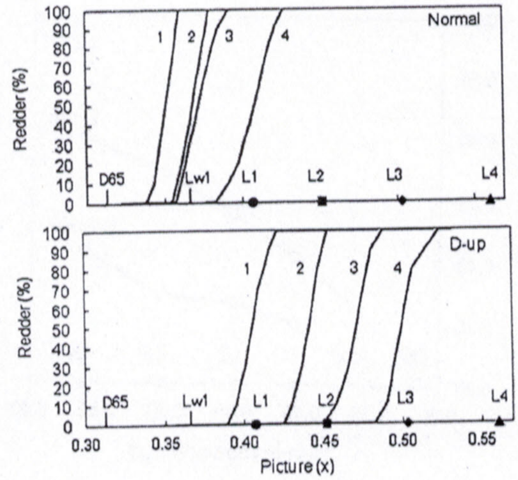

Fig. 6. Averaged frequency of the redder response curves from five subjects in the normal and D-up viewing conditions. Colors of room illumination are shown by symbols ●, L1; ■, L2; ◆, L3; ▲, L4, and numbers on curves correspond the illuminations.

of the 3D space of the experimental room and the color of the 2D plane of the picture stimulus. This asymmetrical comparison might have caused a subject-dependent variation in the judgment.

Values of the redder percentages, at 10, 20, 30, and so on, were extracted from each curve by interpolating between the neighboring two data points and the five values were averaged. The mean results for the five subjects are shown in Fig. 6 for the normal viewing condition and the D-up viewing condition. Numbers attached to curves correspond to the illuminations. With the normal viewing condition, where the five subjects observed the picture stimuli placed on a table in the experimental room illuminated by the white light L_{w2}, all four curves came at a region of small x values nearby the white light L_{w1}. That is, the subjects chose the white picture stimuli to match the color of the experimental room regardless of the orange illumination in the room. Even when the room was illuminated by a very deep orange light L_4 the subjects still chose the picture stimuli color to be near to L_1. These results can be understood if we accept that there is color constancy for the experimental room, which appears white, but no color constancy for the picture stimuli. Then, under this scenario, the subjects should choose the white pictures. The curves gradually shifted towards the right (redder) as the color of the experimental room became more orange. Using an illumination of 1,700, 2,400, 3,400, 6,000, and 30,000 K, Kuriki and Uchikawa[28] showed that the color constancy became less perfect as the room color became more orange. All the present subjects experienced more orange impression for more orange illumination of the room. This imperfection of the color constancy for a real room might have taken place in our experiment with the subjects choosing a slightly more orange picture as the experimental room became more orange.

However, when the subjects used the D-up viewer to see picture stimuli the results were quite different. The curves all

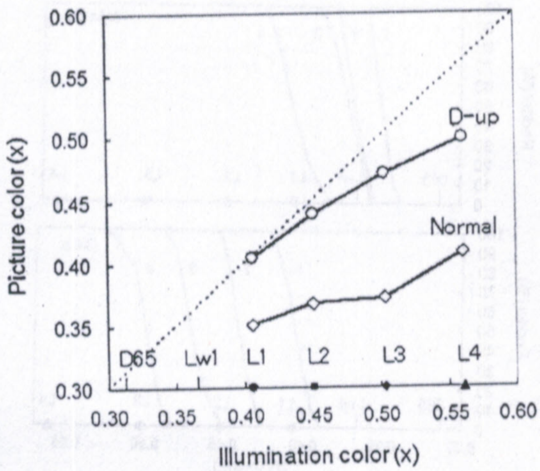

Fig. 7. Relationship between the illumination color of the experimental room and the color of picture stimuli chosen to match the room color for the normal, ◇ and D-up viewing condition, ○. The dotted 45° line indicates that subjects chose picture stimuli of the same color as for the experimental room.

moved towards the right and were distributed in accordance with the level of red in the respective illumination. Subjects chose the picture stimuli of the color that was near to that of the real room. When the room was illuminated by an orange light the subjects also chose picture stimuli of a similar orange color to match the room in color. They did not see extreme orange in the experimental room and nor did they see the extreme orange color in the picture either. Thus, color constancy took place for the pictures when the subjects observed 3D spaces in the pictures through the D-up viewer. Because the curves did not come to the same point as the room illumination color, but remained a little bit at the whiter side, it then appears that color constancy did not take place in exactly the same manner as for the real room.

To see the relationship between the illumination color of the experimental room and the color of the picture stimulus chosen for the room, the x values at 50% of the frequency-of-redder response curves in Fig. 6 were plotted for the four illumination colors as shown in Fig. 7 with open circles for the D-up condition and with open diamonds for the normal viewing condition. The curve of the normal viewing condition is shallow and instead the picture locates way down from the 45° line. Here, color constancy did not take place for the picture stimuli and they just acted as a color scale for matching to the color of the experimental room. On the other hand, the curve of D-up viewing condition came very close to the 45° line with L_1 and L_2 indicating the color constancy in the picture stimuli same as for the real room. The curve gradually deviated away from the 45° line for the deeper orange illuminations, L_3 and L_4. Thus, the picture stimulus seems to have some limitation in being able to present the color constancy, as in the real room situation, when the stimulus is too vivid an orange. That is the picture could not reproduce the same color appearance as the real room when the room illumination became too orange.

5. Discussion

There are found some differences in the results by Mizokami et al.[21] and the present paper. Mizokami et al. showed a large variance among subjects from a high to no color constancy, while we obtained almost the same color constancy as for a real space from all the subjects as indicated in the right column of Fig. 5 and in Fig. 7. We may mention different experimental methods among the two groups for the reason. Mizokami et al. employed a small test patch of the size 1.2° wide and 0.8° high placed in the stimulus picture and asked subjects to choose a patch of the achromatic appearance. There was no reference color to compare with and the subjects had to determine the color of the test patch by so-to-say the absolute judgment. Each subject might have a different criterion for the achromatic perception causing a variety of results as pointed out by Foster[22] and Hurlbert.[23] On the other hand the subjects in the present experiment could compare the color of a picture stimulus with the real room, both having a same scene. The real room worked as a reference and the matching method made subjects' judgment easy to give consistent response. In the normal viewing experiment it was not difficult either to judge the color of the picture stimulus redder or whiter compared to the real room. The difference in the D-up tool may be mentioned. In the Mizokami et al.'s case subjects observed a stimulus picture of the size 27° wide and 21° high through a small window locating at some distance from the eye in the dimension-up viewing box, while in our case they observed a stimulus picture of the size 70° wide and 50° high with the eye pressing the opening of the hood eliminating the feeling of the window observation. The larger visual field and the elimination of visual information other than the stimulus picture in the present method might have offered the subjects a stronger space perception as confirmed by Table 1 and led to high color constancy to all the subjects.

Nevertheless, the color constancy for a picture was not as good as for the real space when the illumination became more orange as shown by the deviation of the D-up curve from the 45° line in Fig. 7. When, for example, the room was illuminated by the L_4 light the subjects perceived more orange in the picture stimulus than they did for the real room and they chose a whiter picture by about $x = 0.062$. If we could reproduce exactly the same 3D scene in a picture as in the corresponding room under the L_4 illumination the lower-level adaptation must be same for both cases. Then the subjects should have chosen that picture stimulus for the L_4 illumination. However, the room colors were not reproduced accurately on pictures, as potentially shown in Fig. 3, where all the colors of a white wall shifted towards smaller x values indicating inaccurate color reproduction. We could not measure colors other than the white wall of the room because of the insensitive color luminometer but we suppose that the reproduction of the other spectral colors was also imperfect, and this imperfect color reproduction might have caused the imperfect 3D perception in the picture and the deviation from the real room.

Table 2. Horizontal visual angle of the front wall and the entire field in degrees.

	Front wall	Entire field
Real room	31	180
D-up	23	70
Normal view	10	35

The difference in the visual field size between the real room condition and the D-up condition should also be mentioned. Table 2 summarizes the horizontal visual angle in degrees for three viewing conditions. Picture stimuli were made so that the visual angle of the front wall was not much different among viewing conditions. The visual angle of the entire field, however, differed quite much, about 180° in the real room but 70° in the D-up condition, thus giving the angle for the side walls about 150° in the real room and only 48° in the D-up viewing. The difference might have caused the difference in the color constancy between the two conditions.

We predicted, based on the RVSI concept, the color constancy to take place in a photograph if one perceives a 3D space in the photograph. The prediction was confirmed but we are aware that the color constancy was approached from various points of view in the past with consequent various explanations, particularly sensory and cognitive explanation.[20,29,30] In these categories the present experiment emphasized the latter explanation and did not particularly intend to investigate the former explanation. Nevertheless, a few remarks may be made. Provided that picture stimuli reproduced exactly the real room in color, which is not quite true, the chromatic distribution on the retina within the picture is same for three viewing conditions, real room, D-up viewing, and normal viewing excepting the visual field size as seen in Table 2. Mizokami et al.[21] investigated the effect of size of picture stimuli for the achromatic setting of a test target and found no systematic difference in the effect for the size varied from 8° × 10° to 31° × 38°. Brenner et al.[31] employed the achromatic adjustment for a 5° target square placed at the center of a 14° by 14° background of which chromatic variability was varied. They showed that the influence of chromatic variability is not limited to a certain region of the scene, but that the average color contrast within the scene determined the magnitude of chromatic induction. The chromatic variability in the present experiment can be considered same among three viewing conditions excepting the normal viewing condition where the picture stimulus was surrounded by the experimental room scene. Brenner and Cornelissen[32] showed that the effect of chromatic induction of the surrounding decreased exponentially reaching the minimum at around 1.8° away from a test target. The surrounding room scene in the normal viewing condition in the present experiment should not affect the chromatic induction. Thus, the retinal adaptation to the picture stimulus is considered not to differ among three viewing conditions in our experiment and the difference in the results of the D-up and the normal viewing conditions shown in Fig. 6 can be interpreted as the effect of 3D perception in the former and the effect of 2D perception in the latter condition.

If we limit our discussion to the real room and the D-up viewing condition we can not exclude the explanation by the low level adaptation as the color distribution on the retinal is very similar. To prove the importance of 3D perception in the D-up viewing condition Mizokami et al.[21] measured the achromatic setting of a test target for mosaic pattern made by cutting a photograph taken under an incandescent lamp into pieces and obtained the setting not as much as that obtained for the photograph to imply the effect of 3D perception for the color constancy. We also prepared five mosaic patterns made of 1,102 pieces cut from picture stimuli of which x values were near to L_{W1}, L_1, L_2, L_3, and L_4 and two of the present authors observed them in the D-up viewer whether they could be used to compare with color impression of the real room. They could see only randomly arranged patches on a 2D plane and could not grasp global color impression over the entire filed. The use of the mosaic patterns for matching the color impression of real room failed. Some other method needs to be developed to eliminate the influence of the low level adaptation. It may be emphasized, however, that it was very easy for subjects to compare the color impression of the real room and of the picture stimuli even under the normal viewing condition where the subjects could not perceive a 3D scene for the picture stimuli. Foster[22] listed seventy works of the color constancy in his review paper but there was not mentioned a similar technique to the present one indicating the newness of the technique.

The finding that color constancy takes place in a picture has an important implication in the evaluation of color appearance. A 2D stimulus is mostly employed in the experiments. If the picture stimulus is observed so that it appears a 3D scene a white object in the picture appears as white even if the picture was taken under an orange illumination. This appearance may correspond to the surface color in Kuriki and Uchikawa[28] and Arend and Reeves[33] experiments. If the stimulus is observed under a pure normal viewing condition the stimulus remains as a mere 2D scene and a white object in the picture appears orange to reflect the illumination, which may correspond to the apparent color in their experiments.[28,33] Hurlbert[34] expressed the situation as that some subjects give somewhat different responses depending on how exactly the request is phrased in the case the stimulus is Mondrian pattern. There are intermediate and ambiguous observing situations of a 2D scene or pattern in between the two viewing conditions. For example if only a 2D test stimulus composing of a test patch and of only a few color patches is illuminated keeping the surrounding space dark or dim a subject constructs a RVSI for the dark space and he sees the test stimulus as a light color or a light source color, or an apparent color, as the stimulus is outside the RVSI.[35] He can also construct another RVSI though not perfect for the stimulus and color patches and he can see the test stimulus as an object color or the surface color. The stimulus appears as partially the apparent color and partially the object color. We like to urge researchers to work on the color appearance by using a 2D display or plate to precisely define the observing condition for the stimulus.

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