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Adapting and adapted colors under colored illumination

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ABSTRACT

The state of chromatic adaptation was investigated by measuring the adapted color for the adapting color by the environment-stimulus independent illumination technique. Seven colors were employed for a subject room and the subject judged the color appearance of an achromatic test patch placed in a test room through a window between the two rooms. The angle from the adapting color to the adapted color was obtained. The angles were read out from other works available in journals and they were all plotted on one graph. The angle did not follow the opponent relation. That is, the unique red adapting color did not cause the adapted color to be the unique green. There were only two adapting colors that gave the opponent colors in the adapted color. The effect of saturation of the adapting color on the adapted color was investigated and no significant effect was found.

1. INTRODUCTION

The state of chromatic adaptation could be known by the apparent color of an achromatic patch placed at the center of a uniform colored background, the phenomenon being known as the simultaneous color contrast. If the background is red the apparent color or adapted color is green, for example. The adapted green is very pale, however, to be used to investigate the chromatic adaptation in detail. Vivid adapted color can be obtained by the two rooms technique or the environment-stimulus independent illumination technique developed by Ikeda and his colleagues[1)]. Even if the psychophysical color expressed by x and y chromaticity coordinates are made equal for a wide area of the retina in both techniques, the uniform colored background and the two rooms, the color appearance of the test patch obtained is almost achromatic by the former, while it is very vivid by the latter[2)]. In the present experiment the two rooms technique was employed and the color appearance of an achromatic test patch was measured by the elementary color naming method for seven different colors of illumination for a subject room. To show the relationship between the color appearance of illumination of the subject room and the color appearance of a test patch the angle from the former to the latter was calculated on the polar diagram used in the opponent colors system. An additional experiment was carried out, where the saturation of the illumination of the subject room was changed and the color appearance of the test patch was measured.

2. APPARATUS

Figure 1 shows the apparatus composing of two rooms, a subject room and a test room separated by a wall on which a large window W of the size 40 cm wide and 30 cm high was opened so that the subject could see an achromatic test patch T made of a white board without any scratches and placed against the back of the test room. It was illuminated by two fluorescent lamps Lt of the daylight type.

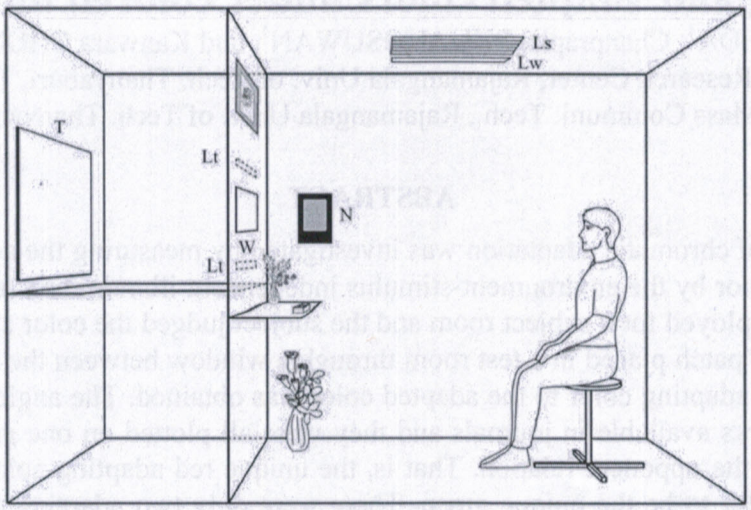

Fig. 1 Apparatus composing of a subject room (right) and a test room (left).

The distance from the subject to the window W was 180 cm and the visual angle of W became 13° × 10°. The subject room was decorated with various objects to simulate a normal room. The five ceiling fluorescent lamps in the subject room Ls were covered by a colored film to give a colored illumination to the subject room. One of the lamps was adjustable in its intensity. To change the saturation of the color another fluorescent lamp Lw was attached to the ceiling.

Seven different colored films were employed for the subject room and their chromaticity coordinates u'v' are shown by open circles in Fig. 2 denoted as CRC3. The illuminance measured on the front shelf in the subject room was kept at 50 lx for all the colors. The subject's task was to judge the color appearance of the window W by the elementary color naming method. The measurement was repeated for five times at different sessions. The horizontal illuminance near to T on the shelf of the test room was kept at 9 lx. In the additional experiment on saturation five colors of illumination of different saturation were employed for red and green illumination as shown in Fig. 3, by open circles for red and open squares for green. The illuminance was not particularly controlled and it varied for different saturation.

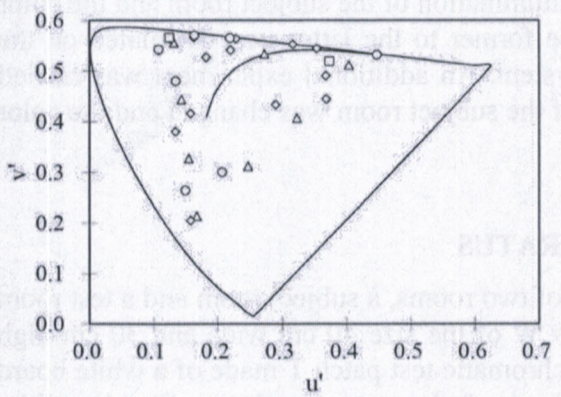

Fig. 2 Colors employed for the subject room illumination. △, Rits[3]; ◊, CRC1[4]; □, CRC2[2]; ○, CRC3, present work.

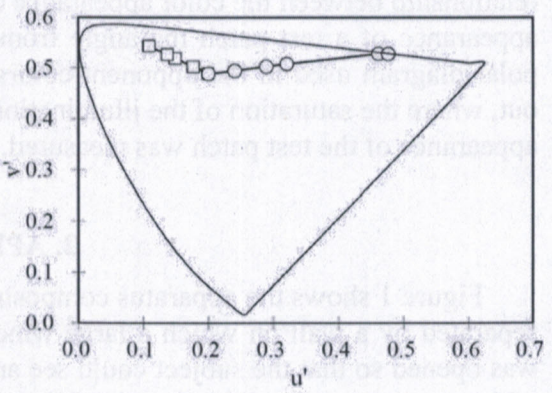

Fig. 3 Colors employed for the subject room illumination in the saturation experiment. ○, red; □, green.

An achromatic patch N of N6 in Fig. 1 was used for the measurement of the color appearance of the subject room. At the measurement the window W was made small, 2 x 2 cm^2, through which a subject looked at N and judged color with the elementary color naming method. The horizontal plane illuminance in front of the white board was kept at 130 lx. The measurement was repeated for five times.

Five subjects participated in the main experiment and two of them in the additional experiment, all normal in color vision as tested by the 100 hue test.

3. RESULTS AND DISCUSSION

For any color of illumination the entire field of the window appeared uniformly colored. Subjects perceived as if a colored paper was pasted on the window, which implied that the subjects perceived the window as an object placed in the subject room. Results of subjects CP and KC from the main experiment are shown in Fig. 4 by a polar diagram for the case of reddish blue illumination. R, Y, G, and B indicate the unique hues of red, yellow, green, and blue and the hue appearance obtained by the elementary color naming is shown by the angle from the unique red. The amount of chromaticness is shown by the radiant distance from the center becoming 100 % at the outmost circle. Open circles show the color appearance of the subject room judged from the test room through a small window, which we called the adapting color. Open squares show the color appearance of the test patch of white board judged from the subject room on the large window, which we called the adapted color. Small symbols indicate five repetitive judgments and large symbols connected by lines through the origin indicate their average. We see that the variance within a subject is not large but the variance among subjects is large.

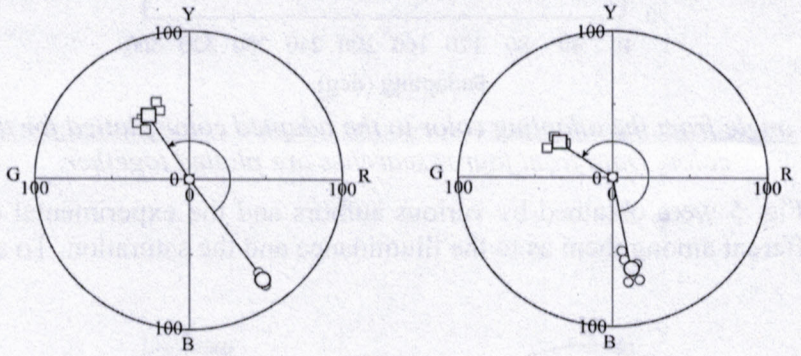

Fig. 4 Adapting and adapted colors for a reddish blue illumination color. ○, adapting color; □, adapted color. Subjects CP (left) and KC (right).

We are interested in the relationship between the adapting color and the adapted color and we obtained the angle from the former to the latter, $\Delta\theta$ measured in anticlockwise as shown in the diagram of the subject CP and KC. It was 176° in CP and 225° in KC. We took the average of $\Delta\theta$ for all five subjects for all the seven colors of illuminations and plotted them for the adapting angle. The results are shown by open circles in Fig. 5. The abscissa gives the adapting angle in degree and the ordinate the angle difference $\Delta\theta$. A horizontal dotted line indicates $\Delta\theta = 180°$.

In the past there are other similar data available, though for different purposes in some cases[2-4]. We read out $\Delta\theta$ from their papers which are listed in Table 1 together with number of subjects, the window size, number of colors investigated, and the color appearance mode. The present work is specified as CRC3. The illumination colors

Table 1 Works used to obtain $\Delta\theta$ plotted in Fig. 5.

Authors	Sub	Test size	Colors	Mode
Rits	5	6cm circluar	8	Object
CRC1	5	4x4 cm^2	14	Object
CRC2	4	4x4 cm^2	2	Object
CRC3	5	40x30 cm^2	7	Object

triangles for Rits[3], open diamond for CRC1[4], open squares for CRC2[2], and open circles for the present work, CRC3, in Fig. 2.

All the angles $\Delta\theta$ read out from these works are plotted together for the adapting color by different symbols in Fig. 5. For the data of CRC1, CRC2, and CRC3 the standard deviations of subjects are shown by short vertical bars. It is clear from these data that $\Delta\theta$ is not necessarily 180° for the adapting color. In fact the exact opponency between the adapting color and the adapted color takes place at only two adapting colors, yellowish green and reddish blue. The data can be approximated by a sine curve as shown by a thick line.

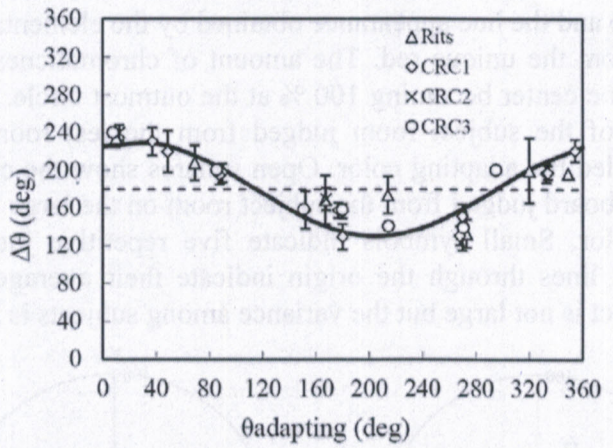

Fig. 5 The angle from the adapting color to the adapted color plotted for the adapting color. Data from four researches are plotted together.

The data in Fig. 5 were obtained by various authors and the experimental condition was inevitably different among them as to the illuminance and the saturation. To see the effect

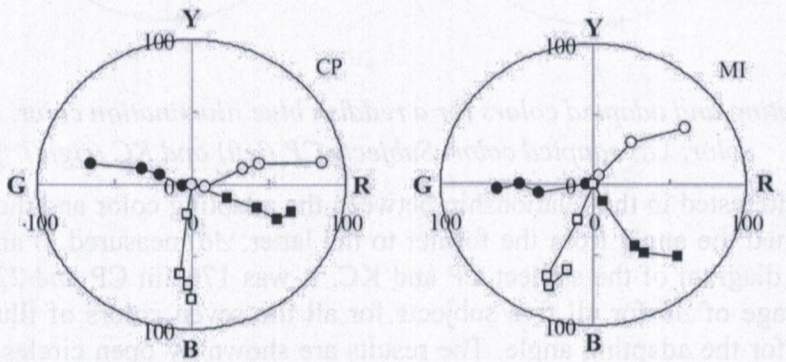

Fig. 6 Adapting and adapted colors for a red (open symbols) and green (filled) illumination. Circles, adapting color; Squares, adapted color. Subjects CP and MI.

of the saturation of the illumination in the subject room the additional experiment was done where the saturation was changed in the red and green colors that were employed for the main experiment as shown in Fig. 3. The results of the color appearance of the test patch are shown for the two subjects CP and MI in Fig. 6. Circles show the color appearance of the illumination and squares that of the test patch. There is observed change in the color appearance of the test patch for different saturation of the illumination but small.

The effect of the luminance of the test patch was investigated by Ikeda et al.[3]. Again there was observed the effect but small.

To conclude the adapting and adapted colors are roughly opposite in the opponent colors diagram but not exact. When the angle from the former to the latter is plotted the curve obeys sinusoidal shape.

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