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Comparison of the chromatic adaptation between LED and fluorescent lamps to investigate the color constancy by adapting-adapted color appearance

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ABSTRACT

LED and fluorescent lamps were compared for the chromatic adaptation by utilizing the two-rooms technique and the elementary color naming. A subject judged the color appearance at the window between the subject room and the test room when the subject room was illuminated lamps of various colors while the test room was illuminated white. It was found that the adapted color and the adapting color are not normally opponent. The state of the chromatic adaptation was exhibited by the difference between the adapting and the adapted color and it was almost same both with the LED and the fluorescent lamps.

Keywords: Chromatic adaptation, Illumination, Elementary color naming, Color constancy, Opponent colors theory, Recognized Visual Space of Illumination RVSI

1. INTRODUCTION

It is generally considered that the color constancy is achieved by understanding and cancelling the illumination in a space. This expression can be put to another way that a person recognizes a space, understands the illumination that fills the space, and adapts to the illumination, which are the essential points in the concept of the recognized visual space of illumination RVSI. It is a big issue to investigate the strategy of the visual system how to understand and cancel the illumination but here in this paper we investigate the state of adaptation of the visual system to illumination on the assumption that the understanding for the illumination is already established in the visual system. The experimental technique is the two-rooms technique composing of a subject room and a test room which are connected by a separating wall with an window through which a subject observes a test stimulus placed in the test room. The illuminations of the two rooms can be independently adjusted and the technique may be called the environment-stimulus independent illumination technique. When the subject room is illuminated by a colored light, say red, and the test room by a white light the window appears very vivid greenish blue because of the chromatic adaptation to the red illumination if the test stimulus in the test room is uniform and large enough to cover the entire window. We can investigate the state of the chromatic adaptation, consequently the color constancy, by measuring the color of the test stimulus for various colors of the subject room. In this experiment we employed two kinds of lamps, fluorescent and LED and compared the state of the chromatic adaptation.

2. EXPERIMENT AND PROCEDURE

Figure 1 shows the apparatus. The subject room was illuminated by either five fluorescent lamps of the daylight type Lf or LED lamps attached at the ceiling. Lf was covered by a colored film to present a colored illumination. The test room was illuminated by two horizontal fluorescent lamps Lt of the daylight type same as for the subject room. They were adjustable in intensity. The window size was 40 cm wide and 30 cm high in the case of fluorescent illumination and 6 cm x 6 cm in the case of LED illumination. They gave the visual angle of 13°x10° and 1.9°x1.9°, respectively when a subject viewed them at the distance 180 cm.

A uniform white board T without any scratches or texture was attached on the back wall of the test room of which size was 90 cm wide and 60 cm high, large enough to cover the window W entirely when a subject looked at the white board binocularly. In this way the test patch T appears as if a paper was pasted at the window. In other words T was perceived as an object in the subject room.

An achromatic patch of N6 was attached on the side wall as indicated by N. By observing the patch binocularly from the test room through a small window W of 2 cm x 2 cm the color appearance of the illumination in the subject room was measured, which was called the adapting color. The color appearance at the window when a subject judged in the subject room was called the adapted color.

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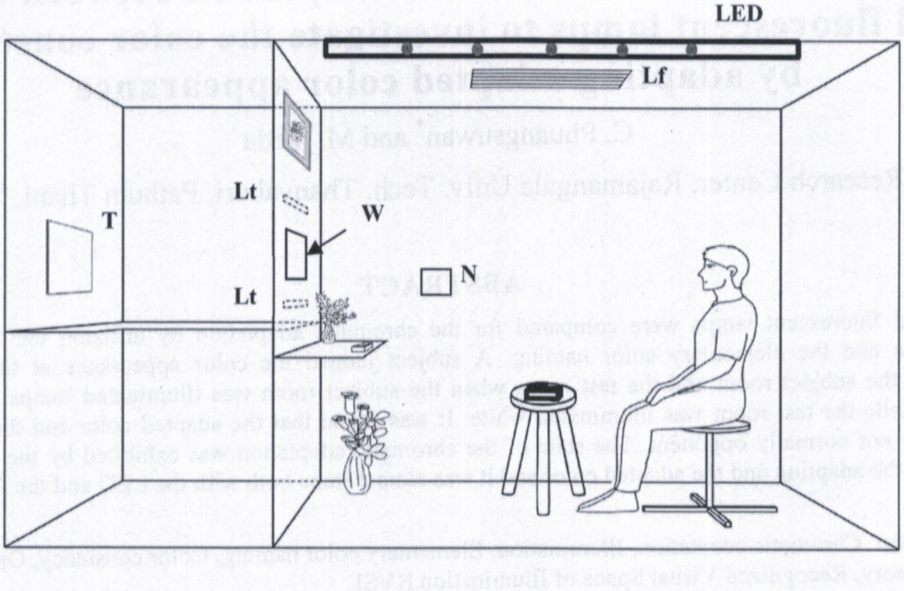

Figure 1. Apparatus

Seven colors were prepared for the subject room by fluorescent lamps as shown by open triangles in Fig. 2. Nineteen colors were prepared with LED as shown by open circles in the same figure.

In the fluorescent experiment the illuminance in the subject room was fixed at 50 lx and that in the test room at 9 lx. In the LED experiment it varied from 79 to 288 lx depending on colors. The illuminance in the test room was kept at 30 lx. In both experiments subjects perceived object color for the adapted color at the window.

The subject's task was to judge the color appearance at the window by the elementary color naming method, namely the amounts of chromaticness, whiteness, and blackness by percentage, and amounts of unique hues in the chromaticness again by percentage. Five subjects participated in the experiment, four Thai and one Japanese. They were all normal for color vision as tested by Ishihara test and 100 hue test.

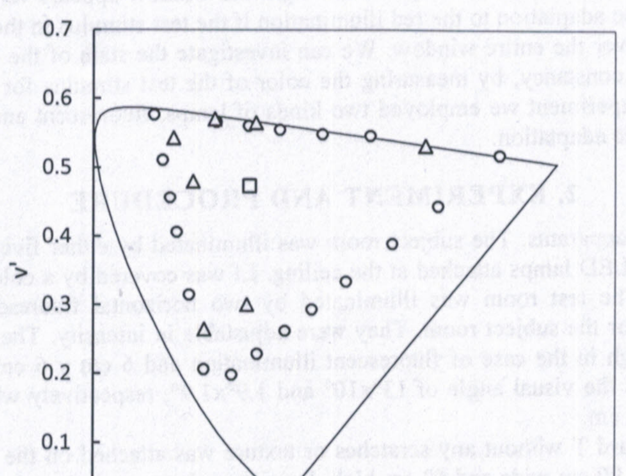

Figure 2 Chromaticities of fluorescent (triangles) and LED (circles).

An open square shows the equi-energy white.

3. RESULTS AND DISCUSSION

Results of two subjects are shown in Fig. 3 for a violet color illumination of LED (u'=0.221 and v'=0.227) by a polar diagram, which is used in the opponent-colors theory.

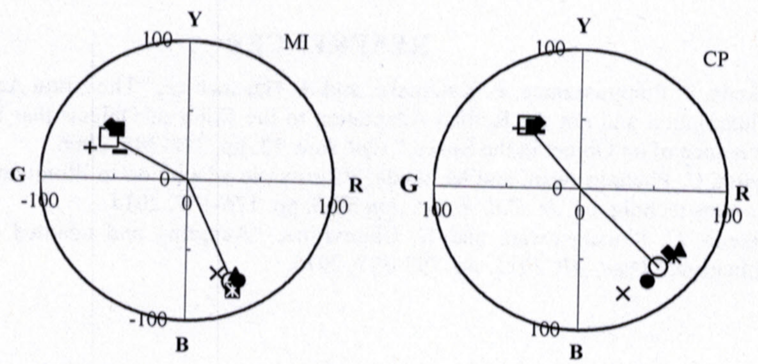

Figure 3. Adapting (lower right) and adapted (upper left) color for a violet illumination.

R, Y, G, and B indicate unique colors of red, yellow, green, and blue and the angle shows apparent hue determined by the amounts of unique colors. The origin of the diagram indicates zero and the circumference 100 % of the chromaticness. Small symbols at the lower right indicate results of adapting color after five repetition and a large open circle connected by a line shows their mean. Likewise, small symbols at the upper left and a large open square for the adapted color. The variance of five data points is not large but the variance between the two subjects is large showing individual difference in judging the color appearance.

We specify the apparent hue angle θ by the angle from the unique red axis in the anticlockwise direction. Then the state of the chromatic adaptation can be known by the difference of the adapted color from the adapting color, $\Delta\theta$. Figure 4 shows $\Delta\theta$ for the adapting color θadapting by open circles for the FL and open squares for the LED.

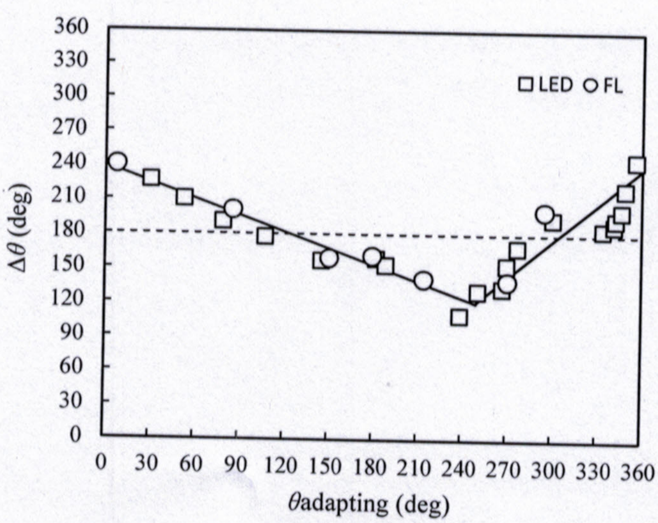

Figure 4. Adapting-adapted color $\Delta\theta$ for the adapting color θadapting.
Solid lines are regression lines and a dotted line are at $\Delta\theta$= 180 deg.

Both results of FL and LED experiments came very close with each other in the Δθ vs θadapting relation implying that there is no difference in chromatic adaptation between the two types of lamps, which at the same time implies the color constancy will take place equally in both lamps. The data together can be approximated by two lines shown by solid lines, of which equations are given by

$$\Delta\theta = -0.475\theta\text{adapting} + 239 \qquad 0 \leqq \theta\text{adapting} \leqq 250,$$

$$\Delta\theta = 1.067\theta\text{adapting} - 145 \qquad 250 \leqq \theta\text{adapting} \leqq 360.$$

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