CHAPTER III
EXPERIMENT

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จุฬาลงกรณ์มหาวิทยาลัย

3.1 Apparatus

The experimental booth was composed of two rooms, a subject room Rs and a test room Rt, separated by a wall with a window W of variable size as shown in Fig. 3-1. The subject room was 1.3 m long, 1 m wide and 2.4 m high and the test room was 1 m long, 1 m wide and 2.4 m high. T indicates the test patch of which color a subject judges in the experiment.

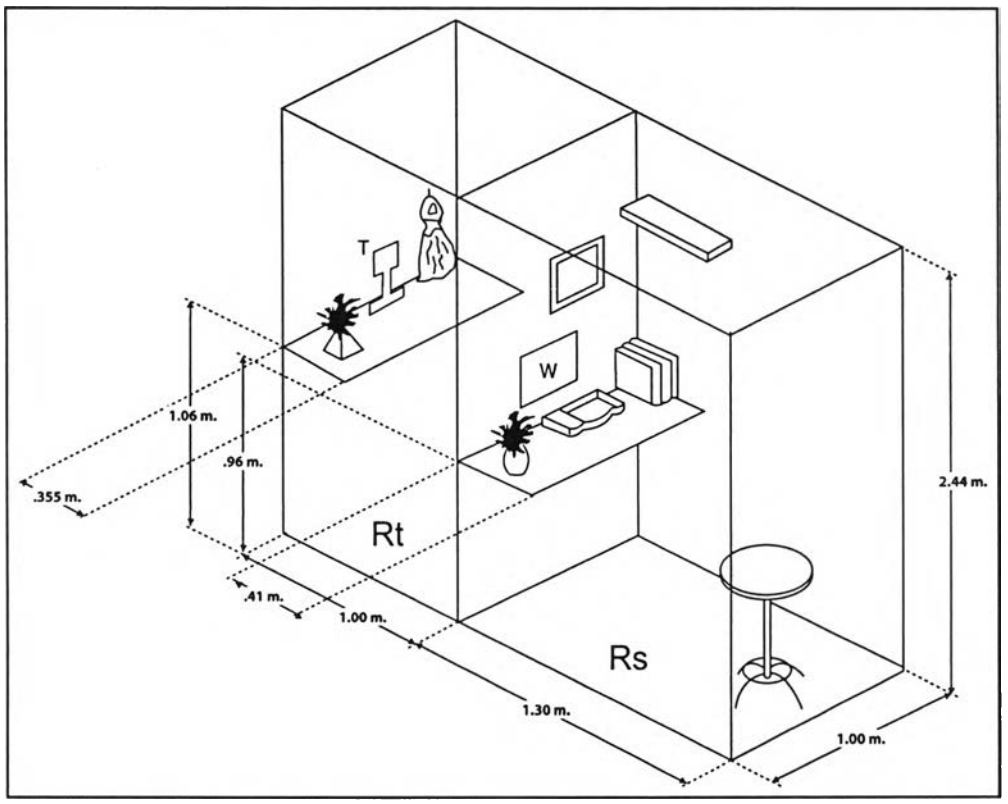

Fig. 3-1 Scheme of the experimental booth
W indicates window

The subject room was illuminated by a daylight type fluorescent lamp FLs and the test room by two daylight type fluorescent lamps FLt as shown in Fig. 3-2. The upper lamp of FLt was covered with one of two color films, red and yellow, in order to give a

colored illumination in the test room. The lower lamp was not covered by any colored film and it was used to desaturate color of illumination. The illuminance of both room were controlled by light controllers. In the subject room the horizontal plane illuminance was kept constant at 30 lx as measured by the chroma meter Minolta CL-200 placed on the shelf Sh, 96 cm high from the floor, in the subject room. In the test room the vertical plane illuminance was kept constant at 25 lx when measured in front of the test patch T.

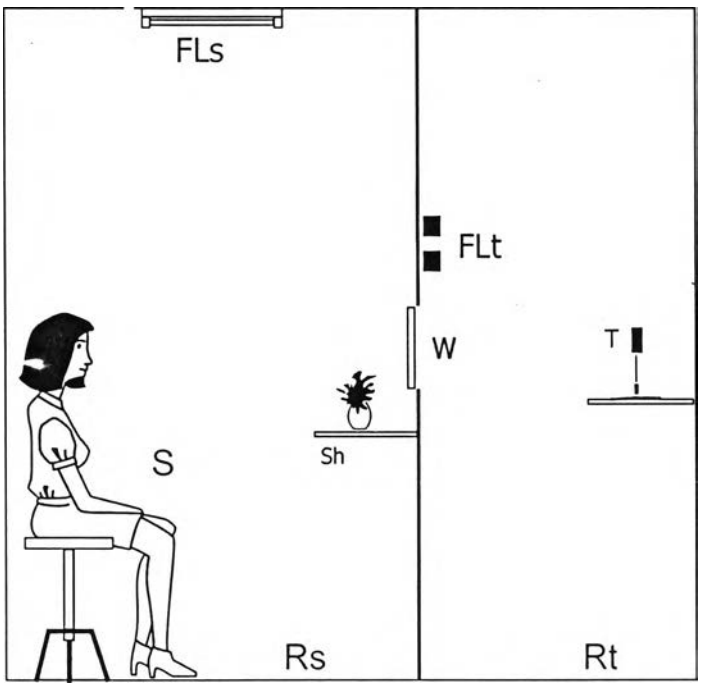

Fig. 3-2 Side view of an experimental booth
W indicates window; T indicates test patch

The wall of the subject room was covered by an achromatic wallpaper of about N9 with some texture. Various objects were put on the shelf attached to the front wall. Pictures and a calendar were also hung on the wall. The objects were books, wooden blocks, an artificial flower, dolls, a real green plant and others as illustrated in Fig. 3-3. A window indicated by a small square W was opened on the front wall at the eye level of the subject sitting on a stool and he/she could see the test room through it. The size of the window was varied by replacing a plywood P, on which a window of various size is attached. Five such plywoods were prepared to present the window 1, 2, 3, 4 and 5, or W1, W2, W3, W4 and W5.

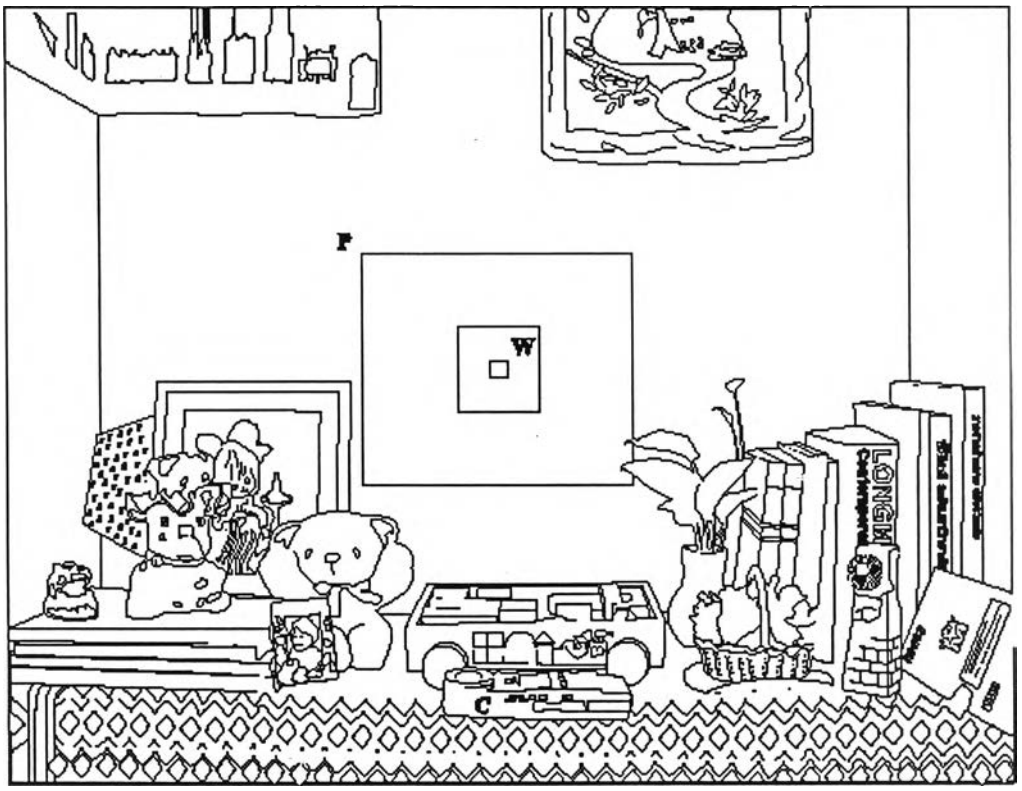

Fig. 3-3 The front wall of the subject room
C indicates chroma meter

The test room was also furnished with the same achromatic wallpaper as the subject room and was decorated by various objects such as wooden blocks, dolls, an artificial plant, a living plant, a lemon, an orange and others as shown in Fig. 3-4. The central square drawn by solid line shown as T was the test patch of the size 8 cm x 8 cm. It was attached at the top of a supporting arm that was temporally fixed on the shelf and could be replaced with other test patches. The depth of the shelf on which the above objects were placed was 35 cm and the test patch was separated from the back wall by 14 cm. Four squares and one rectangle drawn by dotted lines show the extent of visual field viewed with one eye by the subject through different windows. The visual fields of the windows 3, 4 and 5 are indicated by the corresponding numbers. With the small two windows, W1 and W2, they were filled only with the test patches.

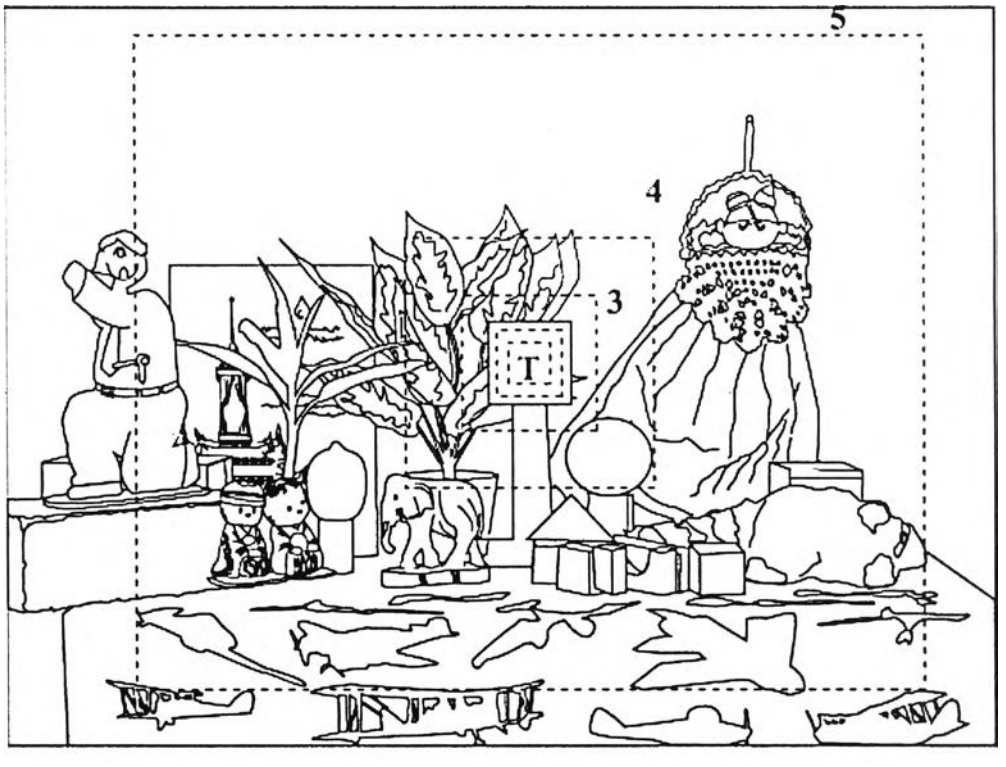

Fig. 3-4 View of the test room

3.2 Experimental Conditions

Two colored illuminations, red and yellow, were employed for the test room. By combining one of these colored illuminations with the daylight type illumination in different intensities we prepared four illuminations of different saturation for each color. The four combinations were 25+0, 19+6, 12+13 and 5+20, where the first value indicated the illuminance of the colored light and the latter that of the daylight. Figure 3-5 shows the chromaticity coordinates of the eight colors of illumination in the test room, yellow illumination by open triangles and red illumination by open squares. An open circle represents the color of the daylight type of illumination.

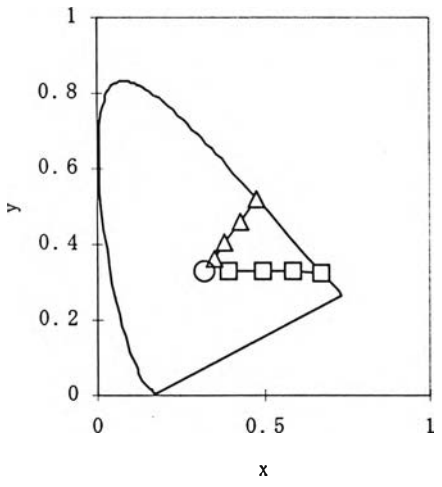

Fig. 3-5 The chromaticity coordinates of the eight colors of illumination and the daylight type illumination. □, red illumination; △, yellow illumination; ○, daylight type of illumination.

Five different colors were employed; 5R5/3, 5Y5/3, 5G5/3, 5B5/3 and N5 for the test patch. Their chromaticity coordinates under colored illumination of four different saturations are shown in Fig. 3-6a and b; a for red illumination and b for yellow illumination. The colorimetric measurement was done by increasing the intensities of both the colored lamp and the white lamp by keeping their ratio same as the ones defined above. This increase of intensities was needed to make the colorimetric measurement possible. For the red illumination the measurement was only possible for the condition R5+W20. Note that the chromaticity points of all test patches lie on the spectral locus with the yellow illumination condition Y25+W0. In Fig. 3-6a, the open squares represent chromaticity coordinates of test patches under condition R5+W20. Filled diamonds show chromaticity coordinates of red illumination with different saturation. In Fig. 3-6b, different symbols represent chromaticity coordinate of test patches under four different saturations, open squares for Y5+W20, open triangles for Y12+W13, exes for Y19+W6, and open diamonds for Y25+W0. Filled diamonds show chromaticity coordinates of yellow illumination of different saturations.

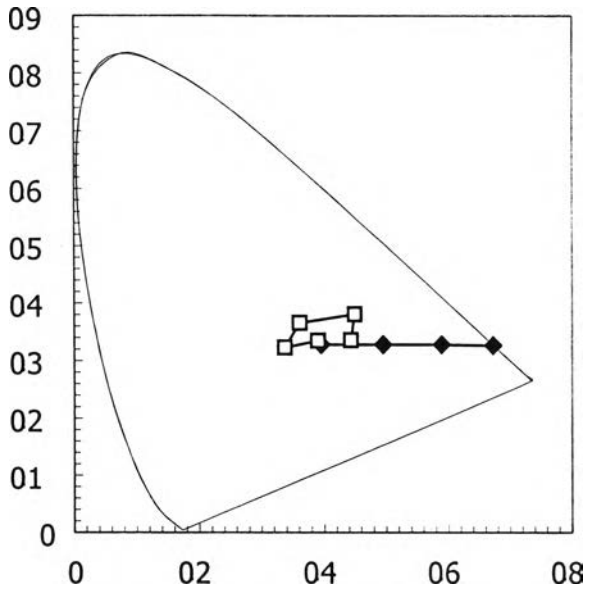

Fig. 3-6a The chromaticity coordinates of test patches under red illumination R5+W20 shown by □.

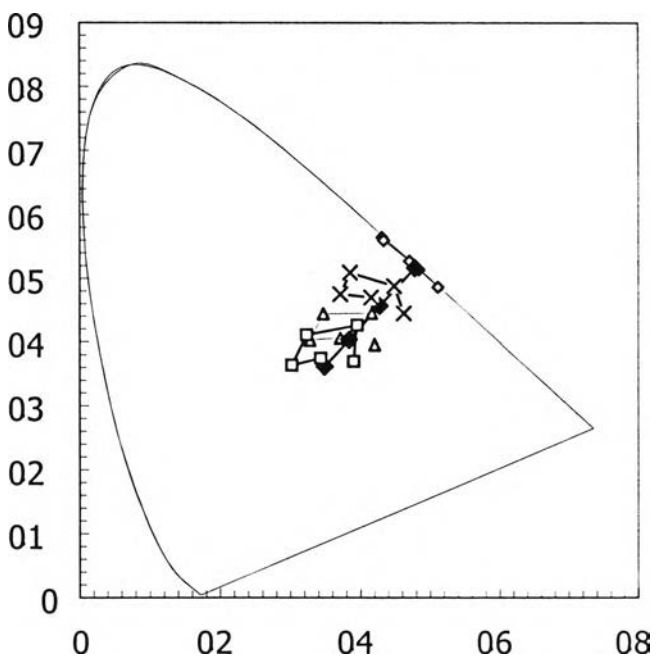

Fig. 3-6b The chromaticity coordinates of test patches under yellow illumination of different saturation.□, Y5+W20; △, Y12+W13; X, Y19+W6; ◇, Y25+W0.

Five different sizes were employed for the window. The actual sizes were 19 mm x 19 mm for W1, 33 mm x 33 mm for W2, 60 mm x 60 mm for W3, 120 mm x 120 mm for W4 and 270 mm x 320 mm for W5. The visual extents of these windows were already shown in Fig. 3-4

3.3 Subjects

Five subjects were employed to cover age and gender, PP (54 years old, female), DH (44, male), JJ (26, female), PH (25, female) and MW (24, male). The first two were lecturers at the Department of Imaging and Printing Technology, the next two subjects were graduate students at the Department of Art Education Music and Dance Education, and at Department of Imaging and Printing Technology, respectively. The last subject was an under graduate student at the Department of Imaging and Printing Technology. The subject PP had prior experience being a subject for this kind of experiment and PH had experience to some extent, but the rest were native subjects. The subject PP and PH used their left eye while DH, JJ and MW used their right eye.

3.4 Procedure

3.4.1 Methodology

3.4.1.1 Elementary Color Naming Method

In this experiment we measured the color appearance of a test patch placed in a test room by the elementary color naming method. Here I will explain about the method first. Hering noticed that there are six elementary colors, red, yellow, green, blue, white and black. Red, yellow, green and blue are called the unique hues. The elementary color naming is to judge the amounts of the elements in a color that a subject looks at. We ask the subject to judge the amounts of whiteness, blackness and chromaticness, first, to make the total amount 100. Namely,

$$W + Bl + Chr = 100$$

where *W* represents whiteness, *Bl* blackness and *Chr* chromaticness. Hering also noticed that red and green are opponent with each other and they do not exist at the same time and at the same place. So yellow and blue are opponent with each other. The second step of the elementary color naming method is to judge the amounts of unique hues in the chromaticness, but as there are opponent color relations we ask the subject to use only one or two hues which are not opponent in the judgment by making the total 100.

An example of the color naming would be

W = 30, *Bl* = 20, *Chr* = 50 from the first judgment, and

R = 60, *Y* =40 from the second judgment.

This would be a pretty vivid orange color.

The way to show the results of the elementary color naming is to use a color appearance diagram as shown in Fig. 3-7. The chromaticness is shown by the distance from the center of the circle, the outmost circumference giving 100. Hue is shown by a direction in the coordinate.

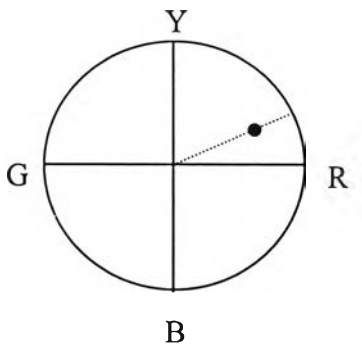

Fig. 3-7 The color appearance diagram to plot the result of the elementary color naming

3.4.2 Experiment

A subject was invited to the subject room and sat on a stool which placed at an appropriate position in order that he/she could see a test patch through the

window. The subject stayed there for a few minutes to adapt himself to the illumination. The experimenter set the illumination of the test room to one of eight illuminations by choosing a colored film for the fluorescent lamp. Then the experimenter set one of five windows and one of five test patches. The experimenter told the subject to start judging the color appearance of the test patch by one eye, the other eye being closed or covered by a black cloth. When the subject gave answer the experimenter recorded the data on a data sheet. If the subject felt that the test patch appeared the light source color he/she told the experimenter. Then the experimenter changed the window as well as the test patch in a random order. When all the windows and the test patches were investigated for this illumination, one session is over. But if the subject could continue the experiment, another illumination was prepared to continue the experiment.

The subject was asked not to gaze the test patch but look around at the subject room even during the judgment time. The subject judged the color of the test patch by using the elementary color naming method, the amounts of chromaticness, whiteness and blackness first and the amounts of unique hues next, both in percentage. Five sessions were carried out for each color of illumination.

Besides the above experiment other two control experiments were carried out. One was to measure the color appearance of the illumination in the test room as exhibited on the achromatic patch N5 when kept the subject room dark. Its color was judged as seen from the subject room through window 1. The other was to measure the original color appearance of the test patches by observing the teat patches through window 5 when both rooms were lit with the daylight type fluorescent lamps. Measurement was repeated five times in both experiments.

When the experiment was completed for five sessions, the calculation was done to obtain the average of the amounts of chromaticness, whiteness, blackness and unique hues of each test patch. The calculation of angle θ to show hue would be done for every saturation of colored illuminations by the equation 3.1 and 3.2. For data of red and yellow the equation 3.1 is used. For data of red and blue the equation 3.2 is

used. For other colors either equation can be used. The way to show such average results of the elementary color naming was to plot the results in color appearance diagrams. The chromaticness was shown by the distance from the center of the circle, the outmost circumference giving 100 units. The circumference was shown as the boundary of the diagram. Hue is shown by coordinates of the diagram as shown in Fig. 3-8.

$$\theta = \left(\frac{R}{100} \times 0\right) + \left(\frac{Y}{100} \times 90\right) + \left(\frac{G}{100} \times 180\right) + \left(\frac{B}{100} \times 270\right) \quad (3.1)$$

$$\theta = \left(\frac{R}{100} \times 360\right) + \left(\frac{Y}{100} \times 90\right) + \left(\frac{G}{100} \times 180\right) + \left(\frac{B}{100} \times 270\right) \quad (3.2)$$

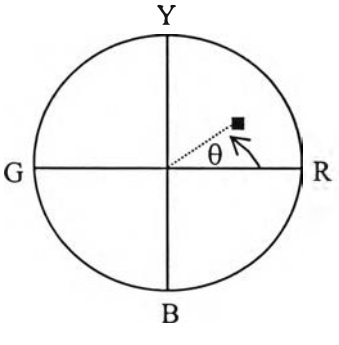

Fig. 3-8 Color appearance diagram