The Subjective Evaluation Experiment for the Estimation of Helmholtz-Kohlrausch Effect under the Ambient Lighting Conditions

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ABSTRUCT

The purpose of this study is to carry out the subjective evaluation experiment for natural images to measure the magnitude of Helmholtz-Kohlrausch effect under ambient lighting conditions. We found that the magnitude of the H-K effect and the saturation tends to decrease as the brigntness of the environment increases.

1 INTRODUCTION

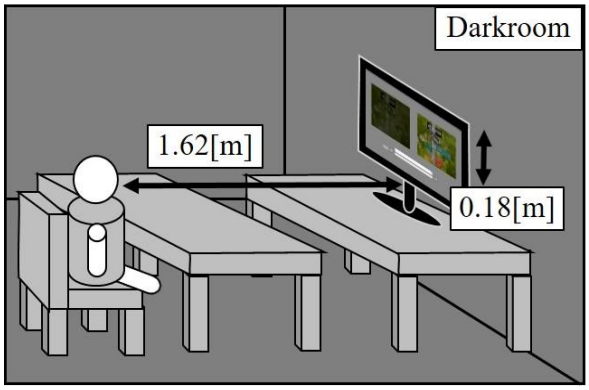
Human visual system has the characteristic of Helmholtz-Kohlrausch (H-K) effect. Hunt et al. interpreted the H-K effect as "For colours of the same luminance, there is a tendency for the brightness to increase gradually as the colourfulness of the colour increases" [1]. Donfrio argued that researches on H-K effect are indispensable for wide color gamut of display equipment and quantification of magnitude of the influence is required for display development [2]. By quantifying the H-K effect, it is expected that it can be applied to the development and evaluation of wide color gamut display devices that have been actively developed in recent years. We reported the quantification and the estimation of the H-K effect for natural images at IDW [3]-[7].

Display equipment is practically used under ambient lighting conditions. The illuminance of a typical office is required over 750 [lx]. We measured the illuminance of a room with south windows. As a result, the illuminance was found 500~1200 [lx] under the illuminant D65 and indirect sunlight. It is necessary to estimate the H-K effect by considering the indirect sunlight. The purpose of this study is, therefore, to verify the H-K phenomenon by the subjective evaluation experiment under three conditions (the darkroom, the room under the illuminant D65, and the room under the illuminant D65 and indirect sunlight) by taking the experiment value as Ground truth. From the experiment results, we confirmed and discussed the influence of the H-K effect under ambient lighting conditions.

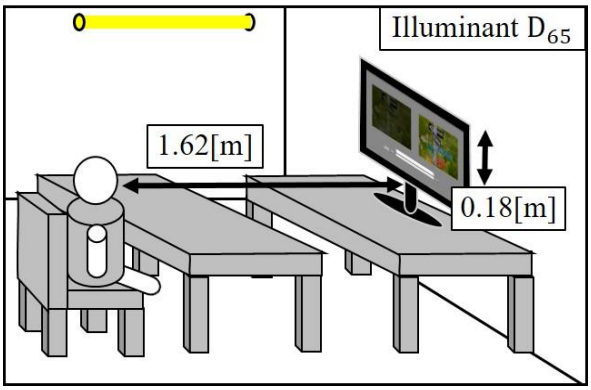
2 EXPERIMENT

2.1 Motivation

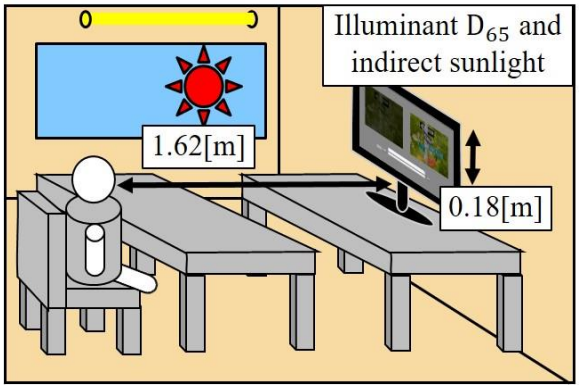
The H-K effect of human visual system must be considered in the development of wide color gamut displays in recent years. We have researched estimation of H-K effect for natural images in the darkroom and the environment of using the display under the illuminant D65. However, the experiment by considering the environment of using the display under the illuminant D65 and indirect sunlight has not been carried out yet. Therefore, in this



(a) Darkroom



(b) Illuminant D_{65}



(c) Illuminant D_{65} and indirect sunlight

Figure.1 Experiment conditions

The distance between display and subject is 1.62[m] in all environments. The height of experiment image is 0.18[m] in all environments.

Table.1 Experiment conditions

Subjects	26 persons
Method	Adjustment method
Illumination	Darkroom (0.00[lx]), Illuminant D_{65} (158[lx]), Illuminant D_{65} and indirect sunlight (1088[lx])
Display	LCD monitor (AdobeRGB 99%)
Viewing distance	9H (1.62[m])[8]

We measured the illuminance on the screen of the display in each environment. The illuminance value is the average illuminance for all subjects.

(a) Sea (b) Autumnal tints (c) Tulip

Figure.2 Natural images

We selected images that don't contain much achromatic color.

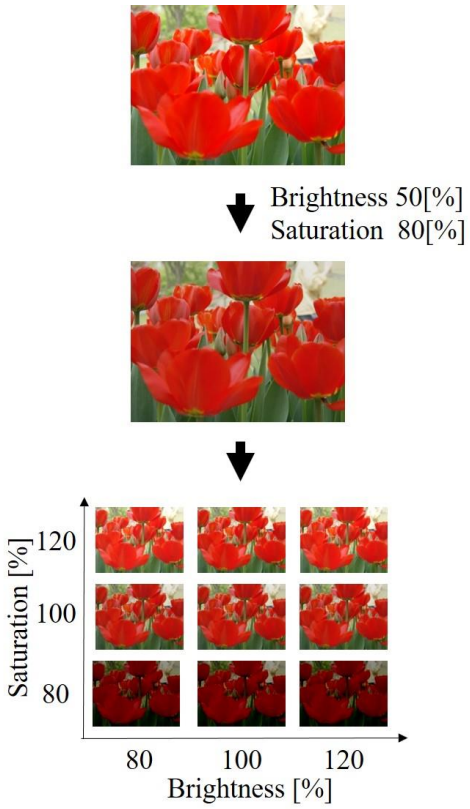


Figure.3 Procedure of preparing evaluation images

We first created an image reduced lightness 50[%] and saturation 80[%] from the original image not to exceed the lightness and saturation of the original image.

study, we aim to do experiment under these two environments as well as in the darkroom environment. The illuminance of room under the ambient light was 500~1200 [lx]. Tristimulus value of light reaching the human eye under ambient lighting conditions is different from the darkroom. We assume that the appearance of the image also changes. In order to observe the changes in appearance when ambient lights were added, we carried out the subjective evaluation experiment by the adjustment methods under various ambient lighting conditions and considered the experimental results.

2.2 Experiment Condition

Experimental environment conformed to the ITU-R BT.500-13 [8]. The experimental environment is shown in Fig. 1 and Table 1. In this study, three images [8] were resized to 800×600 to use as original image (shown in Fig. 2). These images were as follows: a) "Sea" contains primarily cyan color, b) "Autumnal tints" and c) "Tulips" contain primarily red color. The experiments were conducted in the room under three ambient lights (the darkroom, the illuminant D65, and the illuminant D65 and indirect sunlight). We measured the vertical illuminance of the display in each environment and calculated the average value based on the number of subjects. The reason for measuring the vertical illuminance is that it is the light incident on the display that affects the appearance of the image. The vertical illuminance of the display was 0 [lx] in the dark room or 158 [lx] under the illuminant D65, and 1088 [lx] under the illuminant D65 and indirect sunlight. The LCD display covering 99 [%] of Adobe RGB was installed as image output devices. The experiment was conducted using an adjustment method where the subject adjusts the amount of the stimulation to match the target level by comparing the reference image and the evaluation image to make the absolute assessment. Next, the procedure of creating the reference and the evaluation images is shown in Fig. 3. The reference images were created by decreasing the luminance and the chroma to 50 [%] and 80 [%] from the original images respectively, and 27 types of evaluation images were created by varying the luminance and chroma from 80 [%] to 120 [%] per 20 [%] in CIELUV color space from the reference images. The reason of decreasing the brightness to 50[%] from the original image is that there is a tendency to evaluate chromatic images brighter than achromatic images in this study. We set the brightness of reference image to 0.5×2=1(100[%]) with respect to 200[%], the maximum of the prepared comparison images. For the saturation, we set to 0.8×1.2=0.96(96[%]) when creating an image with saturation 120[%].

2.3 Experiment Method

For images described in section 2.2, subjects adjust the brightness of achromatic image by pressing keyboard right arrow key and left arrow key from the keyboard, and then press Enter key when they determine the same brightness for gray images to do the brightness adjustment of the next image. We set 3 seconds before displaying next image on the device and no image is displayed in between that time. The evaluation is performed by ascending and descending series. In addition,

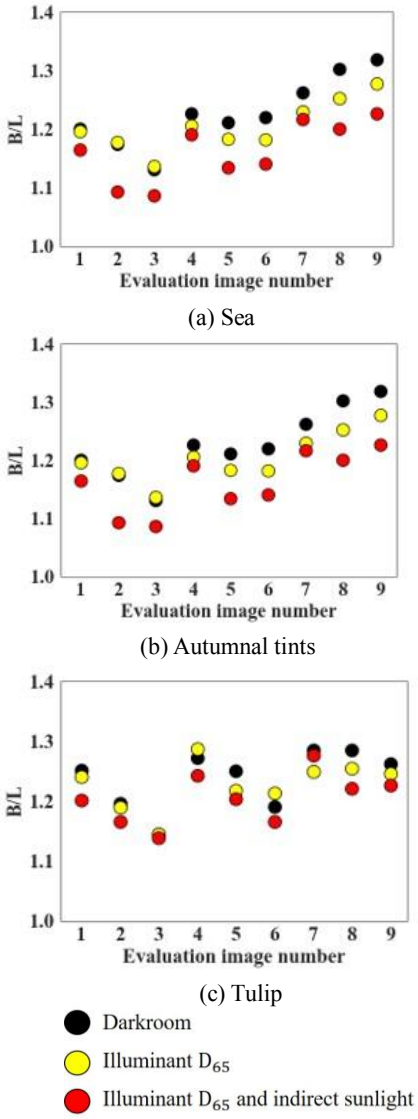


Figure.4 Experiment results

We found the change of B/L value in (a) Sea is small under the ambient lights but the change of B/L value in (b) Autumnal tints and (c) Tulip is large.

Table.2 Evaluation image number

Evaluation image number	Brightness[%]	Chroma[%]
1	80	80
2	100	80
3	120	80
4	80	100
5	100	100
6	120	100
7	80	120
8	100	120
9	120	120

The evaluation image numbers correspond to 9 images of Figure.3.

experiment is conducted by swapping images on the left side and the right side of the display to avoid error. The determination method of B/L value in this experiment is calculated by the lightness of the chromatic image as the denominator and the lightness of the achromatic image as the numerator. We carried out the experiment in the order of the darkroom, the illuminant D65, and the illuminant D65 and indirect sunlight focusing on human eyes adaption. In addition, we did it only on sunny days to get the high illuminance.

3 RESULT

The result of the subjective evaluation experiment discussed in section 2 is shown in Fig. 4 and the evaluation image number is shown in Table 2. Focusing on the evaluation image numbers 3, 6, and 9 in the result of Fig. 4 (a), the B/L value increases as the saturation increases even if the ambient light adds. This suggests that the H-K effect exists not only in the darkroom but also under the ambient light. Also, focusing on the evaluation image numbers 1-3 in the result of Fig. 4 (a), the B/L value decreases as the brightness increases. This tendency is also seen in 4-6 and 7-9. This shows that the lightness tends to be negatively proportional even under ambient lights. These tendencies are also seen in the results of (b) and (c). It is verified that an image quality is influenced by H-K effect under ambient lights.

4 DISCUSSION

We desired to confirm how the experimental results in the section 3 change as the illuminance increased. We calculated the average value of the ratio of the experimental results for each environment to the darkroom results of each evaluation image number. The relative ratio of experiment result is shown in Fig. 5 where the horizontal axis is the illuminance and the vertical axis is the relative ratio to the experimental value in the darkroom. As shown in Fig. 5, it is found that the B/L value of two thirds of experimental images with the increase of the illuminance is decreasing. Generally, it is said that the magnitude of H-K effect is bigger when the saturation of images is higher. We assume that the saturation becomes lower when the ambient lights become brighter.

The displayed color of each pixel of natural images is determined by the value of RGB and a human being determines the perceived color by the emitting light from the display. When the illuminance increases as the environment change, we assume that a human being perceives the different color from the displayed color of natural images because the perceived color is changed by adding the ambient lights. To confirm the change of the saturation under the ambient lights, we carried out the color measurement under the ambient lights. From each result, we calculate the hue and saturation and observe the influence by the illuminance. As a result, we found little influence in the hue that is under 2[degree] by changing the environment in the high saturation. In addition, as shown in Fig. 6, we plotted each result of color measurement in the CIELUV color space because the color gamut of display devices is confirmed by triangle size. We found the triangle representing Adobe RGB shrinks as the

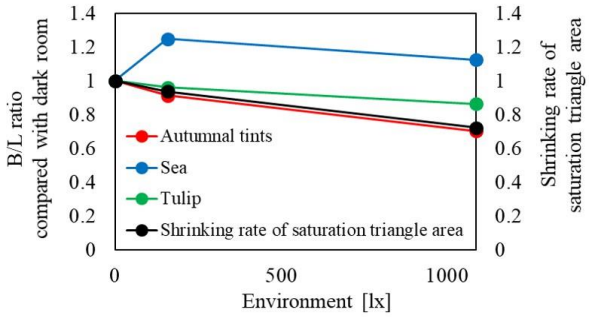


Figure.5 Change of B/L value and shrinking rate of saturation triangle area to difference of environments

The red, blue and green lines are the change in the ratio of results to darkroom when the environment gets brighter. The black line is the shrinking rate of color triangle measuring the color in each environment shown in Figure.6.

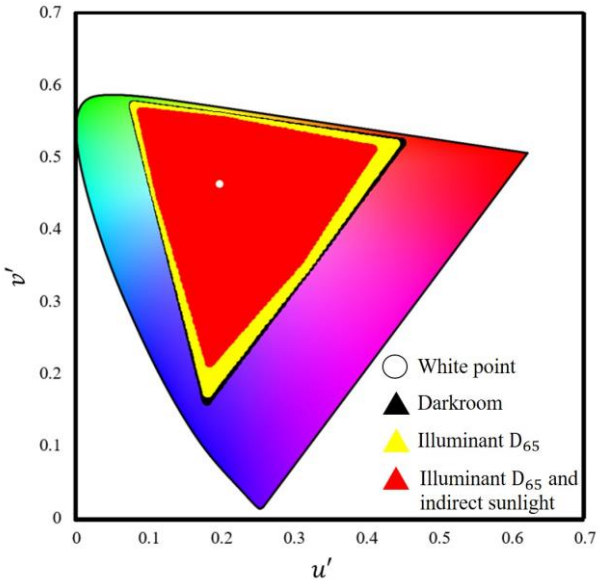


Figure.6 Change of saturation for difference of environments

It is the color coordinate calculated by the result of color measurement under each ambient light. The distance from the white point is the metric saturation in the CIELUV color space.

illuminance increases, and the shrinking rate of the triangle has the similar decreasing tendency to the result of "Autumnal tints" and "Tulips" shown in Fig. 5. In future, we plan to suggest the estimation equation considering ambient lights based on the results of this study.

5 CONCLUSIONS

The impact of our study is that we carried out the subjective evaluation experiment by the adjusting method under three different ambient lighting environments and it was confirmed from the experimental value that an image quality is influenced by the H-K effect under ambient lightings. We suggested that the B/L value which indicates the magnitude of the H-K effect tends to decrease as the environment light becomes brighter and confirmed that the saturation also decreased as the environment light becomes brighter. Based on the above results, we are going to consider the estimation equaion considering the ambient light in future.

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