COMPARISON OF PERCEIVED SATURATION DIFFERENCE BETWEEN COLOR ANOMALOUS AND NORMAL OBSERVERS

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Keywords: saturation perception, brightness perception, color anomalous, staircase method, psychophysical

ABSTRACT

In order to obtain the proper degree of color enhancement for anomalous color vision, difference of perceived saturation between two chromatic stimuli was measured. Before the saturation experiment, brightness matching was done using the test stimuli. Saturation differences are evaluated using a brightness difference for red, yellow, green, and blue stimulus sequences. Results of one weak deuteranomalous observer showed that perceived difference of saturation of the red and green stimulus pairs is smaller than those of normal observers, while no significant difference was obtained for yellow and blue stimulus pairs.

1. INTRODUCTION

In Japan, about 5 % of male is X chromosome-linked congenital color deficiencies, and the number of people becomes larger than 3 million which is non-negligible. Along the stream of color universal design, we introduced a way to enhance color of digital image for color anomalies using a criterion of preference, and examined whether color enhanced images are more preferable than the original ones for 9 protan and deutan observers [1]. Results showed that the enhancement we employed was effective for images that include reddish parts such as cherry fruits or pinkish parts such as flowers. In the way of color enhancement employed in our study, chromaticities of each pixel are extended along the protan or deutan confusion lines, or the lines in between. Although it is not a simple saturation enhancement, our method brought saturation enhancement of original image as a result. It was also indicated that the degree of enhancement where preference evaluation becomes maximum varies with image as well as individuals. However, appropriate degree of color enhancement was not examined precisely, because it is based on saturation perception of individual observers and the measurement is too elaborative and time consuming.

Nowadays genetic base of anomalous color vision has been revealed [2], and various models and simulators have been proposed [3-5]. On the other hand, it has been widely known that there exist large individual differences in the degree of anomalous trichromats from close to normal to nearly dichromats [6]. From practical point of view, to obtain the data of perceived saturation for individual observer is rather important than his/her genetic basis, to provide appropriate color enhancement for the observer. Therefore in this study, we measure the saturation perception of congenital color anomalous observer and normal observers. Saturation differences are evaluated using a lightness difference scale for red, yellow, green, and blue stimulus sequences.

2. EXPERIMENT

2.1 Apparatus

Sizes of the experimental booth were 180 cm (d) × 120 cm (w) × 210 cm (h). Viewing distance of the display and observers was horizontally 120cm. The display used in this study was a SAMSUNG SyncMaster XL24.

2.2 Brightness matching experiment

In order to compare the perceived saturation between anomalous and normal observers, perceived saturation difference between a pair of stimuli that has different purities but the same hue was assessed by the brightness difference between a pair of achromatic stimuli. In such experiment, brightness of the two stimuli should be equal because saturation difference is the amount to be extracted. As widely known [7], there exist large individual differences in the brightness sensitivity to chromatic stimuli, brightness matching experiment was carried out before the saturation evaluation to obtain equal brightness settings for each observer.

Figure 1 shows the chromaticities of test stimuli plotted on the a*b* chromaticity diagram. Values were calculated from the display calibration data, sRGB conversion to XYZ, and the transform to L*a*b* assuming the maximum white as a reference white. For the blue stimuli, one achromatic and two chromatic stimuli were prepared denoted as B0, B1, and B2, respectively. For red, yellow, and green, one achromatic and three chromatic stimuli were prepared, denoted as R0 to R3, Y0 to Y3, and G0 to G3, respectively. Luminance of R0, Y0, G0, and B0 were 100.9, 90.5, 118.2 and 18.1 cd/m^2, respectively. Brightness of the stimuli with the same hue, e.g., R1, R2, and R3, was matched to the brightness of the corresponding gray, e.g., R0. In order to do that, serious of stimuli with nearly constant metric chroma were prepared which was called xx-LUT, e.g., R1-LUT etc. Figure 2 shows the chromaticities of R1-, R2-, and R3-LUT plotted on the a* vs L* plane.

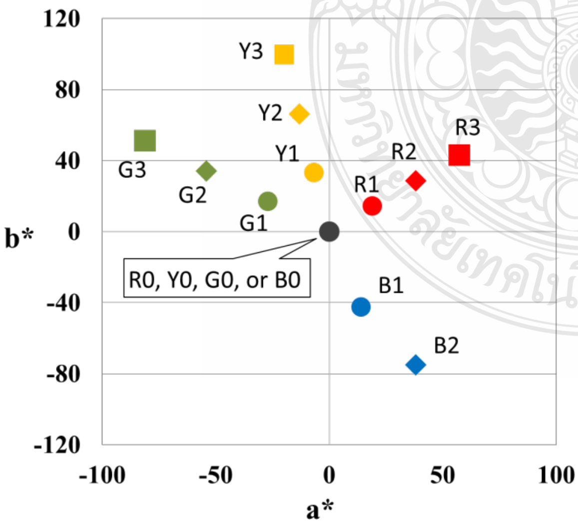

Figure 1. Stimuli plotted on a*b* plane

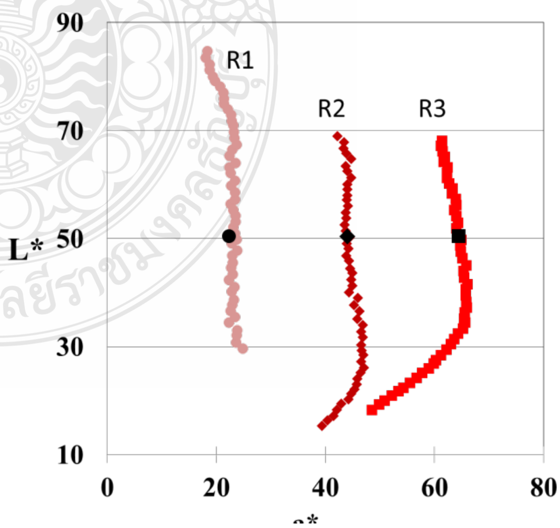

Figure 2. R1-, R2-, and R3-LUT plotted on a*L*plane

In the brightness matching experiment, achromatic and chromatic stimuli were presented as juxtaposed square stimuli. Size of one square subtends 3.198 degree in visual angle. Luminance of the former was fixed and it was regarded as the reference. Brightness matching was carried out using double stair case method. Luminance of the chromatic stimulus was varied along the corresponding LUT. At least 3 sessions were conducted for each of 11 chromatic stimuli, and the average value was employed as the matching point. As expected, large individual differences were observed in the brightness matching results for all stimuli.

2.3 Saturation difference experiment

Figure 3 shows the configuration of the saturation difference experiment. A pair of chromatic stimuli with equal brightness was presented on the left-hand side, and a pair of achromatic stimuli was presented on the right-hand side. Size of one square subtends 3.198 degree in visual angle. One of the achromatic pair was fixed in luminance as the reference, and luminance of the other was varied. At the beginning of the session, luminance of the variable was set either definitely brighter or darker than the reference. Observer was instructed to response difference of which pair is larger than the other. Double stair case method was employed to reach the criterion.

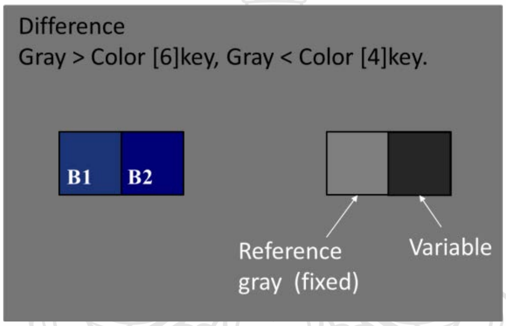

Figure 3. Configuration of the saturation difference experiment

2.4 Observers

Eight observers with normal color vision and one observer who was diagnosed as congenital deuteranomalous participated the experiment. All observers were examined for their color vision using Ishihara charts, panel D-15, and anomaloscope.

3. RESULTS AND DISCUSSION

Figure 4 shows the results of the saturation difference experiment. Horizontal axis indicates the pair of stimuli, and the vertical axis indicates the calculated lightness difference (ΔL^*) of the achromatic pair at the matching point. Vertical bars with the normal observers indicate the standard deviation among 8 normals. Numerals indicates the ratio of ΔL^* between Deuteranomalous and the average of normal observers. As shown in the figure, ΔL^*s of the Deuternomalous are smaller than those of normals for red and green pairs, while ΔL^*s for yellow and blue pairs are close to or even larger than those of normal except the case of B1 vs B2. Reason of large difference found in this pair is not known at the present.

In this paper, only one deuteranomalous observer could participate the experiment. Because his deficiency is rather weak, he seems to perceive red and green to some extent. Further experiment is expected to gather data from anomalous observers to obtain appropriate degree of color enhancement in various applications to aid color vision deficiency.

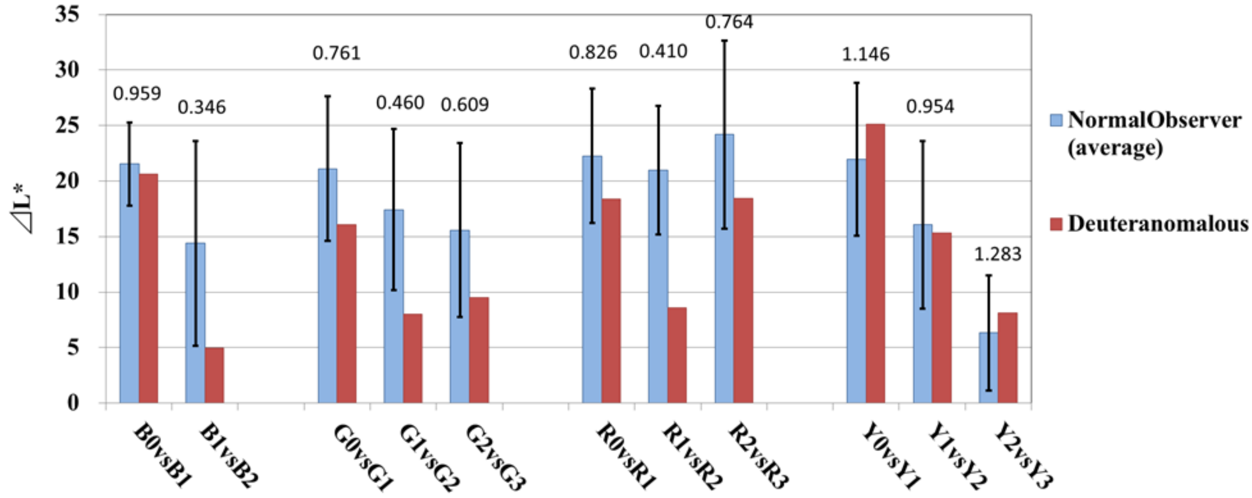

Figure 4. Results of the saturation difference experiment

ACKNOWLEDGMENT

This research was supported by Strategic International Research Cooperative Program: No.AS242Z01620H, Japan Science and Technology Agency (JST).

REFERENCES

1. Chen, Y.C., Guan, Y., Ishikawa, T., Eto, T., Nakatsue T., Chao, J., & Ayama, M., (in press). Preference for Color-Enhanced Images Assessed by Color Deficiencies, *Color Research & Application*.
2. Neitz, J., & Neitz, M., (2011). The genetics of normal and defective color vision. Vision Research, 51(7), 633–651.
3. Brettel, H., Vienot, F., & Mollon, F. D., (1997). Computerized simulation of color appearance for dichromats. *Journal of Optical Society of America, A*, 14(10), 2647–2655.
4. Yang, S., Ro, Y.M., Wong, E.L., & Lee, J.K.,(2008) Quantification and standardized description of color vision deficiency caused by anomalous trichromats - Part I: Simulation and measurement. *EURASIP Journal on Image and Video Processing*, 487618.
5. Yang, S., Ro, Y.M., Wong, E.L., & Lee, J.K.,(2008) Quantification and standardized description of color vision deficiency caused by anomalous trichromats - Part II: Modeling and Color Compensation. *EURASIP Journal on Image and Video Processing*, 246014.
6. Hurvich L M. Color Vision. (1981) Sunderland, MA: Sinauer Associates; 222–269.
7. Ayama, M., & Ikeda, M., (1998) Brightness-to-luminance ratio of colored light in the entire chromaticity diagram. *Color Research & Application*, 23(5), 274-287.