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KANSEI EVALUATION OF THE RED OBJECT IMAGES USING DIFFERENT RED PRIMARIES

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Abstract

To investigate the best color gamut for color reproduction including reddish objects from KANSEI evaluation point of view, subjective evaluation experiment using five adjective pairs was conducted in the conditions of wide gamuts with four different red primaries from 610nm to 640nm. Two sets of 15 color images that were made for sRGB, were used as test stimuli of Group 1 and Group 2. Seven images selected from the ITE Ultra-high definition/wide-color-gamut (UHD/WCG) standard test images were employed as test stimuli of Group 3. The red primaries of 630nm and 640nm provides deep color and impressive feeling, but the most unnatural. Gender difference was observed in the evaluations of beautifulness and likability in the Group 3, suggesting that deep red is not necessarily preferred by female observers.

Keywords: KANSEI evaluation, Natural color image, Color gamut, red primary

1 Introduction

In display quality comparison, gamut area has been employed as one of the important specifications. It is true that the wider the color gamut is, the higher the color reproduction capability [1]. However, what has been required by ordinary observers the most for color reproduction of display or projector, is not a color fidelity but a color reproduction with comfortableness, preference, or impressiveness. These are called KANSEI properties, and their quantitative evaluation is gathering attention in various fields to put additional values to new products [2].

KANSEI is a Japanese word meaning a mental sense of subjectivity, being a higher order function of the human brain. KANSEI properties are usually measured by subjective evaluation experiment using adjective words such as "preferable", "comfortable", and/or "impressive", etc.. Technology to widen color-gamut has progressed immensely in these 10 years, and resulted super-wide color gamut displays in everyday life. Display of mobile phone has DCI-P3 gamut that is 25% larger than sRGB area. However, color images in a laser display or high quality display are sometimes encountered with criticism of that the color is too strong or unnatural. In the history of image technology, sRGB compliant display has been lasted relatively long time, and observers might adapt to color reproduction in a sRGB display. Furthermore, very recent study showed that reddish colors in a laser display appeared less saturated than those in a LCD [3]. Reason is unknown at the present. Despite these problems, only a few have been reported on KANSEI evaluation of color images presented in different color gamut wider than the sRGB (BT. 709) [4-6].

We have conducted a series of experiments on KANSEI evaluation of color images presented on different gamuts [6-9]. In our first approach, we investigated the best blue primary from this point of view using 4 different blue primaries (430nm, 450nm, 470nm, and 480nm) [6]. As a total, 470nm was the best, while 450nm showed the same level of performance. Our results simply showed that when color appearance of pixels in the sky and/or sea area in natural images is closer to unique blue, the higher rating scores in KANSEI evaluation are obtained. In our second study to investigate the best green primary, natural images were displayed in four different color gamuts using 4 green primaries (520nm, 530nm, 540nm, and 550nm) [7]. In this case, it was difficult to conclude specific wavelength as the best green primary among them.

Finally we tried to explore the effect of red primary on KANSEI evaluation of natural images. Different tendency was found in different adjective pairs for both sRGB images [8] and wide color gamut images [9]. However, in these studies, relation between the results of subjective

evaluation and the colorimetrically measured gamut-area was not clarified. Aim of this study is to compare the gamut expansion in the long-wavelength region in a color space with KANSEI evaluations of natural color images.

2 Experiments

Two sets of 15 color images that were made for sRGB, were used as test stimuli of Group 1 and Group 2. In addition to them, 7 images selected from the ITE Ultra-high definition/widecolor-gamut (UHD/WCG) standard test images [10] were employed as the test stimuli of Group 3. Test images labelled "red-blue" in Group 1 and 2, and "flowers" in Group 3 are indicated in Figure 1.

Two projectors (P1 and P2) were used to present test images. P1 is for the green and blue primaries of sRGB, and another one is for variable red primaries. For P2, interference filter (IF) of λ_p = 610nm, 620nm, 630nm, and 640nm were inserted in front of the projector to achieve different red primaries. White point was set nearly the same by inserting appropriate ND filters in front of the two projectors. Two PCs were used to send G&B signals to P1, and R signals to P2, respectively. They were controlled synchronously to present test images. Images from P1 and P2 were very carefully superimposed on the screen. Color gamuts in the CIE 1976 u'v' chromaticity diagram are shown in Figure 2.

Five adjective pairs, "Deep color vs Pale color", "Beautiful vs Dirty", "Like vs Dislike", "Impressive vs Mundane", and "Natural vs Unnatural", were selected based on previous studies [6, 11,12]. Observers were asked to evaluate each test image for each adjective pair by marking proper position on seven point scale (-3 to 3) between the bipolar. Observers were 10 males and 10 females in their 20's with normal color vision.



Figure 1 – Test stimuli of "red-blue" in Group 1 and Group 2, and "flowers" in Group 3

Figure 2 – Color gamuts in this study

3 Results

Significant difference of rating score was found in the test images including reddish objects. As representative results, rating scores of 5 adjective pairs for the test stimuli shown in Figure 1 are indicated in Figure 3. Rating scores of "Deep color vs Pale color" and "Impressive vs Mundane" shown in (a) and (d), respectively, increase with the wavelength of the red primary in all test stimuli. The longer wavelength primaries, 630nm and 640nm, indicate higher rating scores. ANOVA showed the effect of the wavelength of primary is significant with the significance level of 1 %. As shown in Figure 3 (b) and (c), results of "Beautiful vs Dirty" and "Like vs Dislike" in Group1 and Group2 images show the tendency that the longer the wavelength of red primary, the lower the rating score, although the effect was not statistically significant. It is not clear in the Group3 image. In the results of "Natural vs Unnatural", the rating score decreases in the longer the wavelength primaries, contrary to the results of "Deep color vs Pale color" and "Impressive vs Mundane". Effect of the wavelength of primary is significant with the significance level of 1 % for all test stimuli.



Figure 3 – Results of five adjective pairs of KANSEI evaluations. Single and double asterisk indicate significance level of 5 % and 1%, respecticely.

We examined the gender difference in rating scores for 5 adjective pairs. Results of male and female observers are separately shown in Figure 4 for the adjective pairs of "Beautiful vs Dirty" and "Like vs Dislike", where two-way analysis of variance showed significant difference between male and female observers in Group3. Rating scores of female observers are lower than those of males, indicating that female observers do not feel highly saturated flowers beautiful, and consequently they do not like them. No difference was found in the results of Group 1 and Group 2 for both adjective pairs. However, it is interesting that the male results clearly and consistently show the tendency that the longer the wavelength of red primary, the lower the rating score. On the other hand, such a tendency is not consistently shown in female results. In the results of other adjective pairs, no difference was observed between male and female observers. Bars



denote standard errors among observers, and no systematic difference was found between two groups.

Figure 4 – Comparison of rating scores of "Beautiful-Dirty" and "Like-Dislike" evaluations between male and female observers.

4 Colorimetry

Luminance and chromaticity coordinates of the test images on the screen were measured using 2D colorimeter (Konica Minolta CA-2500). Several points including red primary were measured using spectroradiometer (Konica Minolta CS-2000). Some discrepancy was found between the results obtained by the 2 devices. Generally speaking, colorimetric data obtained using spectroradiometer gives more precise than a filter-based colorimeter, however, measuring all RGB combinations, i.e., over 16 million colors is unrealistic. Therefor, we choose 1294 test colors nearly equally sampled in the $L^*a^*b^*$ space, and measured their luminance and chromaticity coordinates using the spectroradiometer for each of 4 red primary conditions. Results of 610 nm and 640 nm red primary conditions are indicated in Figure 5. Figure (a) and (b) are the measured points in the $L^*a^*b^*$ space, (c) and (d) are those in the a^*-b^* plane with medium $L^*(55=< L^* < 65)$. Chromaticities in (d) in the positive a^* region apparently shift toward

larger a* values compared with those in (c). Size of area in the a^*-b^* plane within a certain range of L^* (ΔL^* is about 10) were calculated for each of 4 primary conditions, and compared. Figure 5 (e) shows the area-size comparison on the a^*-b^* plane with 55=< L^* < 65. Vertical axis is the relative value to the area size of 640nm primary condition. Difference in the area size in the $L^*a^*b^*$ space is not large, but expansion in the positive a^* region, especially in the region $a^* > 80$ seems to contribute to significant difference in the KANSEI evaluations examined in this study.





5 Conclusion

To investigate the best color gamut for color reproduction including reddish objects from KANSEI evaluation point of view, subjective evaluation experiment using five adjective pairs was conducted in the conditions of wide gamuts with four different red primaries from 610nm to 640nm. The red primary of 630nm and 640nm provides deep color and impressive feeling, but less natural. On the other hand, the red primary of 610nm, which is the closest to the DCI-P3 primary, gives neither a deep red appearance nor impressive, but it appears more natural for most observers. No systematic trends were found in the evaluation of "Beautiful vs Dirty" and "Like vs Dislike", while gender difference was significant in the results of these adjective pairs. This suggests that female observers' evaluation of beautifulness or likability to reddish objects is more complicated than that of male observers.

Gamuts in the $L^*a^*b^*$ space were derived based on colorimetry of a number of colors on the screen with 4 red primary conditions. Volume difference among 4 conditions is within a several percent. This implies that difference of gamut size in a color space is not a primary factor for the difference in subjective evaluations. But small expansion in positive a^* region in the $L^*a^*b^*$ space might bring relatively large difference in color appearance. More precise relation between color distribution in different color gamuts and the change of color appearance should be investigated.

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