

ORIGINAL ARTICLE

Ranges of Animation Skin Color

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Abstract: Skin color has been studied for color rendering since 1950s. The studies contained skin color of photographs and real skin. However, virtual skin color also became important with developing display recently. In this study, animation skin color was dealt with the main theme, although it has never been treated as a subject before. Two-dimensional animation face images, the farthest from real face, were used as stimuli. In experiments, tolerantly-accepted, preferred, more preferred, and the most preferred skin color were investigated by the cascade selection method. In results, the data points of 50% subjects' consistency fitted ellipses for animation skin color. Moreover, representations of skin color appeared different lightness according facial shapes. In addition, preferred skin colors of animation facial images appeared different in properties from real skin colors, portraits and photographic images. Therefore, skin color representation changes depending on the degree of realism with illuminants and shadows.

Keywords: *Animation, Color tolerance, Preferred color*

1. INTRODUCTION

Skin color is one of the most important colors in natural objects, since it contains a variety of information such as beauty, gender, ages, and health. Skin color reproduction has been studied, mainly based on real human skin color. Since 1950s, MacAdam (1954) indicated that acceptable skin color range was limited for high-quality of color reproduction for film prints. Comparing the distribution of real skin colors with that of painted portraits and photographs from Hollywood film, he mentioned that the sense of realism was related to quality of skin color reproduction [1]. His study was the first try to research preferred skin color in non-real pictures. Bartleson (1959) investigated preferred skin color for photograph [2]. It was reported that preferred skin colors were more similar to memory skin colors than real skin colors. Furthermore, Bartleson (1960) found that only skin colors, significantly different from other familiar objects, were affected by memory colors [3]. He insisted necessity of distinction between memory-color and color-memory for skin color in photograph. Color-memory is simple estimation for color information while memory-color is connected with complex object memory. In the results, memory-color appeared large shifts in hue compared with color-memory. Bartleson and Bray (1962) reached a conclusion that the reproduced skin color based on memory color was more preferred than real skin color [4]. Hunt (2004) categorized six kinds of color reproduction. Among the categories, preferred color reproduction could

be called as pseudo color, which differed from real color. One of typical example of preferred color reproduction was skin color; having the unique trait that memory skin color was preferred than real skin color [5, 6].

Yendrikhovskij et al. (1998) studied perceived naturalness of color images using reproduced object colors in scenes [7]. They showed that the naturalness judgments of skin and those of the whole picture are highly correlated. It meant that one of the most critical object, skin, determined naturalness of a whole reproduction. Therefore, they suggested that adjusting skin color partially enhanced the whole color reproduction. Bodrogi and Tarzali (2001) studied memory skin color shift in realistic photo [8]. They found that memory skin color of photo images shifted explicit than that of skin color patches. Moreover, memory skin color of photo images appeared containing more unique yellow and more saturated than original skin colors. In skin color memory shifts, inter-observer variability of saturation was smaller than that of hue.

In previous studies, skin color ranges were defined for color reproduction. Sanders (1959) did experiments using natural objects under different lamp types for color rendering. He indicated that range of preferred skin color was smaller than that of other objects [9]. Zeng and Luo (2011) made the elliptical skin color modeling of digital photographic images [10]. For enhancing skin color reproduction of photographic images, they designated the range of preferred skin color using the elliptical skin color model [11]. They indicated that hue tolerance was much tighter than chroma tolerance in preferred skin color.

Nevertheless, they did not mention about lightness. Yoshikawa et al. (2012) mentioned the effect of lightness perception along with the redness-yellowness and chroma of skin color [13, 14]. Preferred skin color was studied for color reproduction on the display [15, 16].

Because a variety of media and display was recently developed, it is necessary to study animation face skin colors as well as real human skin colors. Nishimura and Ota (1974) examined preferred skin color by facial images of TV, making a comparison between real face images and Japanese cartoon facial image on TV [17]. In the results, the preferred skin color range of cartoon was wider than that of real face images. However, there is no study for preferred skin color in pictures or cartoon images, except for MacAdam's and Nishimura et al's studies. The previous studies used non-real skin colors as only comparison target for real skin color reproduction. Accordingly, animation skin color has not been treated as the main theme of a study before. Thus, we focused on skin color features of animation as the subject of this study.

In this study, we studied the tolerantly-accepted range of skin colors, and the range of preferred colors in animation facial image of non-realism rendered images. The non-realism images are illustrated using simple line and colored flat without gradient.

In previous studies, subjective evaluation of skin color was carried out by a paired comparison method [11, 12], the systematic arrangement method [17, 18], and method of adjustment [13, 14]. In this study, estimation of skin color for animation film was established by the method of cascade.

2. METHODS




2.1 Apparatus

The stimuli were presented on a color LCD monitor (Coloredge CG245 24.1"; Eizo Corp.) with a PC (GIGA-BYTE Phantus P27G V2 I7). The monitor RGB phosphors were of 8-bit color, and were calibrated using a PhotoResearch PR650. The monitor white was adjusted to a D65 white. The display resolution was 1920 × 1200 pixels.

2.2 Stimuli

We collected a total of 580 skin colors of characters in animation still images of nineteen animation films. These still images were produced by Japanese Ghibli studio™ and American Walt Disney pictures™ between 1937 and 2011. These skin colors were collected under four conditions (light inside, dark inside, light outside, and dark outside) from various images. These 580 skin colors

Table 1: Evaluating gender and ages of facial shapes. Magnitude estimation: (1) Male - (3) Neuter - (5) Female

	Face 1	Face 2	Face 3
Shape			
Gender	Female (3.61)	Male (1.04)	Male (2.58)
Age	16	28	63

of animations are plotted in the a^*-b^* and a^*-L^* planes in Figs. 1 to 3 as blue small dots.

The 580 skin colors were applied to three facial shapes (Table 1) without any shading. In order to focus on facial images, we used only face shapes with same hairstyle in this experiment. In the preliminary experiment, 26 subjects evaluated gender and age of the facial shapes using magnitude estimation. For evaluating gender of facial shape, five-scale magnitude estimation was used (1: male, 3: neutral, 5: female). Means of estimations for age and gender of facial shapes are shown in Table 1. Face 1 was estimated as a 16-aged female, Face 2 as a 28-aged male, and Face 3 as a 63-aged male. Therefore, facial shapes, used in this experiment, were fairly well separated in gender and age.

2.3 Subjects

Twenty-six (fifteen males, eleven females) subjects participated in this experiment. Subjects included twenty Japanese, four Chinese, one Korean and one Mongolian. Twenty-four subjects were graduate students between 21 and 32 years of age. Two subjects were 36 year-old and 41 year-old non-students. Instructions for experiments were given in Japanese and English. Four subjects were experienced, and the others were naïve in this kind of psychophysical experiment. All subjects had normal color vision tested with Ishihara tests plates for color deficiency [19].

2.4 Procedures

The experiments were run in a darkroom. A chin rest was used to fix the subject's head. The viewing distance was 57 cm. Subjects adapted in dark for 1 min, and then to the gray background of the display for 1 min before the trial started. The background (x, y) chromaticity coordinates were (0.312, 0.330) and its luminance was 27.3 cd/m². In a trial, four fixation crosses, which were spaced 10° apart, appeared on the gray background. When a subject pressed a key, the 10° size of the test stimulus was presented for 500 ms. Then, subjects made

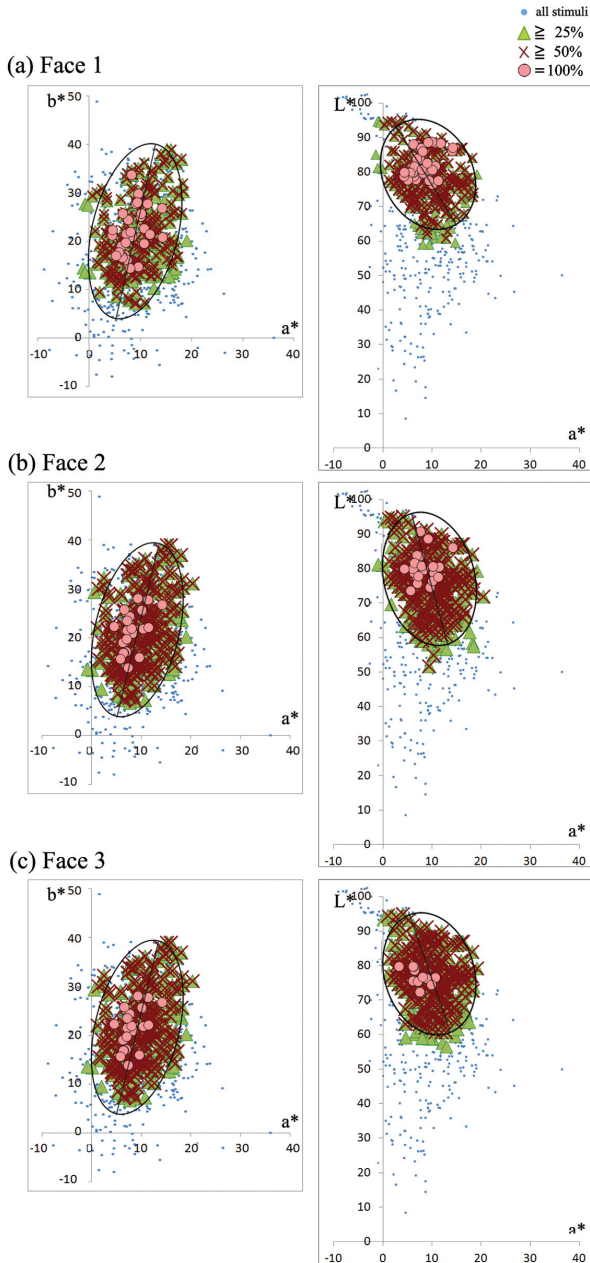


Figure 1: Tolerantly-accepted animation skin colors corresponding percentage selected by subjects.

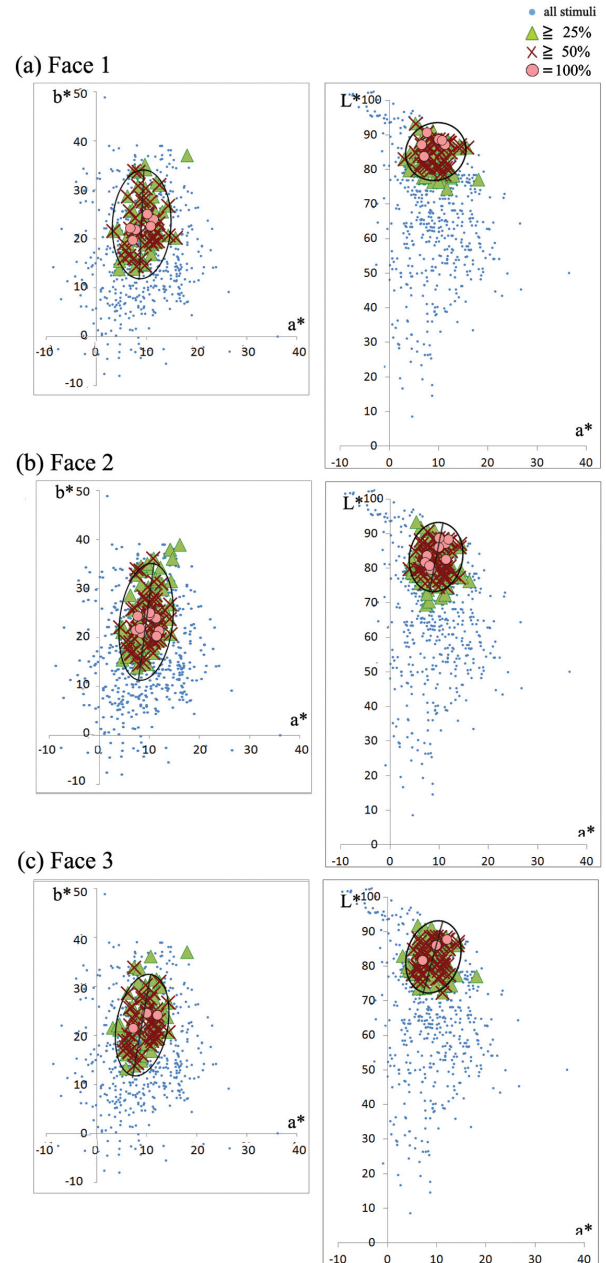


Figure 2: Preferred animation skin colors corresponding percentage selected by subjects.

responses by pushing a key. After subjects' response, the gray screen appeared again with four fixation points. All stimuli were presented in the same manner.

The experimental procedure consisted of four phases. We call this method the cascade selection method (Uchikawa, 1982 [20], 1998 [21]). In the first phase, the subjects' task was to judge whether a skin color of a stimulus was tolerantly acceptable. In this phase, all 580 skin colors were presented in a random order. In the second phase, only accepted skin colors selected in the first phase were used. The subjects' task was to judge whether skin color of a stimulus was preferred. Stimuli were presented in a random order. In the third phase, the

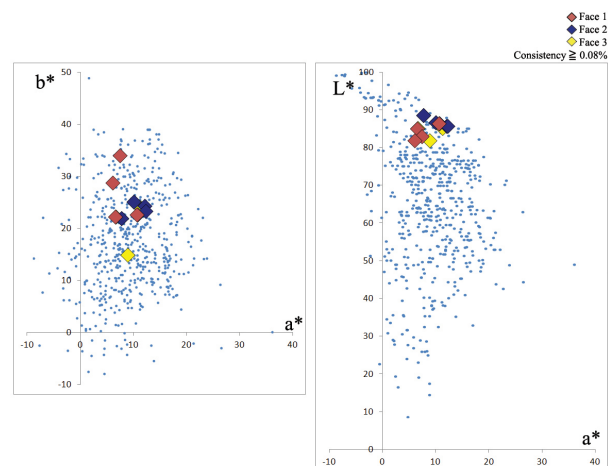


Figure 3: The most preferred animation skin color.

stimuli with preferred skin colors selected in the second phase were presented in a random order. Among the stimuli, subjects chose more preferred skin color. The purpose of this phase was to reduce the number of stimuli for the last phase by selecting the most preferred skin color. In the last phase, subjects had to choose only a stimulus from more preferred skin colors selected in the third phase with the best skin color. For confirming the best skin color, the stimuli were presented twice in the same order. Each phase had three facial shape sets.

3. RESULTS AND DISCUSSION

3.1 The Percentage of Subjects' Consistency

The percentages of subjects' consistency for tolerantly-accepted animation skin color were divided into 25%, 50%, and 100% among the 26 subjects' results. The points of tolerantly-accepted skin color, corresponding each percentage, were plotted in Figure 1. The ellipses were fitted in a 95% confidence ellipse to 50% consistency of subjects.

The percentages of subjects' consistency for preferred animation skin color from the second phase were divided into 25%, 50%, and 80% among the 26 subjects' results. We could not obtain the results with 88% to 100% consistency.

The points of preferred skin color, corresponding each percentage, were plotted in Figure 2. The ellipses were fitted in a 95% confidence ellipse to 50% consistency of subjects.

As shown in Figs. 1 and 2, the angle of the major axes tolerantly-accepted skin colors' ellipses and those of preferred skin colors' ellipses were similar in a^*-b^* coordinates. However, they were different in a^*-L^* coordinates. This means that tolerantly-accepted skin colors and preferred skin colors had been evaluated differently.

The most preferred skin color of animation face, selected with the highest 0.08% consistency of subjects, was plotted in Figure 3. The most preferred skin color appeared different slightly according to animation facial shapes.

3.2 Frequency distribution

Frequency distribution of results were analyzed to divide L^* , a^* and b^* with a 10 interval in CIELAB color space.

The frequency distribution of tolerantly-accepted, preferred, more preferred, and the most preferred skin color according to facial shapes showed in Figure 4. The peak of the frequency distribution were stable expect for L^* . It was shown that the peak of the frequency distribution in L^* changed in the most preferred skin



Figure 4: Frequency distribution of animation skin colors.

color. Therefore, bright skin colors were selected as the most preferred skin color, whereas chromaticness (a^* and b^*) was unchangeable from tolerantly-accepted, preferred, more preferred skin colors.

3.3 Cascade Selection Method

The cascade selection method was used as a new method for evaluating skin color in this study. Subjects selected tolerantly-accepted skin colors, preferred skin colors, more preferred skin colors and the most preferred skin color for animation facial images in successive phases. The results were plotted in Figure 5 by 50% consistency of subjects. Data from Faces 1, 2 and 3 are all combined. Blue dots represent 580 skin colors from animation films. Orange, dark red, red dots show tolerantly-accepted skin colors, preferred skin colors, more preferred skin colors, respectively. Among the dots they picked only a skin color as the most preferred skin color. The black dot was an average of twenty-six dots of the best skin colors. The contours of ellipses of tolerantly-accepted and preferred colors were drawn in Figure 5. Because width of a^* of ellipse was shorter than those of L^* and b^* , subjects' estimation for redness of skin color was strict.

Using the contours, ellipsoids were plotted in Figure 6. Two ellipsoids, selected by 50% of subjects consistently,

have different orientations of major axis.

Central points (L^* , a^* , b^*) of tolerantly-accepted skin colors' ellipsoids were face 1 = (76.13, 9.79, 21.48), face 2 = (76.23, 9.90, 21.48), and face 3 = (76.09, 9.85, 21.57), and those of preferred skin colors' ellipsoids were face 1 = (80.91, 9.41, 21.86), face 2 = (81.07, 9.27, 21.96), and face 3 = (80.88, 9.34, 21.86), respectively. The central points of preferred skin colors' ellipsoids had higher L^* than those of tolerantly-accepted ellipsoids.

Each color difference was calculated from the central point to scatted point, selected by subjects. There was

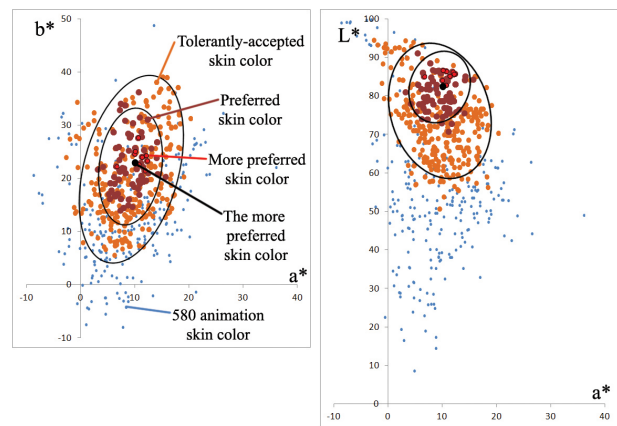


Figure 5: Ellipses of animation skin color by the cascade selection method.

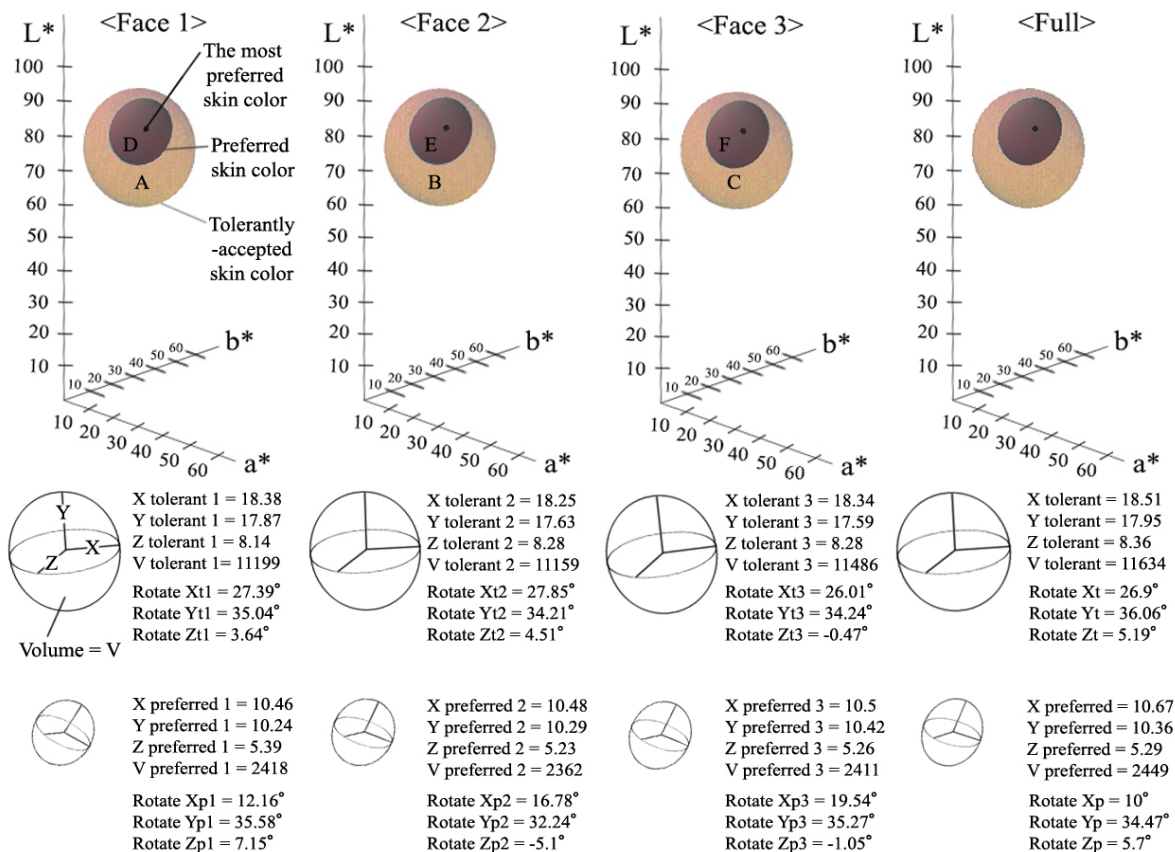


Figure 6: Ellipsoid of animation tolerantly- accepted and preferred skin colors (Length of axis, Volume, Rotation of ellipses).

no significant different (Tukey-Kramer, $p > .05$) between the color differences of tolerantly-accepted skin colors (A, B, C). Moreover, the color differences of preferred skin colors (D, E, F) appeared no significant difference (Tukey-Kramer, $p > .05$). Semi-minor axis (X), semi-major axis (Y), Volumes (V) of tolerantly-accepted ellipsoids, and those of preferred ellipsoids were represented in Figure 6, respectively. Therefore, central points were slightly different, but shapes of ellipsoids according to facial shapes had similar. Consequently, the cascade selection method visualized animation skin color range clearly.

Figure 7 shows the ellipses for three facial shapes. The dots of Figure 7 were selected by 50% of subjects. The ellipses, covering 95% of results, were fitted to the data points. Because the most preferred skin color of animation face had small ranges, the most preferred skin color was averaged for facial shape. The most preferred skin color of Face 1, which looks younger and female, was focused to be brighter than the others.

In Figure 8, it is shown that the three ellipses of tolerantly-accepted animation skin colors were almost overlapped in a^* - b^* coordinates. However, each of ellipses according to facial shapes appeared somewhat dissimilar in a^* - L^* coordinates. There was no significant difference among the tolerantly-accepted skin colors of three facial shapes in a^* and b^* values (Tukey-Kramer, $p > .05$), while L^* values of the results appeared significant difference between Face 1 and 3 (Tukey-Kramer, $p < .05$). In case of preferred skin colors, there was no significant difference (Tukey-Kramer, $p > .05$) in a^* - b^* and a^* - L^* coordinates. Therefore, estimations of animation skin colors had constant hue values according to facial shapes.

3.4 Comparison of Skin Color Boundary between Real Skin and Animation

In order to compare the present results with the range of real skin color, 123 women's skin colors (Shiseido Corp.) from the standard object color spectra database (SOCS) were converted in CIELAB color space. The skin colors were measured from Japanese women's foreheads and cheeks. Both of database's white points were adapted to D65. The real color database, tolerant range of animation skin colors, and animation preferred skin color were plotted in Figure 9.

The range of animation tolerantly-accepted skin colors was wider than that of real skin color. The real skin color range was subset of animation tolerantly-accepted skin color. Based on the range of real skin colors, the ranges of preferred skin colors and tolerantly-accepted skin colors

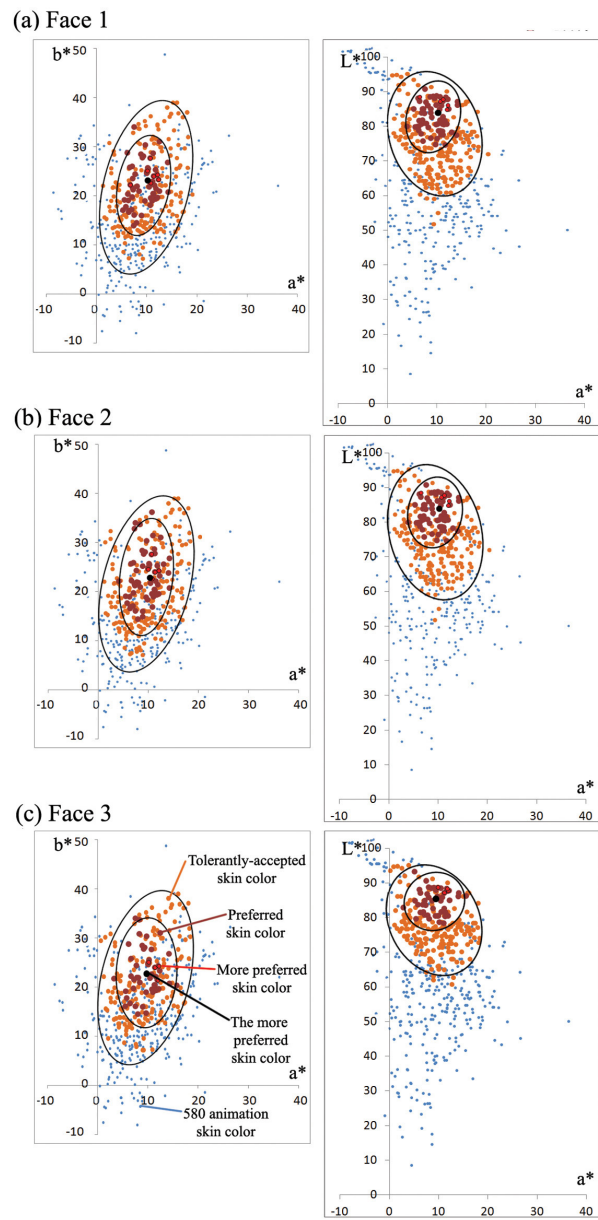


Figure 7: Ellipses of animation skin color according to three facial shapes by the cascade selection method.

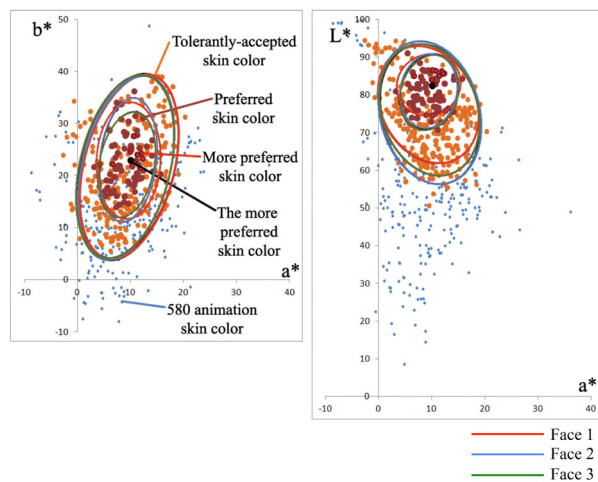


Figure 8: Ellipses' differences of tolerantly-accepted and preferred skin colors according to three facial shapes.

Ranges of Animation Skin Color

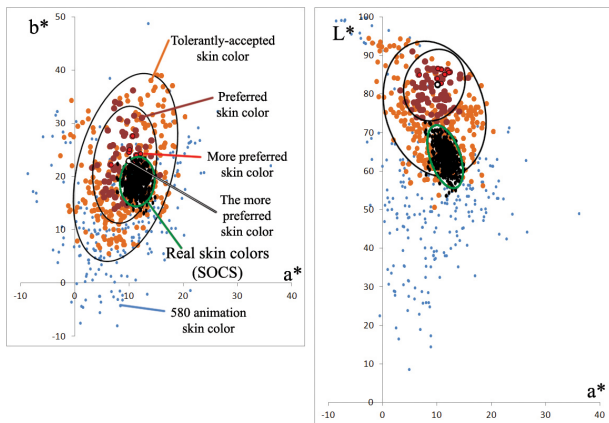


Figure 9: The comparison of range between real skin color (SOCS) and animation skin color.

spread out like a cascade in a^* - b^* coordinates. Animation tolerantly-accepted skin colors were much lighter than real skin colors. Moreover, the range of animation preferred skin colors was not overlapped in L^* - a^* coordinates, because bright skin colors were preferred.

3.5 Comparing Previous Studies of Portrait's Preferred Skin Color

Figure 10 shows the previous studies of portraits' preferred skin colors compared with our results.

Figure 10 (a) shows three races of preferred skin colors. Aoki et al. [22] reported preferred skin color using test images of three races (ISO 20462-2: Caucasian, Mongoloid, Negroid). These results (90% probability ellipses) were different from our animation skin colors' results. A part of animation skin colors' ellipse overlapped with three races' results. Moreover, the angles and ranges of three ellipses differed from those of animation's ellipse.

Figure 10 (b) shows East Asian preferred skin colors using portraits. Yamamoto et al. [18] investigated the influence of cross-cultural effects, surveying the preferred skin color in South Korea, Japan, and China. A woman's portrait (ISO/JIS Standard Color Image Data) was used

for evaluation by the systematic arrangement method. The contours approximate the locus of the 50 percent acceptance rates. Although East-Asian countries' preferred skin colors were similar, those ranges of contours were quite dissimilar to those of animation skin colors.

Figure 10 (c) shows preferred skin colors of men's portraits. Pei et al. [23] researched preferred skin color using three Chinese men's portraits to Japanese and Chinese. The preferred skin color of men's portraits was differed from animation preferred skin color and preferred skin color of women's portraits.

In Fig. 10 (d), preferred skin colors of photographic images made a comparison with preferred animation skin colors. Zeng and Luo [11] made a study for preferred skin color using photographic images, including Caucasian, Oriental and Africans, by a paired comparison method. Their stimuli of photographic images contained a variety of races under a variety of lighting condition, while our experiment was targeted 2D animation characters, dominated Japanese subjects' estimations. In a comparison, animation preferred skin colors were subsets of their results of photographic images. In the range of photographic images, animation preferred skin colors are located in lower saturation part. The lower saturation could be important property of animation preferred skin color.

It was shown that preferred skin colors of portraits differed from those of animation facial images. Because our stimuli had no shadow, it was lack of information for lighting condition. On the other hand, portraits contained shadow, portraits under the same lighting condition were used in Fig. 9 (a), (b) and (c), while photographic images under a variety of lighting conditions collected for experiment in Fig. 9 (d). As a result, the ranges of Fig. 10 (a), (b) and (c) appeared more saturated than those of animation, and the range of Fig. 10 (d) was wider than others. It could be considered that skin colors have different properties according to realism with illuminants and shadows.

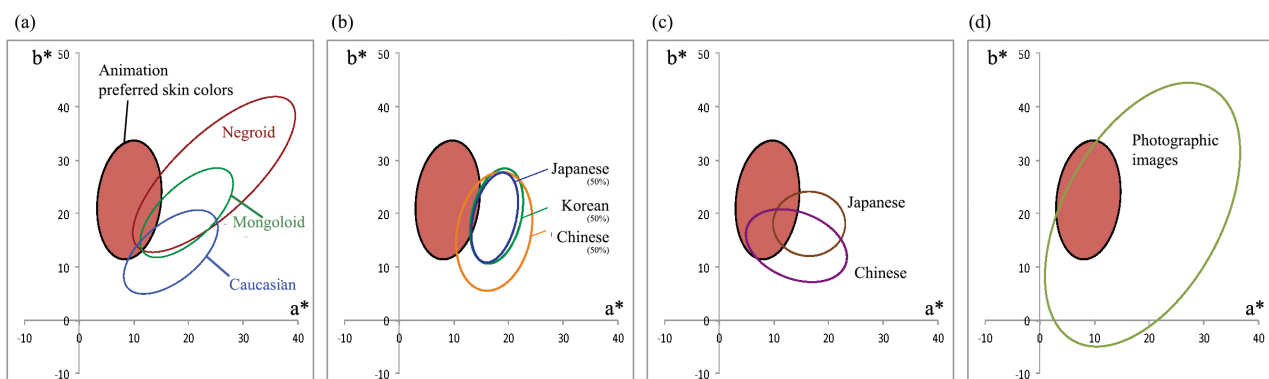


Figure 10: Comparing previous studies of preferred skin color in CIELAB color space.

4. CONCLUSION

In this study, we investigated tolerantly-accepted skin color and preferred skin color of animation using 580 skin colors from animation films as stimulus colors. The method of cascade was useful for evaluating skin color because it clarified skin color ranges visually. Han and Uchikawa's report, preferred skin color changed according to facial shapes in animation [24-26], supported the results. Only L^* values of the results appeared significantly different between animation facial shape in tolerantly-accepted skin colors (Tukey-Kramer, $p < .05$). According animation facial shapes, representations of skin color appeared different lightness.

Based on the peak of frequency distribution, animation skin colors were selected as constant hue values (a^* and b^*) for all facial shapes. In addition, the animation skin color had also stable values (L^*), except for the peak of the most preferred skin color.

Animation tolerantly-accepted range of skin color was more lighter than real skin color (SOCS). In the other studies, two-dimensional faces in animation presented bright skin colors as preferred skin color rather than real skin colors. [27-31] Then, our results of animation skin color were compared to previous studies of portraits' preferred skin colors in CIE LAB color space. Some parts of the portraits' preferred skin colors, contained three races and three East Asian, were overlapped with our range of animation skin. Studies of portraits under the same lighting condition appeared more saturated preferred skin colors than those of animation with no shadow. Moreover, photographic images under a variety of lighting conditions represented wider range of preferred skin color than other studies. It could be considered that skin colors have different properties according to realism with illuminants and shadows.

Therefore, preferred skin colors of animation facial images, one of the non-realism images, appeared different in properties from real skin colors, portraits and photographic images. Skin color representation changes depending on the degree of realism with illuminants and shadows.

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