Preferred Skin Colours of Africans, Caucasians, and Orientals

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Abstract

The human skin tones are important colours in the colour reproduction of digital photographic images. They are memory colours for which people have distinct preference regardless of how they appear in real life. For preferred colour reproduction, the skin tones should be reproduced according to subject's preferences. The skin colour preferences of different ethnic skin tones judged by observer groups with mixed ethnic backgrounds have been studied in the past. However, they did not answer all questions about skin colour preferences of individual-culture backgrounds and skin colour preferences of cross-culture backgrounds. This study is to investigate the skin colour preference of individual-ethnic backgrounds and the skin colour preference of cross-culture backgrounds. The result is to be used for optimising skin colour reproduction of colour imaging products for different geographical regions

1. Introduction

Skin colour preference has been an active research subject in preferred memory colour reproduction [1]. Bartleson [2, 3], Bartleson and Bray [4], Sanders [5], and Hunt et al. [6] studied the skin colour preference of Caucasian. Although their conclusions are not exactly the same, they agree that memory skin colours are different from real skin colours, and preferred skin colours are not the same as memory skin colours and are further away from real skin colours. Sanger et al. [7] studied Mongoloid, Caucasoid, and African skin colours, and found that the colour preferences among these three groups were different. Yano and Hashimoto [8] studied the preferences of Japanese and Caucasian skin colours and concluded that the preferences between these two ethnic groups were different. Park et al [9] applied different preferred skin colours for the preferred skin colour reproduction of Caucasian, East Asian, African, and mixed skin tons. Kuang et al. [10] studied preferred skin colours on Caucasian, Asian, Indian, and African, and concluded that their preferences were different but the differences were not significant among different culture backgrounds. Fernandes et al [11] studied the influence of observer culture background, intra-observer variability, inter-observer variability, and image content variability on the preferred colour reproduction of pictorial images, and concluded that variability in preference due to image content and differences among observers were visually more significant than the variability due to culture background. Topfer et al. [12] studied the regional preference among US, China, and India for the rendition of people. The experimental result demonstrates that preferences for the rendition of Caucasian and Asian skin tones differ substantially; more reddish and desaturated renditions of skin colour were preferred in India and China; the preferred skin colours for India and China overlap, which suggests that similar appearances of skin tones are preferred in both countries, however, Indian skin tones show a wider variety in lightness than Chinese skin tones, and are on average somewhat darker; the orientation of the preferred skin colour ellipses changes by region; for Caucasian skin tones, hue is the most important attribute; wider variations in hue were tolerated in China; and individual preferences for the rendition of skin colour showed much less variation in China than in India and the US.

It has been reported that preferred skin colours are different from actual skin colours; preferred skin colours are within a smaller region of skin colours; preferred skin colours were not largely different among observers having different culture backgrounds by some researchers, while they were considered substantially differently for preferred memory colour reproduction to some other research. In order to have a better understanding of skin colour preference of digital photographic images, skin colour preferences for different ethnic skin tones judged by mixed ethnic groups have been studied by the authors [1]. However, it did not answer questions about skin colour preferences of individual-culture backgrounds (colour preference of skin tones of a single ethnic background judged by observers with the same culture background) and skin colour preferences of cross-culture backgrounds (colour preference of skin tones of an ethnic type judged by observers with another culture background). This study is to investigate the skin colour preference of individual-culture backgrounds and the skin colour preference of cross-culture backgrounds.

In the next section, psychophysical experiments to study skin colour preferences of Africans, Caucasians, and Orientals are presented; the third section is the discussion of experimental results; and the last section is the conclusion remark.

2. Experimental

Images were displayed on LCD monitors under dim surround condition in the previous studies. In this study, an HP P1100 21-inch CRT monitor was used to display images in a completely dark room. An African image, a Caucasian image, and an Oriental image were chosen for judgment (see Fig. 1). 18 Caucasians (British dominated), 16 Africans from Africa and England, and 21 Oriental observers (19 Chinese and 2 Korean) between 19 and 45 years old participated the experiment, and they all passed through Ishihara's Tests for Colour-Blindness.

***Fig. 1** Images for testing*

Skin colours of each image were detected using an elliptical skin colour model [13] and detected skin colours were morphed toward nine pre-determined skin colour centres to produce nine versions of images in which skin colours are different and other colours are the same. Fig. 2 is a block diagram for skin colour adjustment [14]. Mahalanobis distance of a colour (L*, a*, b*) to the elliptical centre, Φ(L, a, b), is computed. A colour to be a skin colour or a non-skin colour is determined by a threshold, ρ. If $\Phi > \rho$, the colour is not a skin colour and no colour adjustment is done for the pixel. Otherwise, the colour is a skin colour, and a weight, w, to adjust the skin colour is computed based on the Mahalanobis distance. The weight is applied to adjust a*b*.

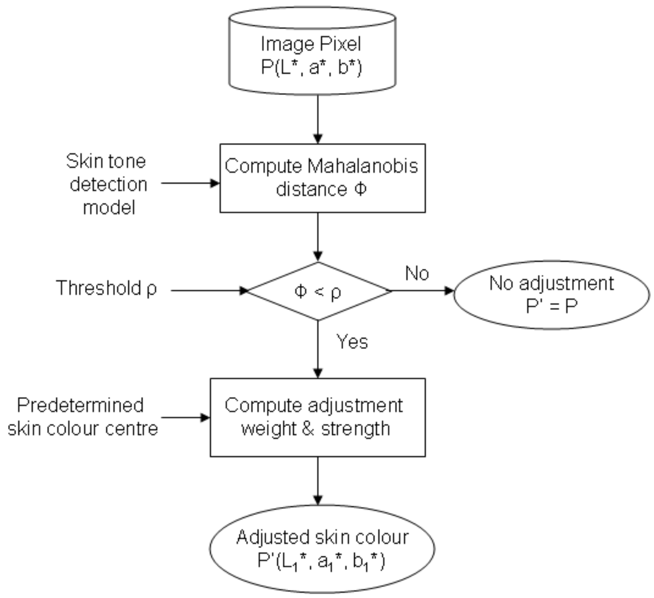

***Fig. 2** A Block diagram for skin colour adjustment*

A skin mask was created from each original image to determine skin colours that were used to compute a mean skin colour to represent the skin colour of a test image. Fig. 3 shows a skin mask of the African image. White pixels are non-skin colours and others are skin colours. The mask is binarized and a mean skin colour of each version of images is computed by averaging colours of skin pixels. Fig. 4 shows the mean skin colours of nine versions of images processed from every test image. A successful design is to have each set of nine mean skin colours distributed around observers' preferred skin colour centres. A simple approach to meet this requirement is to have these nine images distribute around a large skin colour region. However, since a final preferred skin colour centre is to be interpolated from all or some of these nine colours using Z-scores or frequencies as weights, the accuracy from interpolation will degrade if these nine colours spread around a large region. Therefore, the best design is to have these nine skin colour centres spread around a region just enough to cover observers' preferred skin colours. However, since preferred skin colours were not known yet, parameters to determine how to spread these nine skin colour centres were guessed based on the knowledge from prior experiments.

The parried-comparison method was chosen for the experiment to determine a preferred skin colour centre. A preferred skin colour centre of a test image can be computed from each image using the a*b* of nine colour centres and their corresponding z-scores as weights:

$$a^* = \frac{\sum_{i=0}^{8} a_i^* \cdot Z_i}{\sum_{i=0}^{8} Z_i},$$

$$b^* = \frac{\sum_{i=0}^{8} b_i^* \cdot Z_i}{\sum_{i=0}^{8} Z_i}$$

where (a^*_i, b^*_i) and Z_i are the a*b* and the Z-score of the i-th version of an image, respectively.

***Fig. 3** Skin mask of a test image*

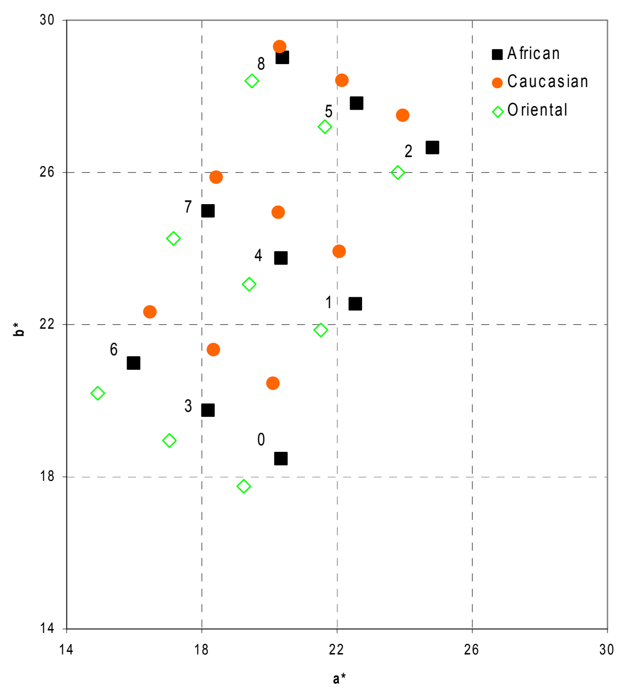

***Fig. 4** Mean skin colours of nine versions of images from each of three original images*

The total number of judgements on each image by an observer is 9x8/2 = 36. As a pair of images was displayed on the display each time, the remaining area of the display was filled with uniform medium gray. Each observer was instructed to sit at a distance that was most comfortable for viewing, followed by the presentation of an image pair on display at a time, and was asked to indicate which rendition of the two was preferred for skin colours. After the response was recorded, the next image pair was loaded and the observer proceeds until all samples were evaluated. All 36 pair combinations of the nine treatments were presented to each observer via a script that randomized the order and the placement (left/right) of the treatments.

3. Skin Colour Preference of Each Culture Background

The Z-scores of the African image judged by Africans, the Caucasian image judged by Caucasian, and the Oriental image judged by Oriental are shown in Fig. 5. The 95% confidence error bar is shown as well.

The maximum Z-score in the African image judged by African is in #4 which is not on the boundary (see Fig. 6 to visualise relative locations of these nine skin colours). This means that these nine skin colour centres encompass a preferred skin colour, i.e., the range of skin colour sampling is large enough for observers to choose their preferences. Similar result was found in the Caucasian image judged by Caucasian observers (see Fig. 7).

The peak Z-score among Z-scores of the Oriental image judged by Oriental observers is at #3, which is on the low chroma boundary of the nine sampled mean skin colours (see Fig. 8). Although the peak value is close to that of the centre point #4, it is possible that a more pleasant colour centre is slightly out of range, toward a less chromatic direction.

The blue ellipse in Fig. 9 is the overall preferred skin colour ellipse from all three ethnic groups. Although it distributes around a large chroma area, it occupies a smaller hue range. The location and orientation of preferred skin colour ellipses confirm that the distributions of preferred skin colours are more consistent in hue than in chroma.

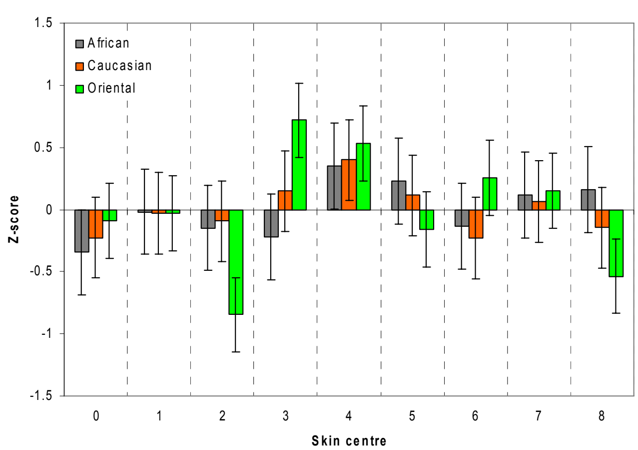

__Fig. 5__ Z-scores of the African, Caucasian, and Oriental images judged by African, Caucasian, and Oriental observers, respectively

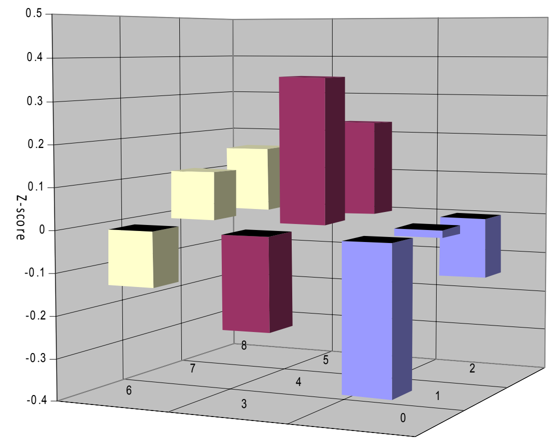

__Fig. 6__ Z-scores on nine skin colour centres in the African image judged by African observers

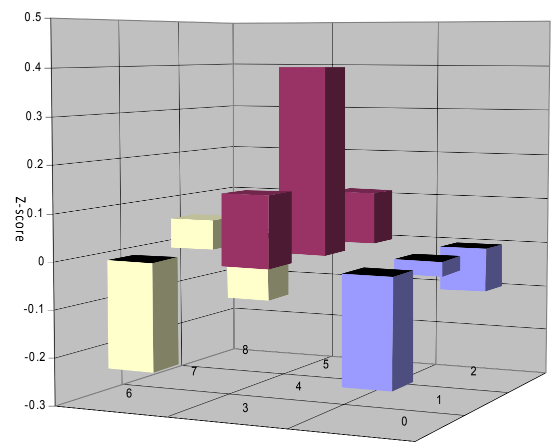

__Fig. 7__ Z-scores on nine skin colour centres in the Caucasian image judged by Caucasian observers

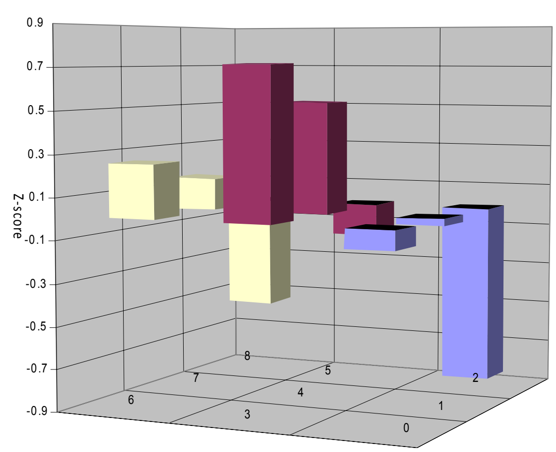

__Fig. 8__ Z-scores on nine skin colour centres in the Oriental image judged by Oriental observers

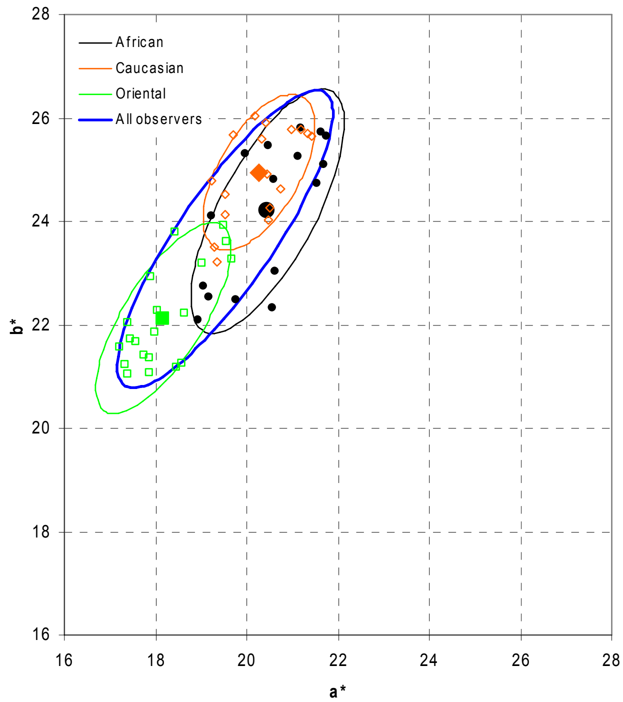

Fig. 9 Preferred skin colours of African, Caucasian, and Oriental judged by African, Caucasian, and Oriental observers, respectively

4. Cross-Culture Skin Colour Preference

Z-scores from the African image judged by Africans, Caucasians, and Orientals separately are drawn in Fig. 10. Note a*-b* coordinates of the skin centres are the mean skin colours of the nine versions of the image shown in Fig. 3. Skin centres #0, #3, and #6 are in the low chroma side; #2, #5, and #8 are in the high chroma side; and #1, #4, and #7 are in the middle. Z-scores from Orientals are lower in #2, #5, and #8, which means that Orientals prefer less chromatic African skin colours than Africans and Caucasians. Caucasians prefer #2, #5, and #8 more than Africans and Orientals, which means Caucasians prefer more chromatic African skin colours than Africans and Orientals.

Z-scores from the Caucasian image judged by Africans, Caucasians, and Orientals separately are drawn in Fig. 11. Z-scores from Africans are lower in #0, #3, and #6, and are higher in #2, #5, and #8. Oppositely, Z-scores from Orientals are in overall higher in #0, #3, and #6, and lower in #2, #5, and #8. The results suggest that the chroma preference on Caucasian skin colours from highest to lowest is Africans, Caucasians, and Orientals.

Z-scores from the judgments on the Oriental image by Africans, Caucasians, and Orientals are plotted in Fig. 12. In general, Z-scores from Africans are lower in #0, #3, and #6, and are higher in #2, #5, and #8 than Z-scores from Orientals. Oppositely, Z-scores from Orientals are lower in #2, #5, and #8 than Z-scores from Africans and Caucasians. The results suggest that the order of chroma preference on Oriental skin colours from high chroma to low chroma is Africans, Caucasians, and Orientals.

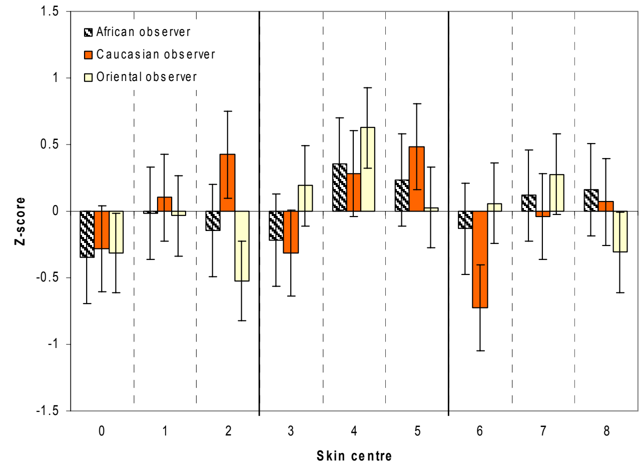

Fig. 10 Z-scores of the African image judged by three ethnic groups

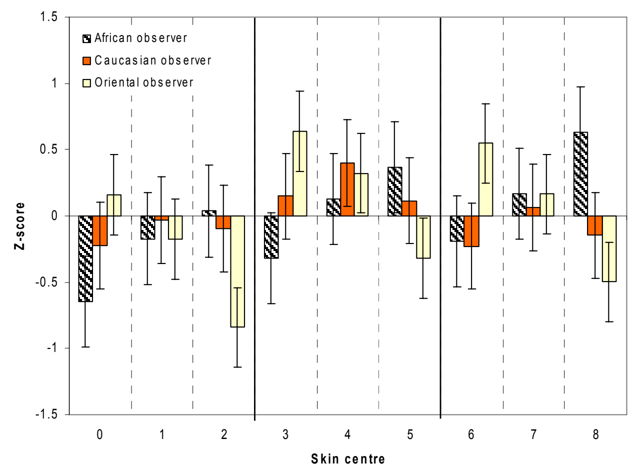

Fig. 11 Z-scores of the Caucasian image judged by three ethnic groups

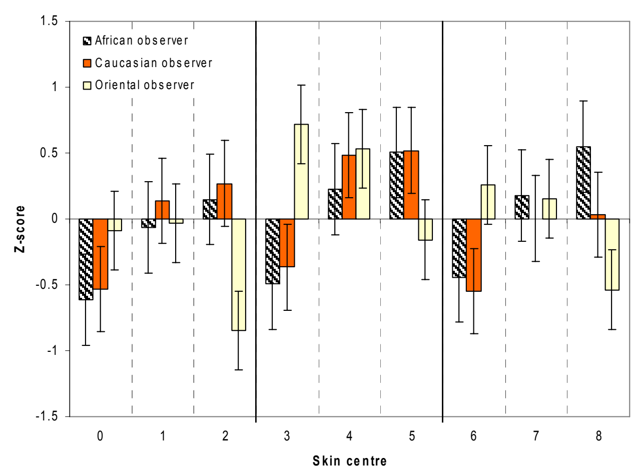

Fig. 12 Z-scores of the Oriental image judged by three ethnic groups

5. Discussion

5.1 Compensation from Display Colour Characterisation

An X-Rite Eye-One Pro sensor was used to measure the monitor display for colour characterisation. Because the display's white point was close to D65 and the gamma value of each primary was close to 2.2, the original video LUT was not adjusted. An ICC profile was generated for the display colour transformation. The ICC profile was formulated with a model using a 3x3 matrix and a set of R, G, and B tone curves for the transformation between CIEXYZ and display RGB.

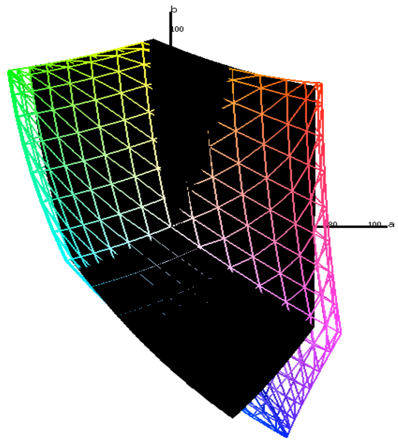

Fig. 13 *The results of the display colour characterisation using X-Rite Eye-One Pro (colour) and Konica Minolta CS-1000A/ST (black)*

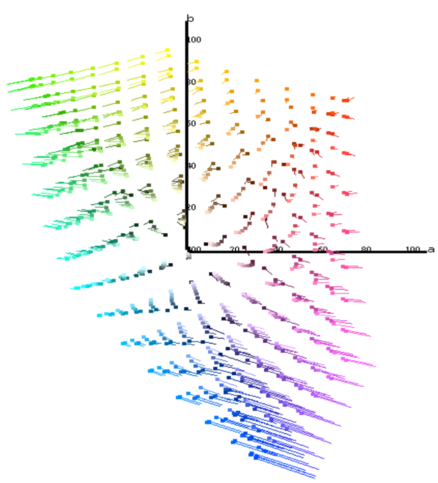

Fig. 14 *Colour differences of the display characterised using X-Rite Eye-One (line end) and Konica Minolta CS-1000A/ST (dot)*

The display was also characterised with measurement using a Konica Minolta CS-1000A/ST spectroradiometer. Fig. 13 shows gamut differences using two colour characterisation sets. Fig. 14 shows colour differences of 7x7x7 uniformly sampled RGB colours transformed using two colour characterisation sets. Colours in green, blue, and magenta regions characterised with measurements using two instruments are very different. Fortunately, colours in the skin colour region are much closer.

To numerically investigate the colour accuracy of the colour transformation in the skintone region, a skin colour, L*a*b* = (60, 21, 24) in D50 illuminant, in the preferred skin colour region was converted to RGB of the display using the display ICC profile; and then a uniform colour patch with this RGB colour was displayed on the screen and measured using the Eye-One spectrophotometer. A white patch (RGB=255, 255, 255) was measured as well, which was to convert absolute colours to colours relative to the white point of the display. The measured skin colour in CIEXYZ colour space was fully adapted to D50 using the linear Bradford linear chromatic adaptation matrix and converted to CIELAB. The result is (60.8, 21.9, 23.9). The ΔE^*_{ab} between the direct measurement and from the colour transformation using the ICC profile is 1.2.

The same RGB colour patch and the white patch were also measured using the CS-1000A/ST spectroradiometer. The skin colour was adapted to D50, and converted to CIELAB, which becomes (60.5, 21.6, 23.8). The ΔE^*_{ab} between the direct measurement and from the colour transformation using the ICC profile is 0.8.

The above analysis explains that the colour transformation using the ICC profile is about 1 ΔE^*_{ab} in the skin colour region. The major chroma error is in a*. The a*b* computed using the ICC profile should add about (0.9, -0.1) to correlate with the measurement using Eye-One, or add about (0.7, -0.2) to correlate with the measurement using CS-1000A/ST. The ΔE^*_{ab} for the skin colour measured using two instruments is 0.4, which is insignificant.

5.2 Preferred Skin Colours of Three Ethnic Groups

As discussed above, another step of colour transformation was applied to compensate the residue colour error in using the ICC profile. The a*b* transformed using the ICC profile should add (0.9, -0.1) so that they approximately agree with the measurement using Eye-One. Taking this colour characterisation factor into account, the preferred skin colour centres are adjusted and plotted in Fig. 15 and listed in Table 1. Orientals prefer less chromatic skin colours than Africans and Caucasians and Caucasians may prefer slightly more yellowish skin colours than Africans and Orientals.

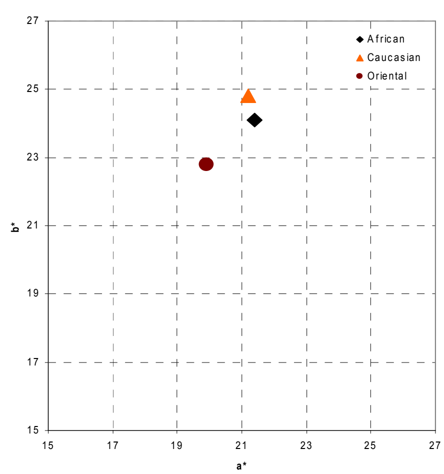

Fig. 15 *Preferred skin colour centres of African skin tone judged by Africans, Caucasian skin tone judged by Caucasians, and Oriental skin tone judged by Orientals*

Table 1: Preferred skin colour centres of individual-culture backgrounds in CIE a*b* adapted to D50 white point

	*a**	*b**	C^*_{ab}	h_{ab} *(degrees)*
African	21.4	24.1	32.2	48.4
Caucasian	21.2	24.8	32.6	49.5
Oriental	19.9	22.8	30.3	48.9

5.3 Comparing the Results between the Current Study and an Earlier Study

Preferred skin colour centres obtained from the authors' earlier study [1] is listed in Table 2 to compare to the result from the present study listed Table 1. In the earlier study, five LCD displays were used to display images in a dim surround viewing condition, and a single observer group with mixed culture backgrounds (Caucasian dominated, plus Hispanic, African, and Asian) judged all images; while in the current experiment images were displayed on a CRT monitor in the dark surround viewing condition, and the judgement by each observer group with a uniform culture background was analysed separately. Because nine predetermined skin colour centres were computed using different parameters among these two experiments, a set of nine versions of images generated from an original image are different among different experiments, even if a same original image is used.

Table 2: Preferred skin colour centres from previous study

	*a**	*b**	C^*_{ab}	h_{ab} *(degrees)*
African	20.5	23.3	31.0	48.7
Caucasian	19.3	22.1	29.3	48.8
Oriental	20.7	24.4	31.9	49.7

Preferred African skin colours from these two experiments are very close. One of the factors that the preferred Caucasian skin tone from the earlier experiment is less chromatic may be that one of the test images is a high-key image, its original chroma is low, its chroma may be limited by the gamut of the device when adjusted, and the 3-D depth effect on the face is low when increasing chroma. The result that chroma of the preferred Oriental skin tone is not lower than that in preferred Caucasian and African skin tones in the earlier experiment may be that the same group of observers judged all three groups of images.

Another study from the authors [15] using four Oriental images judged by a completely different group of 19 Chinese observers were conducted previously. The same method was applied for the psychophysical experiment. Images were displayed on a 21-inch Eizo ColorEdge CG241W TFL active matrix large-gamut LCD monitor in a typical office viewing condition (average surround lighting condition). A preferred skin colour centre was found to be a*b* = (19.9, 23.0), C^*_{ab} = 30.4, and $h_{ab} = 49.3^o$. The result is very close to the preferred Oriental skin colour found in the current study. This suggests that the skin colour preference is not affected much by the viewing conditions.

6. Conclusions

African, Caucasian, and Oriental images were judged by African, Caucasian, and Oriental observers in this psychophysical experiment to study skin colour preferences of these three ethnic groups. The results of skin colour preferences of individual-culture backgrounds are: the preferred hue angle in CIELAB adapted to the D50 white point is about 49^o in all three groups; Orientals prefer slightly less chromatic skin colours than Africans and Caucasians, and the inter-observer variation of the skin colour preference of Africans is larger than those of Caucasians and Orientals. In cross-culture preference, Orientals consistently prefer slight less chromatic skin colours than Caucasians and Africans, and Africans prefer more chromatic Caucasian and Oriental skin colours than Caucasians and Orientals.

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