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Facial Skin tone Judgement Criterion

Katsuaki Sakata[1], Hitomi Shimakura[2]

sakata00031@venus.joshibi.jp
[1]Joshibi University of Art and Design, Japan
[2]MIRAI Technology Institute, Shiseido Co., Ltd, Japan

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ABSTRACT

Perceptual judgment of facial skin tone has practical applications. Response probability experiments and analyses of the 27 participants'—and their in-groups'—skin colour properties revealed that discernment reference points are those closest to the average facial skin tone of an individual's belonging group. People may unconsciously memorise and reference the facial skin tone of a familiar person as a criterion for skin tone judgment.

1 Introduction

All male American monkeys possess dichromatic vision [1]. Nevertheless, many catarrhines, such as African monkeys, apes, and humans, have three types of cones and exhibit trichromatic colour vision in which all kinds of colour perception can be metamerically matched using red (R), green (G), and blue (B). Therefore, most displays realise natural colours using luminescent R, G, and B sources that allow us to see natural scenes. This principle suggests that the way we perceive colours should be the same regardless of what we look at, but this is not the case.

Many studies have reported that the perception of facial skin tone is characteristically different from that of other colours [2–5]. However, reports indicate that discrimination performance is not particularly superior in regard to the human skin colour direction [6]. This peculiarity seems to indicate that facial skin tone perception is particularly important for humans, and several studies have revealed that human communication is facilitated by the perception of facial colour [7–9]. Some researchers say that humans' trichromatic colour vision is related to facial skin tone perception [10,11].

Additionally, colour perception is always relative. Light is judged compared to an achromatic colour or another standard. A criterion for judging normal skin tone probably exists, as one can judge whether someone is drunk or ill by perceiving the change in their facial skin tone, despite the wide variety of skin colours existing within the same race [12]. However, the standard of skin tone judgement and how these attributes are decided are topics that have not been previously studied.

2 Experimental

2.1 Hypothesis

The following five hypotheses could be considered for deciding the criteria for instantaneous and accurate judgement of facial skin tone in daily life:

Hypothesis 1: Regarding the centroid facial skin tone encountered in daily life, people judge facial skin tones based on the facial skin tones of those they observe in their own daily lives.

Hypothesis 2: Regarding the centroid facial skin tones of one's generation, people judge facial skin tones based on the skin tone of others in their generation that they encounter in daily life.

Hypothesis 3: Regarding the measured value of one's facial skin tone, people base their facial skin tone on their own skin tone.

Hypothesis 4: Regarding facial skin tone memory, people judge facial skin tone colour based on their memory of the colour of their own skin.

Hypothesis 5: Regarding skin colours taught in childhood, i.e., the "skin colour" according to JIS (Japanese Industrial Standards), people judge facial skin tone based on the colours of drawing materials they used as children.

We experimentally verified which of these five hypotheses most closely describes the actual colour judgement criterion.

2.2 Method

We conducted an experiment wherein participants looked at stimuli in a 5AFC task to determine which colour—red, green, blue, yellow, or white—was the strongest compared with what they considered a 'normal' skin colour.

2.3 Stimuli

The stimuli presented in this study were one uniform stimulus and four face stimuli (Fig. 1). The uniform stimulus was a "Rectangular uniform patch" of the same size as the face stimuli. The face stimuli comprised an "East Asian face" (d) the facial image of an average 39-year-old Japanese female and a "Caucasian face" (e) the

facial image of an average 39-year-old Caucasian female. The same average generated face images for both Japanese and Caucasian females were presented to all participants. For variations in the face stimuli, we used scrambled images for (b)—scrambled (47 × 36)—and (c)—scrambled (4 × 3)—to avoid potential bias effects due to image contrast.

To obtain the colour of the face image of the stimulus used in this experiment, the facial skin tone of 104 Japanese females aged 20–39 years and 105 Japanese females aged 40–59 years was measured. Out of the 36 chromaticity variations, the stimuli colours used were determined from the range of the approximately 1σ facial skin tone distribution of these data by dividing the range into six steps of a^* and b^*, respectively. The average chromaticity was L^* = 66, a^* = 9, and b^* = 18 (Fig. 2). Each participant performed 3,240 trials in total (36 chromaticity × 18 repetitions × 5 images). For the participants, the total time needed to complete all of the trials in the experiment was approximately 2 hours and 30 minutes.

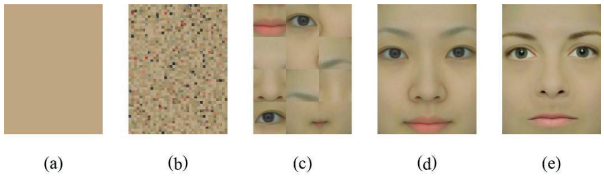

Fig. 1. Examples of stimuli used in Experiment 1. (a) "Rectangular uniform patch" that is the same size as the face image panels; (b) and (c) are scrambled face images: a scrambled face image divided into 47 × 36, and a scrambled face image divided into 4 × 3, respectively; (d) "East Asian face" image; and (e) "Caucasian face" image.

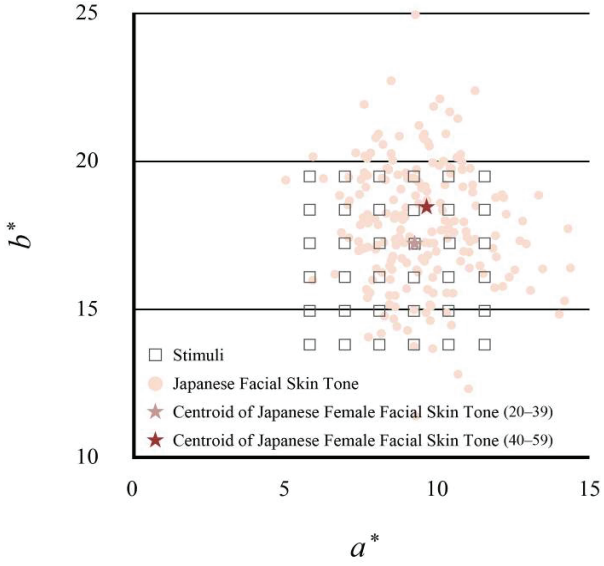

Fig. 2 The 36 chromaticity of the experiment's stimuli (empty squares), with the measured facial skin tone of Japanese females aged 20–59 years (beige circles), the centroid facial skin tone of Japanese females aged 20–39 years (light red star), and the centroid facial skin tone of Japanese females aged 40–59 years (dark red star).

2.4 Procedure

The experiment was started after the participants adapted to the luminance of the background through a practice trial wherein the stimuli were presented for approximately 10 min. In the actual trial, a stimulus was displayed on the centre of the monitor screen for 500 ms after a fixation cross was displayed for 500 ms, followed by a random dot pattern in which the average luminance was identical to the grey background for 500 ms (Fig. 3).

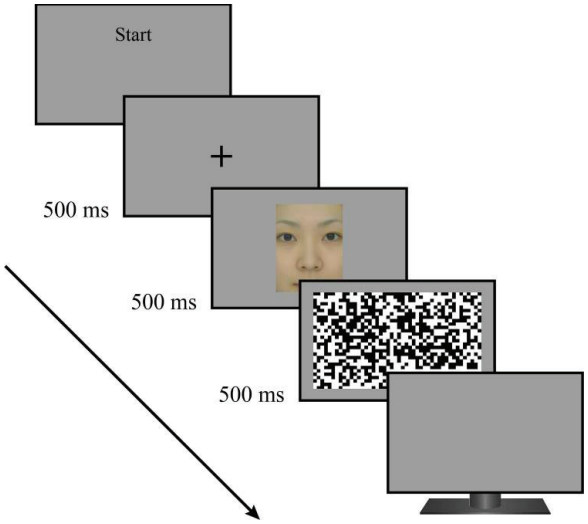

Fig. 3. The time course of stimulus presentation. The order of stimuli was as follows: a 500 ms presentation of a fixation cross (+) at the centre of the screen, followed by an image on a grey background for 500 ms and a random dot pattern for 500 ms.

At the end of the experiment, the participants measured their foreheads, cheeks, and lower eyes twice using a colour meter (CM-700d, KONICA MINOLTA, INC., Tokyo, JAPAN). Next, they selected the face image that seemed to be the closest to their own facial skin tone among 36 colour variations.

2.5 Participants

The participants included 27 Japanese females aged between 20 and 39 years old who had never participated in a colour vision experiment. All participants were confirmed to have a normal colour vision using Ishihara's pseudo-isochromatic plates, and their visual acuity, including corrected visual acuity, was within the normal range. Study participants were all female because skin tone has a particularly significant influence on attractiveness judgments in females [13], and females have a small but significantly heightened ability to discriminate between colours and their shades [14]. We obtained ethics approval for our study for research with human participants from the Review Board of the Shiseido Global Innovation Center and from Joshibi University of Art and Design. The participants in the experiment provided written informed consent for their participation and data (including optical measurement data) to appear in a scientific publication.

2.6 Data analysis

The criterion for judging facial skin tone was assumed to be the centroid (chromaticity coordinates of averages of a^* and $b^{*)}$ of acceptable skin tone, which was considered as the point equidistant from each colour selected as "too strong". Among the selection rates of colour, when the observer saw a face image stimulus, the rates of red, yellow, and white uniformly increased and decreased as the chromaticity changed. Therefore, the chromaticity at which the selectivity became 50% was regarded as the border of facial skin tone acceptability. Using the International Commission on Illumination (CIE) 1976 colour space (CIE $L^*a^*b^*$ space), we regarded the shade of red at 50% of participant selection probability as the border of acceptable skin tone redness (a^*). The 50% value for yellow was used as the border of skin tone yellowness (b^*) and the 50% value for white (the saturation as a distance from the achromatic point) as the border of whiteness (C^*ab). The midpoint between the C^*ab and the intersection of a^* and b^* was defined as the centre of the three criteria for judgement (Fig. 4).

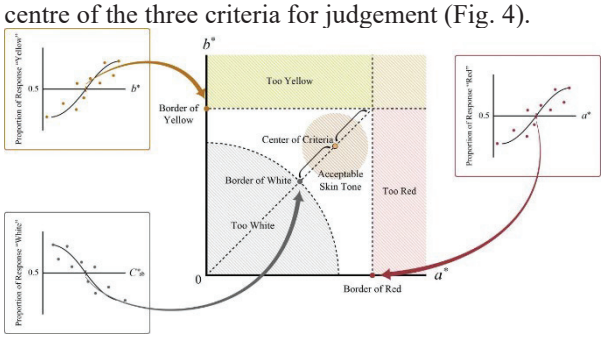

Fig. 4. The border of acceptable facial skin tone was defined to be the chromaticity at 50% of the selection probability of red, yellow, and white colours that the participants had judged to be "too strong" when viewing the facial stimulus image, and the centroid of this area was regarded as the judgement criterion.

The effects of the hypothesis and stimulus image type were analysed statistically using a 2-way analysis of variance (ANOVA) after the confirmation of equality of variances using Levene's test. The main effects of each factor were confirmed through multiple comparisons of the *t*-test with Bonferroni correction.

3 Results

The average of the distances of each stimulus image from the centre of the judging criteria to each reference point of the hypothesis is shown in Fig. 5. Here, not only the centroid facial skin tone value of Japanese females but also that of Caucasian females ($L^* = 60$, $a^* = 12$, $b^* = 15$) were calculated from a previous study (Xiao et al., 2017), and the distances were calculated and compared. Pairwise comparisons of the combined data from all the stimulus image conditions showed that the distance to the centroid facial skin tone of Japanese females aged 20–39 years showed significant differences compared to all other hypothesis data ($p < 0.0001$), except for those of the facial tone of Japanese females aged 40–59 years ($p = 0.076$).

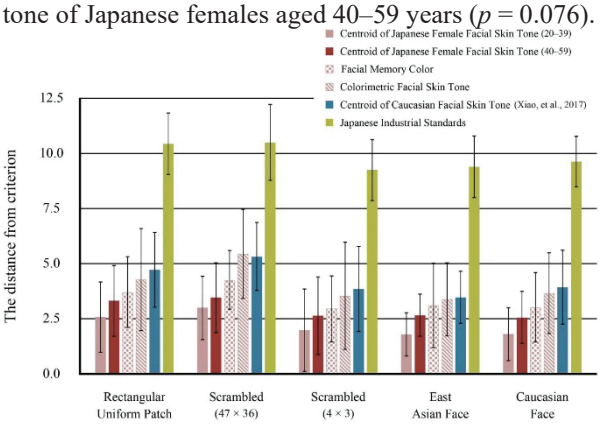

Fig. 5 The distance from the criteria's centres to the chromaticity of each hypothesis. To examine which of the hypotheses is closest to the location of the centre of the criteria, we compared the distance between the centre of the criteria and the centroid of each hypothesis.

4 Discussion

The results showed that the participants' criteria of facial skin tone judgement were closer to the centroid facial skin tone observed daily than the chromaticity of the observer's measured or remembered facial skin tones. Human perception of facial skin tone seems to be based on our adaptation to the skin colour of people in our surroundings. Regardless of which facial image was used, East Asian or Caucasian, participants judged the facial skin tone based on the centroid skin colour of their own group. This may suggest the superiority of the environmental effect on colour perception over race or a priori knowledge in humans' judgement of facial skin tone.

The sensitivity of our colour perception is adjusted by adapting to the colour distribution of the surrounding environment [15], and our colour perception is influenced by the skin colour of people in our daily environment [16,17]. The perception of facial skin tone seems to be judged based on adaptation to the skin colour of people in our surroundings.

The criterion for judging facial skin tone was closest to the centroid of the facial skin colour to which the observer belonged; however, the distance became larger in the case of scrambled facial images and furthest in the case of the uniform colour patch. This implies that our colour perception is not sensitive because it considers the colour gamut of the skin; it is sensitive because the recognition of the skin tone perception of the face is crucial. The findings of this study indicate that facial colour perception is a special function of the visual mechanisms of humans, and this interpretation is supported by the latest neuroscientific findings.

Although the colour perception mechanisms revealed in this study are perceptual mechanisms of skin colour, the same results were confirmed for the British [18]. Therefore, these mechanisms may not differ between

races or regions, and they seem to be part of a psychological mechanism common to humans.

5 Conclusion

Humans unconsciously memorise the facial skin tones of the people they encounter in daily life and judge facial skin tones based on the centroid. Furthermore, the recognition of an image as a face is critical to the evaluation of facial skin tone.

The characteristics of human skin colour perception differ from others not because we are especially sensitive to skin colour but because we recognise a colour as a facial colour, and this recognition seems to be a common perception characteristic among mankind, regardless of skin colour.

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