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Investigation of effect of skin tone to facial attractiveness

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Abstract

Previous research has shown the perceptual importance of skin tone appearance and how it contributes to perceived facial attractiveness, yet facial-colour perceptions may vary with different ethnic groups. This research was designed to explore the cross-cultural effects of the facial skin tone on perceived attractiveness between Caucasian (CA) and Chinese (CH) observers. 80 images of real human faces were used for facial attractiveness assessment by the two groups of observers using the categorical judgment method. The results showed overall similar preference but fine-scale differences in the perception of their own-ethnic facial images and other-ethnic facial images. Both groups of observers tended to use different criteria when judging the facial tone of different ethnic groups. Our findings show the aesthetic difference of different cultures in perceptions and underline the important role of ethnic differences with respect to skin tone preference.

Introduction

As one of the most significant features of a human face, facial colour conveys vital personal information and influences the impression perceived by others and the preference of facial images [1, 2]. Previous research works have shown the significant impact of visible skin condition, especially the skin colour, on facial attractiveness [3-5]. Increased facial skin lightness, redness, and yellowness, which approximately relate to the L*, a* and b* parameters of the CIELAB colour space respectively, have been claimed to enhance healthy appearance and therefore increase facial attractiveness [6, 7]. Skin colour homogeneity, driven by the distribution of melanin and hemoglobin, has been found to have an influence on the perception of age, health and attractiveness, whereby a more even distribution of colour is associated with greater attractiveness [8, 9].

Most research works that have investigated the impact of facial colour appearance on perceived attractiveness was conducted among Caucasian populations [3-9]. Facial colour perception, however, may vary between different ethnic groups. In colour imaging, people typically rely on their own perceptions and preferences to judge the quality of the colour reproduction of faces, thus it is important to know the perceptual differences for preferred colour reproduction when diverse populations of both observers and the observed are involved. Cultural differences in the perception of facial colour appearance are also worthy of consideration because of the increasing number of applications that need to define the preferred colour reproduction based on the needs of different people, including photography and graphic arts, dermatological diagnosis and surgery in medical applications, mannequin display in retail and e-commerce, the product development of cosmetics, and colour rendition under various types of light source [10-13].

As far as we are aware, three studies have focused on the perceptual cultural differences in facial colour appearance in terms of perceived attractiveness. Two studies by Stephen et al. were conducted amongst Caucasian and African populations [14, 15]. They found similar perceptual preferences for colour appearance when viewing own-ethnicity faces, both for African and Caucasian observers. A study conducted by Chengyang et al. [16] however, did not find a cross-cultural similarity in facial colour preference but found significantly different preferences for facial colour between Chinese and Caucasian participants.

It can be noted that, when researchers have studied the impact of facial skin colour on perceived attractiveness, they commonly altered the colour of a set of facial images and had observers judge the colour change in the images. The images used in the experiments were either a computer-generated generic face, which was usually a morphed image averaged from several images of real faces, or a set of real human facial images [5-7, 14-16]. The computer-generated or morphed facial images, however, may lose skin texture and appear to be unrealistic after image processing. Although the colour of each pixel of the real facial images can be simultaneously changed along the L*, a* and b* dimensions, the uniform color shift applied to each pixel of the facial image is not necessarily consistent with naturally occurring coloration changes since the variation in the color pattern depends on the distribution of blood vessels across the face which is not uniform. In addition, the preference of colour change in one real face, or the generic face, may not represent the preference of other faces due to the influence of facial shapes, features, etc.

This research was designed to explore the cross-cultural effects of the facial skin colour on perceived attractiveness between Caucasian and Chinese observers. We investigated (1) whether attractiveness judgements are made consistently between the two ethnic groups of observers; (2) whether these judgements depend on the ethnicity of the viewed faces, on the ethnicity of the observers, or both; (3) the degree to which these judgements are driven by the skin colour (lightness, redness, yellowness) of the viewed faces. The targets were approached by conducting experiments of facial attractiveness evaluation both on Caucasian and Chinese groups. To try to overcome some of the difficulties found in the previous studies, we used images of real human faces without changing the original colour appearance and used a relatively large number of images to provide a set of images that cover a wide diversity of facial shape and facial features.

Materials and Methods

Photography and Image Processing

The facial images used in this study were selected from the Liverpool-Leeds Skin-colour Database (LLSD), which included data for 188 subjects from four ethnic groups (Caucasian, East

Asian, South Asian and African, including both genders) and was established by the Universities of Liverpool and Leeds [17]. These facial images were obtained by photography in a VeriVide DigiEye® light booth, which provided a uniform matte mid-grey background and even, diffuse, fluorescent illumination that simulated CIE illuminant D65. There was no other lighting in the room where the photography took place. During data collection, the participant sat in the viewing cabinet and their target facial area was adjusted to fit within the camera image. A digital SLR camera (Nikon D7000), controlled by the DigiEye system software, was used to capture images of training colour charts for camera characterization and of each subject's face. The distance from the participant to the camera was approximately 57.5 cm and the participant looked straight into the camera.

80 real facial images, including 40 Caucasian images and 40 Chinese images, all with a neutral facial expression and in the same age group, were selected from the LLSD data base for this study. The RGB data of each pixel of each image was transformed into CIELAB colour coordinates via a camera characterization process. A BenQ professional colour display, with a white point set to D65, was used to process the images. The method of piecewise linear interpolation assuming constant chromaticity (PLCC) [18] was used for the colour characterization of the display and the CIELAB values for each pixel were transformed to display RGB values for each facial image. The hair, ears, and any visible clothing was removed from each image and the image then scaled to be in the centre of the screen with a mid-grey background (L*, a*, b* = 50, 0, 0). Figure 1 shows an example of a Chinese real facial image and a Caucasian real facial image used in this study.

Figure 1. *An example of a Chinese real facial image (left) and a Caucasian real facial image (right)*

Stimulus Description

The mean colour specification, in terms of CIELAB coordinates, of 80 test facial images (40 Chinese and 40 Caucasian) were calculated as the overall mean of each pixel in the facial area, excluding the mouth, nose, eyes, and eyebrows. As shown in a*b* and L*C* space in Figure 2, the Caucasian images have higher lightness (L*) and lower yellowness (b*) compared to the Chinese images. The ethnic difference of skin colour was larger along the lightness and yellowness dimension and smaller in redness. The colour variations in these images were representative of the skin colour variations in the respective populations [19,20].

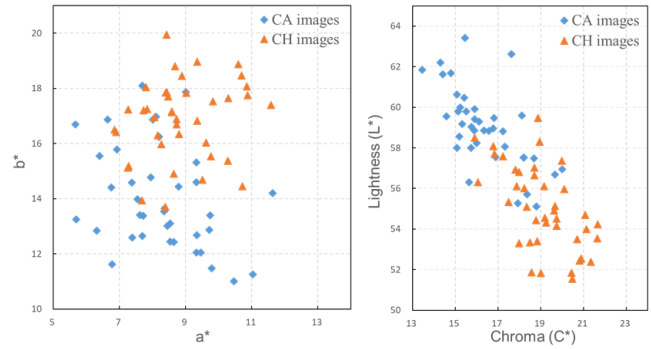


Figure 2. *The distribution of the mean facial colours of the test facial images in CIELAB a*b* space (left) and L*C* space (right): ♦ Caucasian (CA), ▲Chinese (CH)*

Psychophysical Experiment

A psychophysical experiment was conducted using 44 observers with normal acuity, or corrected-to-normal colour vision, including 22 Caucasians (13 male; mean age ± SD = 24.27 ± 5.30) and 22 Chinese (7 male; mean age ± SD = 26.05 ± 3.96), who each viewed the colour appearance of each test facial image and then scale overall attractiveness based on the skin colour. All the 80 facial images were presented in a random order. Using a categorical judgment method, the perceived facial attractiveness was rated on a 7-point Likert-type scale where 1 represented 'least attractiveness' and 7 represented 'best attractiveness'. All the observers were given instructions in English and confirmed their understandings before the experiments. The Chinese observers were from mainland China and, at the time of the study, they were at Leeds. On average, they spent about 1-3 years in UK. After the experiment, all the rating scores of all observers were first normalized to Z scores and then transformed into an interval scale where scores are based on the relative position of stimuli with respect to category boundaries using Torgerson's law of categorical judgment [21].

Results and discussion

Observer consistency

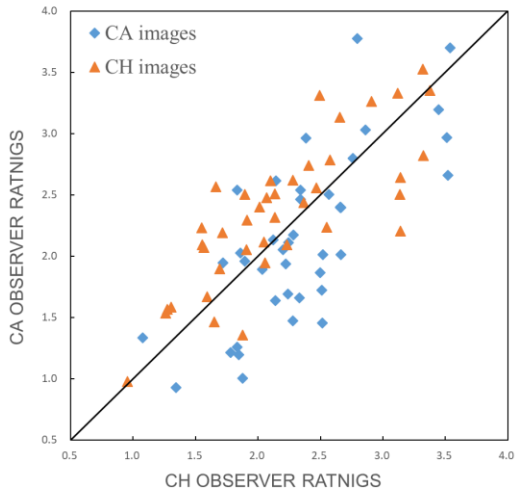
The Cronbach Alpha Coefficient was used to assess the inter-observer variability of the Caucasian and Chinese observers [22]. As shown in Table 1, the values of Cronbach's alpha coefficient are all greater than 0.93, suggesting the high internal consistency in the judgements of attractiveness for both the Caucasian and Chinese groups of observers. Moreover, inter-observer variability was relatively a little higher when rating their own ethnic's images for both observers which means people agreed more strongly on what is attractive in their own-ethnicity faces compared to other- ethnicity faces.

Table 1. The Cronbach Alpha Coefficient for assessing the inter-observer variability of the Caucasian (CA) and Chinese (CH) observers (sample size)

	CA	CH	CA & CH
CA images	0.96 (22)	0.93 (22)	0.96 (44)
CH images	0.95 (22)	0.96 (22)	0.97 (44)

Table 2. The Pearson Correlations Coefficient of Caucasian (CA) and Chinese (CH) z-scores

	CA images	CH images	Combined images
Attractiveness ratings	0.733***	0.792***	0.714***



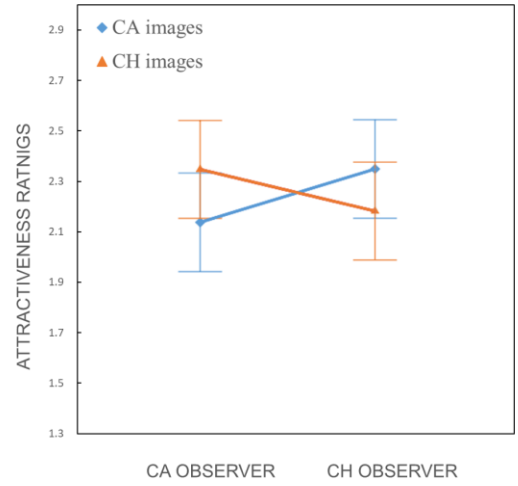


Figure 3. *Associations between Caucasian z-scores and Chinese z-scores: ♦Caucasian images (CA), ▲Chinese images (CH). A line has been drawn at 45□ to facilitate comparison (Left)* ***Figure 4.*** *The interaction between image ethnicity and observer ethnicity: ♦Caucasian images (CA), ▲Chinese images (CH). The error bars indicate 95% confidence intervals (Right)*

Ratings of Caucasian vs. Chinese Observers

The Pearson Correlation Coefficient (two-tailed) was used to assess the cross-ethnic agreement in the rating scores, as transformed into z-scores. The values are shown in Table 2 and they show that the judgements of facial attractiveness for Caucasian images, Chinese images, and combined images are all highly correlated ($P < 0.001$). Thus, it can be concluded that the judgements made by both the Chinese and Caucasian groups of observers were similar. As the scatterplot of Caucasians z-scores and the Chinese z-scores shows, all the data points are clustered around the 45° line which indicates a good agreement between different ethnicities (figure 3).

While the ratings between the Chinese and Caucasian observers are correlated, there are systematic interactions between observer ethnicity and image ethnicity. To quantify the differences between observers of two ethnicities, the repeated measures ANOVA with the ethnicity of images as repeated measure and the ethnicity of observers as between-subjects factor was carried out for the attractiveness scores. There was no main effect of image ethnicity ($F(1,78)=0.049$, $p=.826$) or observer ethnicity ($F(1,78)=0.055$, $p=.816$), but we found a weak interaction between the ethnicity of images and observers ($F(1,78)=3.787$, $p=.055$), as shown in figure 4. The results indicated that Caucasian observers tended to give higher attractiveness scores to most Chinese faces and lower scores to most Caucasian faces which was opposite to Chinese observers. These results can also be seen from figure 3 that most blue diamonds lie below the diagonal line while most orange triangles lie above the diagonal line. Both groups of observers generally considered images of the other ethnic group more attractive.

The relationship between the perceptual attractiveness ratings and the skin colour

The attractiveness ratings were then subjected to a multiple regression analysis (backward method) in order to investigate whether skin colour variables can be predictors of facial attractiveness, and if so, how much variation in the ratings can be explained by the colour of the face. The linear regressions were performed separately for both groups of observers rating their own-ethnicity faces and the other-ethnicity faces. As summarized in Table 3, three out of four linear models were significant at $p<0.05$. The interaction effects of L*, a*, b* were included in regressions first, but automatically excluded from the models due to their negligible contributions to predict attractiveness ratings. All variance inflation factors (VIFs; an indicator of multicollinearity) in all regression analyses were＜2.

Table3. Multiple linear regression models

	CA observers	CH observers
CA images		
Model	$R^2=0.107$, $F_{2,38}=3.282$, $P=0.049^*$	$R^2=0.119$, $F_{1,38}=6.131$, $P=0.018^*$
L*	β=-0.458 , $P=0.015^*$	
a*	β=-0.274 , P=0.136	β=-0.377 , $P=0.018^*$
b*		
CH images		
Model	Not significant	$R^2=0.246$, $F_{2,39}=7.352$, $P=0.002^{**}$
L*		β=0.597 , $P=0.000^{***}$
a*		
b*		β=0.291 , P=0.070

*P≤0.05, ** P≤0.01, ***P≤0.001.

When Caucasian observers viewed Caucasian facial images, a decrease in lightness (L*) was associated with greater attractiveness (R^2=0.107), with decreased redness (a*) remaining in the model but only as a non-significant trend. When Caucasian observers viewed Chinese faces, they didn't link facial attractiveness with any of the skin colour variables. In contrast when Chinese observers rated Chinese faces, an increase in lightness was strongly associated with greater attractiveness (R^2=0.246); for Caucasian faces, a decrease in facial redness (a*) is associated with an increase in attractiveness (R^2=0.119).

Our results indicated that although facial attractiveness can be affected by various factors such as facial features and contrast, skin colour can be an important predictor of facial attractiveness. Moreover, perceptual differences in facial attractiveness between ethnicities were also found here. The observers in the two ethnic groups assign different weights to lightness, redness and yellowness when making the judgements of attractiveness depending on the ethnicity of the viewed image. One of the most robust examples is facial skin lightness (L*) which is strongly associated with attractiveness but only when Chinese observers judge facial images of their own ethnicity. Caucasian observers, on the other hand, linked decreased lightness with greater attractiveness but only when judging Caucasian faces. The opposite preference for facial lightness may somewhat reflect a mainstream of aesthetic conceptions in Western and in China. Carmen et al. claimed that increased melanin colouration was found preferred compared to lower levels of the pigments [23]. Our study yielded consistent results but limited its applicability to Caucasian people. It was apparent that both ethnic groups tended to use different criteria when judging the facial colour of their own ethnicities and the other ethnicities. The perceptual impression of the facial colour properties are not universally agreed amongst different ethnic groups. Therefore, it must be accepted that the preferred facial colour reproduction of faces of different ethnicities may vary according to the ethnic group of the observer.

Conclusion

In the current work, the ethnic differences in the perception of attractiveness, based on facial colour appearance was investigated. In total, 80 real facial images were used as representative of the complexion and skin colour variation of real, Caucasian and Chinese, human faces.

Overall, we have provided evidence that, although Chinese and Caucasian observers showed overall similar perceptions of facial colour appearance, fine-scale differences existed in the perception of their own-ethnic facial images and other-ethnic facial images. Both groups of observers agreed more strongly on what is attractive in their own-ethnicity faces compared to other-ethnicity faces. However, both observers judged facial images of the other ethnicity as more attractive in comparison to own-ethnicity images, which suggest an interaction between observer and image ethnicity in the deployment of facial cues. The subsequent regression analysis showed that Caucasian observers and Chinese observers utilized the colour cues differently to evaluate facial attractiveness when viewing the faces of different ethnic groups. These results show aesthetic differences in different cultures and underline the importance of cultural differences regarding skin colour preference which should be considered in many applications with respect to preferred skin colour reproduction.

References

[1] M. Alam, A. C. Bhatia, R. V. Kundu *et al.*, *Cosmetic dermatology for skin of color*: McGraw-Hill Medical New York, NY, 2009.

[2] P. L. Van den Berghe, and P. Frost, "Skin color preference, sexual dimorphism and sexual selection: A case of gene culture co- evolution?," *Ethnic and Racial Studies,* vol. 9, no. 1, pp. 87-113, 1986.

[3] B. Fink, L. Bunse, P. J. Matts *et al.*, "Visible skin colouration predicts perception of male facial age, health and attractiveness," *International Journal of Cosmetic Science,* vol. 34, no. 4, pp. 307-310, 2012.

[4] J. Jimenez, T. Scully, N. Barbosa *et al.*, "A practical appearance model for dynamic facial color," *ACM Transactions on Graphics (TOG),* vol. 29, no. 6, pp. 141, 2010.

[5] B. Fink, K. Grammer, and P. J. Matts, "Visible skin color distribution plays a role in the perception of age, attractiveness, and health in female faces," *Evolution and Human Behavior,* vol. 27, no. 6, pp. 433-442, 2006.

[6] D. E. Re, R. D. Whitehead, D. Xiao *et al.*, "Oxygenated-blood colour change thresholds for perceived facial redness, health, and attractiveness," *PloS one,* vol. 6, no. 3, pp. e17859, 2011.

[7] I. D. Stephen, M. J. L. Smith, M. R. Stirrat *et al.*, "Facial skin coloration affects perceived health of human faces," *International journal of primatology,* vol. 30, no. 6, pp. 845-857, 2009.

[8] B. Fink, P. Matts, D. D'Emiliano *et al.*, "Colour homogeneity and visual perception of age, health and attractiveness of male facial skin," *Journal of the European Academy of Dermatology Venereology,* vol. 26, no. 12, pp. 1486-1492, 2012.

[9] P. J. Matts, B. Fink, K. Grammer *et al.*, "Color homogeneity and visual perception of age, health, and attractiveness of female facial skin," *Journal of the American Academy of Dermatology,* vol. 57, no. 6, pp. 977-984, 2007.

[10] H. Zeng, and R. Luo, "Modelling memory colour region for preference colour reproduction." p. 752808.

[11] K. Xiao, F. Zardawi, R. van Noort *et al.*, "Developing a 3D colour image reproduction system for additive manufacturing of facial prostheses," *The International Journal of Advanced Manufacturing Technology,* vol. 70, no. 9-12, pp. 2043-2049, 2014.

[12] S. Okuda, and K. Okajima, "Effects of spectral component of light on appearance of skin of woman's face with make-up," *Journal of Light & Visual Environment*, pp. IEIJ160000575, 2016.

[13] A. L. Jones, A. Porcheron, J. R. Sweda *et al.*, "Coloration in different areas of facial skin is a cue to health: The role of cheek redness and periorbital luminance in health perception," *Body Image,* vol. 17, pp. 57-66, 2016.

[14] I. D. Stephen, V. Coetzee, and D. I. Perrett, "Carotenoid and melanin pigment coloration affect

perceived human health," *Evolution and Human Behavior,* vol. 32, no. 3, pp. 216-227, 2011.

[15] I. D. Stephen, I. M. L. Scott, V. Coetzee *et al.*, "Cross-cultural effects of color, but not morphological masculinity, on perceived attractiveness of men's faces," *Evolution and Human Behavior,* vol. 33, no. 4, pp. 260-267, 2012.

[16] C. Han, H. Wang, A. C. Hahn *et al.*, "Cultural differences in preferences for facial coloration," *Evolution and Human Behavior,* vol. 39, no. 2, pp. 154-159, 2018.

[17] M. Wang, K. Xiao, S. Wuerger *et al.*, "Measuring human skin colour," in Color and Imaging Conference, 2015, pp. 230-234.

[18] D. L. Post, and C. S. Calhoun, "Further evaluation of methods for producing desired colors on CRT monitors," *Color Research Application: Endorsed by Inter- Society Color Council, The Colour Group , Canadian Society for Color, Color Science Association of Japan, Dutch Society for the Study of Color, The Swedish Colour Centre Foundation, Colour Society of Australia, Centre Français de la Couleur,* vol. 25, no. 2, pp. 90-104, 2000.

[19] K. Xiao, J. M. Yates, F. Zardawi *et al.*, "Characterising the variations in ethnic skin colours: a new calibrated data base for human skin," *Skin Research and Technology,* vol. 23, no. 1, pp. 21-29, 2017.

[20] K. Xiao, N. Liao, F. Zardawi et al., "Investigation of Chinese skin colour and appearance for skin colour reproduction". Chinese Optics Letters. 10(8), pp. 083301-83305,2012.

[21] W. S. Torgerson, *Theory and methods of scaling*: New York: John Wiley and Sons, Inc., 1958.

[22] L. J. Cronbach, "Coefficient alpha and the internal structure of tests," *psychometrika,* vol. 16, no. 3, pp. 297-334, 1951.

[23] C. E. Lefevre, and D. I. Perrett, "Fruit over sunbed: Carotenoid skin colouration is found more attractive than melanin colouration," *The Quarterly Journal of Experimental Psychology,* vol. 68, no. 2, pp. 284-293, 2015.

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