Different Colour Predictions of Facial Preference by Caucasian and Chinese Observers

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Research Article

Keywords: Facial colour, Caucasian (CA) and Chinese (CN) populations, colour cues.

Posted Date: January 7th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1155296/v1

Abstract

Facial colour characteristics convey vital personal information and influence social interactions and mate choices as contributing factors to perceived beauty, health, and age. How various colour characteristics would affect facial preference and whether there is a cultural difference are not fully understood. Here, we provide a useful and repeatable methodology for skin colour research based on a realistic skin model to investigate the effect of various facial colour characteristics on facial preference and compare the role of colour predictors in Caucasian (CA) and Chinese (CN) populations. Our results show that, although the averaged skin colour of facial areas plays a limited role, together with colour variation and contrast, there are stronger links between colour and facial preference than previously revealed. We also find large cultural differences in facial colour perceptions. Interestingly, Chinese observers tend to rely more heavily on colour cues to judge facial preference than Caucasian observers.

Introduction

Facial preference judgement has a profound impact on diverse important social outcomes, such as mate choices and social decision making, thus it has been studied from various facial perspectives[1,2]. In particular, facial symmetry, averageness and sexual dimorphism have been widely studied over the years from an evolutionary or biological perspective[3,4]. Compared to non-colour related facial traits, the colour appearance of a human face has been relatively less investigated but has gained increasing attention in recent years, which may suggest an important role for facial colour characteristics in any of the preference-related evaluations including facial attractiveness, perceived healthiness, and perceived ageing.

Colour is a perceptual stimulus which is essential in daily life and is often considered in terms of aesthetics[5]. The colour appearance of human faces can change either slowly and continuously due to UV exposure[6], fruit and vegetable (FV) consumption[7] or rapidly and momentarily due to change of physical or emotional state, use of coloured cosmetics, change in the lighting environment. Skin colour, and all these subtle colour variations, can be sensitively perceived by human observers[8]. As a consequence, skin colour preference has been a subject of great interest in many fields including cosmetology, image capture and reproduction, computer graphics, lighting engineering, etc., where effort has been made to satisfy people’s desire to have a beautiful, healthy-looking or youthful facial appearance[9].

Different facial colour characteristics have been assessed by previous work, including average facial skin colour[10–15], local skin colour[16], skin colour variation[17–19], and facial colour contrast[20–23], in terms of their role in facial preference judgements. With a few notable exceptions, these studies generally examined the role of a single colour characteristic in predicting facial preference. The exceptions include a study that compared average skin colour with structural facial features, which showed that skin colour did not predict facial attractiveness[14,24]. Studies that investigated skin colour and various biophysical properties such as wrinkling and sagging on age perception, showed that skin colour had only a weak association with perceived age, while skin colour uniformity was the most important attribute[25,26]. Tan et al. used cropped cheek skin images to investigate the role of both skin colour and skin colour variation on health perception among Malaysian Chinese and claimed that homogenous skin texture and increased skin yellowness positively predicted the rated health[27]. The results are mixed, and none considered all the different colour characteristics together. It is not known how these colour characteristics taken together would affect facial preference, whether they are correlated themselves, and which characteristics are more important in terms of predicting facial preferences including attractiveness, healthiness, and visual age. Therefore, one aim of the present study is to investigate the effect of various colour characteristics on facial preference evaluation and compare their distributions in predicting facial preference.

More importantly, the existing studies on the same colour predictors generated disputable results due to the different methodologies that were used. With regard to the widely used methods of image manipulation to provide the stimuli for the experiments, generally much stronger associations between facial colour characteristics and preference have been revealed compared to recent studies using non-manipulated facial images[14,15,27–29]. In studies that use image manipulation, observers were asked either to manipulate the facial colour to enhance their perceived preference or to rate or make a forced choice between the colour-manipulated facial images in terms of their preference. As a result, increased facial skin lightness, redness and yellowness have been claimed to enhance healthy appearance and facial attractiveness at a statistically significant level, mostly for Caucasian people[12,13,30–33]. Some limited studies, however, did use non-manipulated real facial images for preference evaluation and revealed very weak correlations between average skin colour and perceived healthiness ($p>0.636$)[14], a limited role for colour in predicting attractiveness ($p>0.05$)[24], and much weaker associations between skin colour and perceived age compared to skin colour uniformity or distribution[25,26].

Although image manipulation could be an effective way to explore the effect of one single variable on preference evaluation while holding all other variables constant, it may not be a reliable method to conduct comprehensive examinations of the various variables. More importantly, since observers can only manipulate a particular colour characteristic or choose manipulated facial images along fixed dimensions (e.g. CIELAB L^*, a^*, b^*) for preference enhancement, the role of such colour characteristic may be overestimated in this process. First, manipulated skin colour change could be impractical when uniform colour shifts are ideally applied over the face, and sometimes the result can be outside of the real skin colour gamut. Second, the preference judgement process in real situations could be much more complex when various colour characteristics are considered together. Moreover, the computer-generated or morphed facial images may lose skin texture and appear to be unrealistic after image processing.

Considering all the above, the present study aims to discuss facial colour preference within an evolutionary meaningful parameter space, and to provide a useful and repeatable methodology for skin colour research based on a realistic skin model. Figure 1 shows the schematic diagram of the methodology used in this study. We have used a set of high-resolution images of real human faces without changing the original colour. Facial colour analysis was performed to each of the real facial images and a rigorous process of colour characterization for both the camera and the display was performed to truly present the colour appearance of those facial images to observers in the preference evaluation experiments.

While the effect of facial colour characteristics on preference judgement has been most studied using Caucasian examples, both as participants and to provide stimulus material, there are some cross-cultural studies that showed controversial results. Stephen et al. and Coetzee et al. conducted studies amongst Caucasian and African populations and demonstrated similar preferences for skin colour in relation to perceived health and attractiveness[31,34,35]. A study conducted by Han et al., however, did not find a cross-cultural similarity in facial colour preference but found significantly different preferences between Mainland Chinese and Caucasians such that Chinese observers prefer lighter skin and decreased yellowness compared to Caucasian participants[36]. Malaysian Chinese, by contrast, linked increased yellowness and redness, but decreased lightness with enhanced perceived healthiness[37]. Our previous study also found the skin colouration is not a universal but culturally-specific cue for attractiveness, healthiness, and youthfulness in observers of Chinese and Caucasian ethnic groups[15]. Noted that only the average skin colour were considered in studies mentioned above, thus, in the present study, the cultural difference in facial preference judgement is investigated between Caucasian and Chinese populations and the cultural difference is further explored based on various facial colour characteristics.

The objectives of the present study are: (i) to evaluate the role of different facial colour characteristics in predicting preference using non-manipulated images of real faces; (ii) to identify the most important colour characteristics for each of the three facial preference attributes: attractiveness, healthiness, and visual age; (iii) to investigate the cultural difference on preference judgement between Chinese and Caucasian observers. To address these objectives, colour characteristics including average/local skin colour, skin colour variation, and facial colour contrast were measured using non-manipulated images of both real Caucasian and real Chinese faces. A rating study was conducted, using both Caucasian and Chinese observers, to obtain preference evaluations including facial attractiveness, perceived healthiness, and visual age. Finally, we provided a comprehensive assessment of various facial colour characteristics that predict facial attractiveness, perceived healthiness, and perceived age in the two ethnic groups.

Our results reveal a moderate role for colour characteristics in determining facial preference within an evolutionary meaningful parameter space. Although the averaged skin colour of facial areas plays limited role, together with colour variation and contrast, there are stronger links between colour and facial preference than previously revealed. Moreover, different facial colour cues are found to be utilized by different observers according to the different preference attributes they are accessing. Interestingly, Chinese observers tend to rely more heavily on colour cues to judge all facial preference attributes than Caucasian observers. The results highlight the importance of examining various facial colour cues to obtain the full picture of colour predictors utilized in facial preference evaluation and demonstrate the large cultural difference between Caucasian and Chinese populations. Our study provides a useful and repeatable methodology that is based on a realistic skin model and thus could be effectively adopted in the future for skin colour research related to preference evaluation.

Results

1. Variation in facial colour characteristics across Caucasian (CA) and Chinese (CN) images

All the facial colour characteristics are quantified in CIELAB colour space, which is designed to be perceptually uniform. Figure 2 shows all the parameters measured for the forty CA faces and the forty CN faces. The lightness and colour variations in these images were representative of the colour variations in the respective populations[38]. CA and CN faces differ in various facial colour characteristics. The mean values and standard deviations for each group can be found in Appendix 1, together with the results of a two-sample *t*-test (P values) for the difference between the two ethnic datasets. Generally, all colour characteristics are statistically different (P<0.05) between two samples except for the cheek redness (cheek-a*) and the skin colour variations (MCDM-cheek and MCDM). The mean scores and standard deviations of all three preference ratings for both datasets are also given in Appendix 1.

2. Role of different facial colour characteristics in predicting each facial preference

The Pearson Correlation Coefficient (two-tailed) was used to identify correlations between each colour characteristic and facial attractiveness, healthiness, and visual age rated by the observers, for the Caucasian and Chinese datasets, respectively. The results for each of the three preference ratings are shown in below and the complete correlation matrix of preference ratings and facial colour characteristics can be found in Appendix 2.

For each ethnic group, separate multiple regressions were performed for each of the three categories of colour characteristics first (average/local skin colour, skin colour variation, and facial colour contrast) to examine the role of different colour characteristics in predicting each facial preference ratings and identify the most significant predictors. The colour characteristics were not analysed together in one regression model because there are correlations between some of them as shown in Appendix 2. Facial preference could be influenced by several colour characteristics while modelling them together may underestimate the contribution of some of the individual characteristics. Previous studies have used a similar method for data analysis[24]. All the facial colour characteristics were included in the multiple regression analysis as independent variables except for the colour difference, △E, around the three facial features (eyes, brows, mouth-△E), which originated from one of the separate colour contrast channels (L*, a*, or b*) for both groups according to the correlations in Appendix 2 (r>0.86, p<.001).

Facial attractiveness. As shown in Figure 3, facial colour characteristics are linked differently with facial attractiveness by the Caucasian and the Chinese observers. In the Caucasian dataset, facial attractiveness was positively correlated with facial yellowness (b*, p<0.05) and b* contrast around the mouth (mouth-C-b* p<0.05), but negatively with L* contrast around the mouth (mouth-C-L*). In the Chinese dataset, facial attractiveness was positively correlated with facial lightness (L*, p<0.01), a* contrast around the mouth (mouth-C-a*, $p<0.001$), and colour difference around the mouth (mouth-△E, $p<0.01$), which may also result from the a* contrast considering the high correlation between a* contrast and △E around the mouth ($r=0.859$, $p<0.001$ in Appendix 2). Chinese facial attractiveness is negatively correlated with facial redness (a*), both skin colour variation (MCDM-cheek and MCDM), and a* contrast around the brows (brows-C-a*).

Table 1 summarizes the results of the multiple regression analyses for facial attractiveness. For the Caucasian dataset, the colour predictors of average/local skin colour and facial colour contrast could explain 9.1% and 11.1% of the variation in facial attractiveness, respectively. Greater attractiveness was predicted by increased yellowness ($p=0.033$) and increased b* contrast around the mouth ($p=0.021$). Regression analysis revealed no role of skin colour variation in predicting rated attractiveness of Caucasian images. For the Chinese dataset, all three different colour characteristics were utilized and 26.7%, 13.7%, and 43.4% of the variation in facial attractiveness was explained by skin colour, colour variation and colour contrast, respectively. The most significant predictors were facial lightness (L*, $p<0.001$) and a* contrast around the mouth (mouth-C-a*, $p < 0.001$), with higher lightness and higher contrast predicting higher facial attractiveness. This was followed by the a* contrast around the brows (brows-C-a*, $p=0.001$) and the overall skin colour variation over the face (MCDM, $p = 0.011$), which both negatively predicted facial attractiveness of the Chinese images of faces. The regression lines of the significant colour predictors in each model can be found in Appendix 3.

Table 1
Facial colour predictors of facial attractiveness.

	CA				CN			
	β	**SE**	***t***	**P**	**β**	**SE**	***t***	**P**
Regression 1: average/local skin colour								
Model	$F_{1,38}$=4.904; P=0.033*; Adjusted R^2=0.091				$F_{2,37}$=8.095; P=0.001**; Adjusted R^2=0.267			
L*	-	-	-	-	0.235	0.059	3.990	<0.001***
b*	0.143	0.064	2.214	0.033*	0.167	0.083	2.025	0.050
Regression 2: skin colour variation								
Model	NS				$F_{1,38}$=7.214; P=0.011*; Adjusted R^2=0.137			
MCDM	-	-	-	-	-1.541	0.574	-2.686	0.011*
Regression 3: facial colour contrast								
Model	$F_{1,38}$=5.848; P=0.021*; Adjusted R^2=0.111				$F_{2,37}$=15.98; P<0.001***; Adjusted R^2=0.434			
Brows-C-a*	-	-	-	-	-4.424	1.234	-3.584	0.001**
Mouth-C-a*	-	-	-	-	6.482	1.59	4.076	<0.001***
Mouth-C-b*	6.39	2.643	2.418	0.021*	-	-	-	-
NS= not significant; *P<0.05; **P<0.01; ***P<0.001.								

Perceived healthiness. The attractiveness ratings and healthiness ratings are highly correlated for both groups (r>0.9, p<0.001 in Appendix 2), thus colour cues utilized for healthiness perception are somewhat similar to those for attractiveness judgements. As shown in Figure 4, for the Caucasian dataset, perceived healthiness is positively correlated to facial yellowness (b*, p<0.05) and b* contrast around the mouth (mouth-C-b*, p<0.05), but negatively correlated to overall lightness (L*, p<0.01), periorbital lightness (periorbital-L*, p<0.05), and overall skin colour variation (MCDM, p<0.05). For the Chinese dataset, perceived healthiness is positively correlated to facial skin lightness (L*, p<0.01), colour contrast around the eye and the mouth (eyes-C-b*, △E, p<0.05; mouth-C-a*, △E, p<0.01). Perceived healthiness for the Chinese dataset is negatively correlated with facial redness (a*, p<0.05) and a* contrast around the brows (brows-C-a*, p<0.01).

Table 2 shows the facial colour predictors of perceived healthiness. For the Caucasian dataset, perceived healthiness was predicted by skin colour, colour variation, and colour contrast, explaining 12.3%, 10.9%, and 10.4% of the variation, respectively. Perceived healthiness was significantly and positively predicted by facial yellowness (b*, p=0.015), b* contrast around the mouth (mouth-C-b*, p=0.024), and negatively by skin colour variation (MCDM, p=0.021). For the Chinese dataset, 15.0% and 40.1% of the variation in perceived health could be explained by facial skin colour and colour contrast, respectively. Similar to the perception of attractiveness, the most significant predictors of healthiness for the Chinese dataset were facial lightness (L*, p=0.008), a* contrast around the mouth and brows (mouth, brows-C-a*, both p=0.002). however, skin colour variation was found not to predict rated healthiness in the Chinese dataset.

Table 2
Facial colour predictors of perceived healthiness.

	CA				**CN**			
	β	**SE**	***t***	**P**	**β**	**SE**	***t***	**P**
Regression 1: average/local skin colour								
Model	$F_{1,38}$=6.460; P=0.015*; Adjusted R^2=0.123				$F_{1,38}$=7.906; P=0.008**; Adjusted R^2=0.150			
L*	-	-	-	-	0.161	0.057	2.812	0.008**
b*	0.177	0.07	2.542	0.015*	-	-	-	-
Regression 2: skin colour variation								
Model	$F^{1,38}$=5.773; P=0.021*; Adjusted R^2=0.109				NS			
MCDM	-1.693	0.704	-2.403	0.021*	-	-	-	-
Regression 3: facial colour contrast								
Model	$F_{1,38}$=5.516; P=0.024*; Adjusted R^2=0.104				$F_{3,36}$=9.9; P<0.001***; Adjusted R^2=0.401			
Eyes-C-L*					5.964	3.111	1.917	0.063
Brows-C-a*	-	-	-	-	-4.36	1.287	-3.387	0.002**
Mouth-C-a*	-	-	-	-	5.449	1.645	3.312	0.002**
Mouth-C-b*	6.861	2.922	2.349	0.024*	-	-	-	-
NS= not significant; *P<0.05; **P<0.01; ***P<0.001.								

Perceived age. As shown in Figure 5, for the Caucasian dataset, perceived age is only significantly and positively associated with skin colour variation (MCDM-cheek and MCDM, both p<0.01), which means larger variation in Caucasian skin colour is linked to older visual age. For the Chinese dataset, in addition to skin colour variation (MCDM-cheek and MCDM, both $p<0.05$), perceived age is also positively correlated with facial redness (a^*, $p<0.01$), colour contrast around the brows (brows-C-L^*, a^*, $p<0.05$). In addition, it is negatively correlated with facial lightness (L^*, $p<0.001$), colour contrast around the eye and mouth (eyes-C-b^*, $p<0.01$; mouth-C-a^*, $p<0.001$; mouth-$\triangle E$, $p<0.01$).

Table 3 shows the facial colour predictors in determining perceived age. For the Caucasian dataset, perceived age was only significantly and positively predicted by skin colour variation with 24% of the variation explained. Homogeneous skin colour distribution with smaller variation over the face (MCDM, $p=0.045$) predicted a younger visual age. The MCDM on the cheek remains in the model but only as a non-significant trend. For the Chinese dataset, perceived age was predicted by all three colour characteristics, but in different degrees. Skin colour, variation and contrast explain 30.8%, 12.4%, and 54.8% of the variation in perceived age, respectively. A younger perceived age was significantly predicted by higher lightness (L^*, $p<0.001$), lower skin colour variation (MCDM, $p=0.015$), stronger mouth contrast (mouth-C-a^*, $p<0.001$), and weaker brows contrast (brows-C-a^*, $p<0.001$).

Table 3
Facial colour predictors of perceived age.

	CA				CN			
	β	**SE**	***t***	**P**	**β**	**SE**	***t***	**P**
Regression 1: average/local skin colour								
Model	NS				$F_{1,38}$=18.37; P<0.001***; Adjusted R^2=0.308			
L*	-	-	-	-	-0.682	0.159	-4.286	<0.001***
Regression 2: skin colour variation								
Model	$F_{2,37}$=7.169; P=0.002**; Adjusted R^2=0.240				$F_{1,38}$=6.527; P=0.015*; Adjusted R^2=0.124			
MCDM	4.658	2.246	2.074	0.045*	4.449	1.742	2.555	0.015*
MCDM-Cheek	2.715	1.426	1.904	0.065	-	-	-	-
Regression 3: facial colour contrast								
Model	NS				$F_{2,37}$=24.69; P<0.001***; Adjusted R^2=0.548			
Brows-C-a*	-	-	-	-	16.506	3.322	4.969	<0.001***
Mouth-C-a*	-	-	-	-	-19.522	4.28	-4.561	<0.001***
NS= not significant; *P<0.05; **P<0.01; ***P<0.001.								

3. Role of significant facial colour predictors together in determining facial preference.

Finally, the significant colour predictors in each separate multiple regression model for the same preference rating were chosen to predict that preference in one regression model (Table 4). For the Caucasian dataset, different skin colour predictors together only explain 19%~28% of the variation in different preference ratings. For the Chinese dataset, different colour predictors were utilized and 35%~56% of the variation in different preference ratings was explained. Although there is potential for further model optimisation, the results to some extent reflect the difference between the Caucasian dataset and the Chinese dataset in that colour cues were deployed to judge facial preference in varying degrees.

Table 4
Facial colour predictors of each preference rating in CA model and CN model.

	CA				CN			
	β	SE	*t*	P	β	SE	*t*	P
Regression 1: DV = Attractiveness								
Model	NS				$F_{4,35}$=8.4; P<0.001***; Adjusted R^2=0.432			
L*	-	-	-	-	0.022	0.062	0.356	0.724
MCDM	-	-	-	-	-0.619	0.517	-1.199	0.239
Brows-C-a*	-	-	-	-	-3.978	1.353	-2.941	0.006**
Mouth-C-a*	-	-	-	-	5.387	1.922	2.803	0.008**
Regression 2: DV = Healthiness								
Model	$F_{3,36}$=5.949; P=0.002**; Adjusted R^2=0.276				$F_{3,36}$=7.908; P<0.001***; Adjusted R^2=0.347			
L*	-	-	-	-	0.016	0.064	0.255	0.8
b*	0.122	0.093	1.307	0.2	-	-	-	-
MCDM	-1.96	0.641	-3.057	0.004**	-	-	-	-
Brows-C-a*	-	-	-	-	-3.546	1.416	-2.504	0.017*
Mouth-C-a*	-	-	-	-	5.951	1.971	3.02	0.005**
Mouth-C-b*	4.257	3.886	1.095	0.281	-	-	-	-
Regression 3: DV = Age								
Model	$F_{1,38}$=10.02; P=0.003**; Adjusted R^2=0.188				$F_{4,35}$=13.15; P<0.001***; Adjusted R^2=0.555			
L*	-	-	-	-	-0.189	0.166	-1.143	0.261
MCDM	6.573	2.076	3.166	0.003**	1.178	1.377	0.855	0.398
Brows-C-a*	-	-	-	-	14.36	3.605	3.984	<0.001***
Mouth-C-a*	-	-	-	-	-15.044	5.121	-2.938	0.006**
NS= not significant; *P<0.05; **P<0.01; ***P<0.001.								

Discussion

The present study provides a useful and repeatable methodology for the comprehensive assessment of various facial colour characteristics that affect facial preference. Colour predictors of facial attractiveness, perceived healthiness, and perceived age were studied in both Caucasian and Chinese populations. Our findings demonstrate the importance of all three facial colour characteristics (average skin colour, skin colour variation, facial colour contrast) in facial preference judgements and also addressed the cultural difference between Caucasian and Chinese observers that Chinese observers tend to rely more heavily on colour cues to judge facial preference than Caucasian observers.

Colour predictors for facial attractiveness and perceived healthiness

For both Caucasian and Chinese observers, the significant colour predictors of attractiveness and perceived healthiness are somewhat overlapping since these two perceptual ratings were highly correlated for both datasets (r=0.912 for CA dataset, r=0.927 for CN dataset, see Appendix 2). The averaged skin colour was found to be a predictor for both Caucasian and Chinese observers, playing a limited role in determining facial attractiveness and perceived healthiness. Consistent with previous studies on the preference of skin colour, increased facial yellowness enhanced the facial attractiveness and the perceived healthiness of Caucasians, which could be explained by the carotenoid-linked health-signalling system[32]. No role was found for L*, a* or local skin colour in predicting Caucasian preference as found in previous studies, which may be due to the small range of naturally occurring skin colour variation and thus the observers focused on other colour cues when rating the real facial images. For Chinese observers, skin lightness (L*) is the strongest and consistent cue to judge facial preference and they positively and significantly linked facial lightness with enhanced facial attractiveness, and healthiness, which is consistent with previous studies that used Chinese samples[36]. While Chinese observers showed their strong preference for skin lightness, Caucasian observers linked decreased lightness with healthiness ($r=-0.351$, $p<0.05$), which in turn was linked to their opposite preference for skin tanning [32] and suggested the mainstream aesthetic difference between the two cultures. Skin colour variation was adopted differently by Caucasian and Chinese observers to rate attractiveness and perceived healthiness. Larger variation in skin colour was linked to enhanced facial attractiveness by Chinese observers, but enhanced healthiness by Caucasian observers, both to a limited extent. Our study did not find facial colour contrast to be an important predictor of preference in Caucasians which has been shown in previous studies[20,21,23], only contrast around the mouth showed a limited role in attractiveness and perceived health. The reason for this is also likely to be the limited range of facial colour contrast in real faces without any applied cosmetics. For Chinese observers, facial colour contrast was the most important predictor among different colour characteristics to judge both attractiveness and healthiness, which has not been previously noted due to the limited study of Chinese facial colour contrast.

Colour predictors for perceived age

Skin colour variation was found to be a significant predictor of perceived age in both the Caucasian and Chinese datasets. Particularly, it is the only important colour cue for age perception of Caucasian observers judging faces of their own ethnicity. Larger variation in skin colour was linked to older visual age. This is in line with the study of Nkengne et al., which looked at the influence of various skin attributes (skin yellowness, skin texture, etc.) on the age perception of Caucasians and found that skin colour uniformity was the most important attribute. The results were largely different for the Chinese dataset. Since all three perceptual ratings from Chinese observers were highly correlated (r>0.818, in Appendix 2), the significant colour predictors of perceived age were similar to the predictors of attractiveness and healthiness. Consistently, Chinese observers also considered skin lightness (L*) as the strongest colour cue for age perception and they linked higher facial lightness with youthfulness (younger visual age). In line with Caucasian observers, the Chinese observers also agreed that more evenly distributed skin colour was perceived as being younger. However, skin colour variation only played a limited role compared to skin colour and contrast. The results also revealed that facial colour contrast was the most important predictor among different colour characteristics for the Chinese observers to estimate visual age. With a very limited study on Chinese facial colour contrast, only Porcheron et al. tested the relationship between the same set of facial colour contrasts and the chronological age in Chinese subjects and found the mouth a* contrast also had significant and negative correlation with real age and the brows a* contrast had positive correlations with age[39]. More research would be necessary to explore the effect of colour contrast on facial preference of the Chinese population, maybe using a wider range of contrast with the help of coloured cosmetics.

Cultural difference between Caucasian and Chinese observers

As noted above, different facial colour cues are utilized by different observers and according to different preference attributes they were accessing. Cultural difference was not only restricted to the utilization of the average facial skin colour as we previous revealed[15]. Actually, the cultural differences included the opposite preference for facial lightness, the utilization of skin colour variation in judging different preference attributes, and the different colour contrast cues used in preference evaluation. Generally, Chinese observers tended to utilize more facial colour cues when evaluating facial preference (attractiveness, perceived healthiness, and visual age) compared to Caucasians. More correlated colour characteristics in relation to facial preference were found for Chinese (Figures 3-5) and more variation in preference was explained in the linear regression models of all three perceptual ratings for Chinese observers compared to Caucasians (Tables 1-4). These results suggest one important aspect of the cultural difference between Caucasians and Chinese, which has nerver been discussed in previous studies. Coetzee et al. investigated the role of facial shape cues and colour cues on attractiveness preference of White Scottish and Black South African people and found that Black South Africans rely heavily on colour cues while White Scottish rely more heavily on shape cues[35]. Given that Asians were less influenced by some structural facial features than Caucasians[40], it is likely that Caucasians make facial preference judgement from more structural facial features than colour cues while Chinese rely more heavily on facial colour cues, a suggestion that needs further investigation.

The role of facial colour characteristics on preference evaluation in real faces

Using the non-manipulated real facial images, our study revealed the moderate role of facial colour characteristics in determining facial preference judgements. The average skin colour (L*, a*, b*) explained 9%~31% of the variation in facial preference across different regression models and was a more important predictor than local skin colour (cheek a* and periportal L*) in all conditions. Skin colour variation explained 11%~24% of the variation in facial preference across models and, especially, was the most important predictor of perceived age for Caucasians (24% of the variation explained). The overall skin colour variation was a more important colour cue than skin colour variation within the cheek area in predicting any of the facial preferences. Overall, facial colour contrasts explained 10%~55% of the variation in facial preference and were more important predictors for Chinese than Caucasians in any of the perceptual ratings, including attractiveness, healthiness, or perceived age.

In the present study, 80 calibrated non-manipulated images of real Caucasian and Chinese human faces were used, various colour characteristics in these images were representative of the natural occurring variations in both populations. Earlier studies using manipulated images may have found more significant relationships between the manipulated colour cues and preference ratings[16,30,39,41,42]. As the differences between the two methods have been addressed in the introduction, image manipulation could be an effective way of testing certain variables with others held constant and it is understandable that when judging facial preference on real human faces, the relationship between facial colour cues and preference ratings could be much weaker due to the complexity of the human face and the influence of other extraneous factors. Considering the importance of facial colour preference in various applications, our study provided a scientific method to assess the role of facial colour characteristics on real human faces with natural colour variations and discuss the facial colour preference within an evolutionary meaningful parameter space.

On the other hand, more recent studies have started to use non-manipulated images to study facial preference, but found much weaker associations between skin colour and facial preference[14,15,24,25,27,43]. Our previous study found both Chinese and Caucasian observers make use of average skin color and lightness to rate attractiveness, healthiness, and perceived age, but to a lesser degree than previously thought[15]. Foo et al. investigated skin colour (L*, a* and b*) and other structural facial features as the preference predictors, and they claimed that skin colour did not predict attractiveness while facial yellowness played a limited role in predicting healthiness[24]. Jones et al. also compared facial shape cues and colour cues in health perception using average facial L*, a*, and b*, and they found skin colour showed no utilization as short-term health cues with non-significant correlations (all $p>0.636$)[14]. Tan et al. studied skin texture and colour in health perception and found homogenous skin texture and increased skin yellowness positively predicted rated health of Malaysian Chinese faces, however, facial colour contrast was not considered in their study which may also be an important predictor[27].

Consistent with those studies that used non-manipulated images, our results showed that average skin colour (L*, a*, and b*) itself, as a single factor, was not a very strong predictor for facial preference evaluation but played a limited role (r^2=0.09~0.31), especially for Caucasian people (r^2=0.09~0.24). However, since not all the facial colour cues were considered in those studies, it may not give the full picture of colour predictors utilized in facial preference evaluation. Given that different facial colour cues were utilized according to different observers and different preference attributes they were accessing, facial colour cues, as a whole, should be judged comprehensively in terms of preference evaluation. Otherwise, the role of colour in facial preference may be underestimated when only part of the facial colour characteristics is considered.

Methods

Photography and facial image processing

Eighty facial images, including 40 Chinese images and 40 Caucasian images were selected from the Liverpool-Leeds Skin-colour Database (LLSD)[38]. All the facial images were captured by a digital SLR camera (Nikon D7000) in a VeriVide DigiEye® light booth, which had a mid-grey matte background and was illuminated by a D65 fluorescent simulator offering evenly diffused illumination. Each subject was asked to sit 57.5 cm in front of the camera with a neutral facial expression and their target facial area was adjusted to fit within the camera image. Images were captured and stored in uncompressed tagged image file format (.TIF) at a resolution of 3264 x 4928 pixels and 72 dots per inch (dpi). No colour correction or spatial filtering was applied to these images. After camera colour characterization, the device-independent CIE colorimetric coordinates of each pixel could be derived. For each facial image, the hair, ears, and any visible clothing were then removed, and the face was scaled to be in the centre of the image with a mid-grey background (L*, a*, b* = 50, 0, 0). An example of a Caucasian facial image is shown in Figure 6a.

Analysis of facial colour characteristics

In total, three categories of facial colour characteristics were analysed for each of the 80 facial images. All the areas of interest shown in Figure 6 were selected manually for each image and all the calculations were performed in MATLAB.

Average facial colour and local skin colour. The average facial colour specification, in terms of CIELAB coordinates (L^*, a^*, b^*, C^*, h_{ab}), 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 Figure 6b. Considering the study of Jones et al.[16], the local skin colour of cheek redness, a*, and periorbital lightness, L*, were also calculated as the overall mean of each pixel within the selected areas (Figure 6c).

Skin colour variation. To access the facial skin colour variation, the mean colour difference from the mean (MCDM) was adopted, a measure commonly used to describe colour variation for a set of data points in CIELAB space, using the following equation[44,45],

$$MCDM = \frac{\sum_{i=1}^{N}[(L_i^* - \bar{L}^*)^2 + (a_i^* - \bar{a}^*)^2 + (b_i^* - \bar{b}^*)^2]^{1/2}}{N}$$

In this study, MCDM was used to evaluate skin colour variation of any target facial areas, where L_i^*, a_i^*, and b_i^* are the CIELAB coordinates for the ith pixel of the area, $\bar{L}^*$, $\bar{a}^*$, and $\bar{b}^*$ are the average CIELAB coordinates of the facial area and N is the number of pixels within the area. As outlined in Figure 6c, the MCDM of the forehead, cheek, nose, and chin areas was calculated and the grand mean of the MCDM values of the four parts was then obtained to represent the skin colour variation over the whole facial area. Both the skin colour variation of the whole facial area (MCDM) and the cheek (MCDM-Cheek) were analysed in this study. The smaller the value of the MCDM, the smaller the colour difference and the more even/homogeneous is the skin colour distribution.

Facial colour contrast. Both the adapted version of the Michelson contrast and the CIELAB colour differences (△E) were used in the present study to describe facial colour contrast between three facial features (eyes, eyebrows, and mouth) and their surrounding skin (Figure 6d). The adapted Michelson contrast of the three dimensions (L^*, a^*, b^*) was considered, as defined by the following equation,

$$C_{\text{Feature}} = \left| \frac{A_{\text{Skin}} - A_{\text{Feature}}}{A_{\text{Skin}} + A_{\text{Feature}}} \right|$$

where A_{Skin} is the respective CIELAB coordinates (L^*, a^*, b^*) of the surrounding facial skin and A_{Feature} is the respective CIELAB coordinates (L^*, a^*, b^*) of the facial features (eyes, eyebrows, and mouth). Meanwhile, the CIELAB colour differences (△E) between the three facial features and their surrounding skin were also calculated and the facial colour contrast was defined by the following equation,

$$\Delta E = [(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2]^{1/2}$$

where L_1^*, a_1^*, and b_1^* are the CIELAB coordinates of the facial features, and L_2^*, a_2^*, and b_2^* are the CIELAB coordinates of their surrounding skin area. For both C_{Feature} and ΔE, the bigger the value, the larger the facial colour contrast.

Ratings of facial preference

A psychophysical experiment was conducted to obtain the subjective ratings of facial preference regarding the skin colour of each facial image. A BenQ professional colour display, with the white point set to CIE illuminant D65, was used to reproduce the real facial images in the experiments. After display colour characterization, the CIELAB values for each pixel were transformed to display RGB values for each facial image. 44 observers, including 22 Caucasians (13 male; overall mean age ± SD = 24.27 ± 5.30 years) and 22 Chinese (7 male; overall mean age ± SD = 26.05 ± 3.96 years) evaluated the colour appearance of the 80 facial images in terms of the three attributes of facial preference: attractiveness, perceived healthiness, and visual age. The three attributes were judged in three separate sessions. Each observer was given 8 seconds to view each facial image and then was asked to make a judgement of the facial skin colour without a time limit. Based on the categorical judgment method, the perceived facial attractiveness and healthiness were rated using a 7-point Likert-type scale where 1 represented ‘least attractiveness’ / ’healthiness’ and 7 represented ‘best attractiveness’ / ‘healthiness’. The visual age was rated on a single-year step scale from 1 to 99 years. The ages of subjects in the 80 images were in the range of 20-40 years although the observers were not aware of this fact.

This study was approved by the Ethics Committee at the University of Leeds (PVAR 13-057, LTDESN-090) and all methods were performed in accordance with the relevant guidelines and regulations. All the observers were given instructions in English, and each gave written informed consent before the experiments took place. The informed consent was obtained for publication of identifying information/images in an online open-access publication.

Data analysis

Separate analyses were caried out for each ethnic group to examine the colour variables that might predict each preference rating; thus, the Caucasian dataset is the preference ratings of the Caucasian images judged by the Caucasian observers and the Chinese dataset is the preference ratings of the Chinese images judged by the Chinese observers. Inter-observer variability was high (Cronbach's $\alpha > 0.90$) for both the Caucasian and Chinese datasets[46]. The mean values and standard deviations of facial colour characteristics and preference ratings were calculated for both ethnic datasets. The Pearson Correlation Coefficient (two-tailed) was used to assess the relationships between the various facial colour characteristics and each of the three preference ratings: facial attractiveness, perceived healthiness, and perceived age. To further investigate the role of different colour characteristics in predicting the preference of real human faces, and identify the most important predictors, stepwise multiple regression analyses were performed separately on the Caucasian dataset and the Chinese dataset. All stepwise regression models were implemented using the function *ols_step_both_p()* in *olsrr* R package. The Variance Inflation factor (VIF) was used as an indicator to avoid multicollinearity in the model and the VIFs of all regression analyses were <2. For each multiple regression model, the *t*-test was used to test the regression coefficients of the colour predictors. The determination coefficient (R^2), a widely accepted standard statistic for the predictive success of the models, was used to evaluate the relative importance of various facial colour characteristics in preference prediction.

Declarations

Acknowledgement

We would like to acknowledge contributions statistic test and analysis by Dr Wanchang Lin, Experimental Officer Bioinformatics at Imperial College London, United Kingdom.

Author contributions

Designed research: Y.L., K.X., C.L. Performed research: Y.L., K.X., J.Y., C.L. Analyzed data: Y.L., K.X., M.P., S.W. Wrote the paper: Y.L., K.X., M.P., S.W.

Competing interests

The authors declare no competing interests.

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Figures

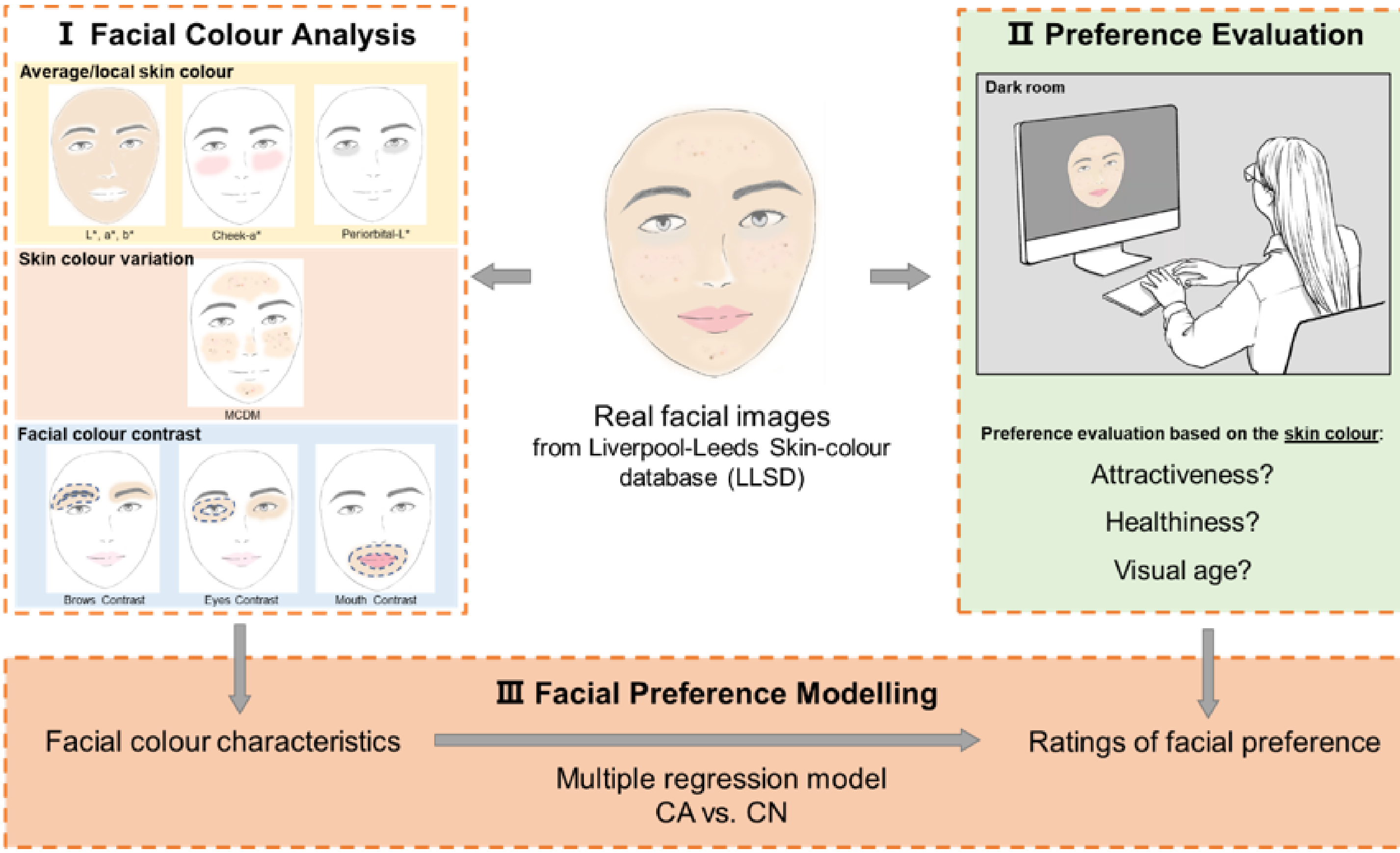

Figure 1

A schematic diagram of the key idea in this study. I. Analysis of various facial colour characteristics of 80 real facial images from LLSD II. Observers evaluated the colour appearance of the real facial images in terms of the three attributes of facial preference: attractiveness, perceived healthiness, and visual age. III. Multiple regression analyses were performed to predict facial preference from colour predictors. The cultural difference was investigated between Caucasian and Chinese populations.

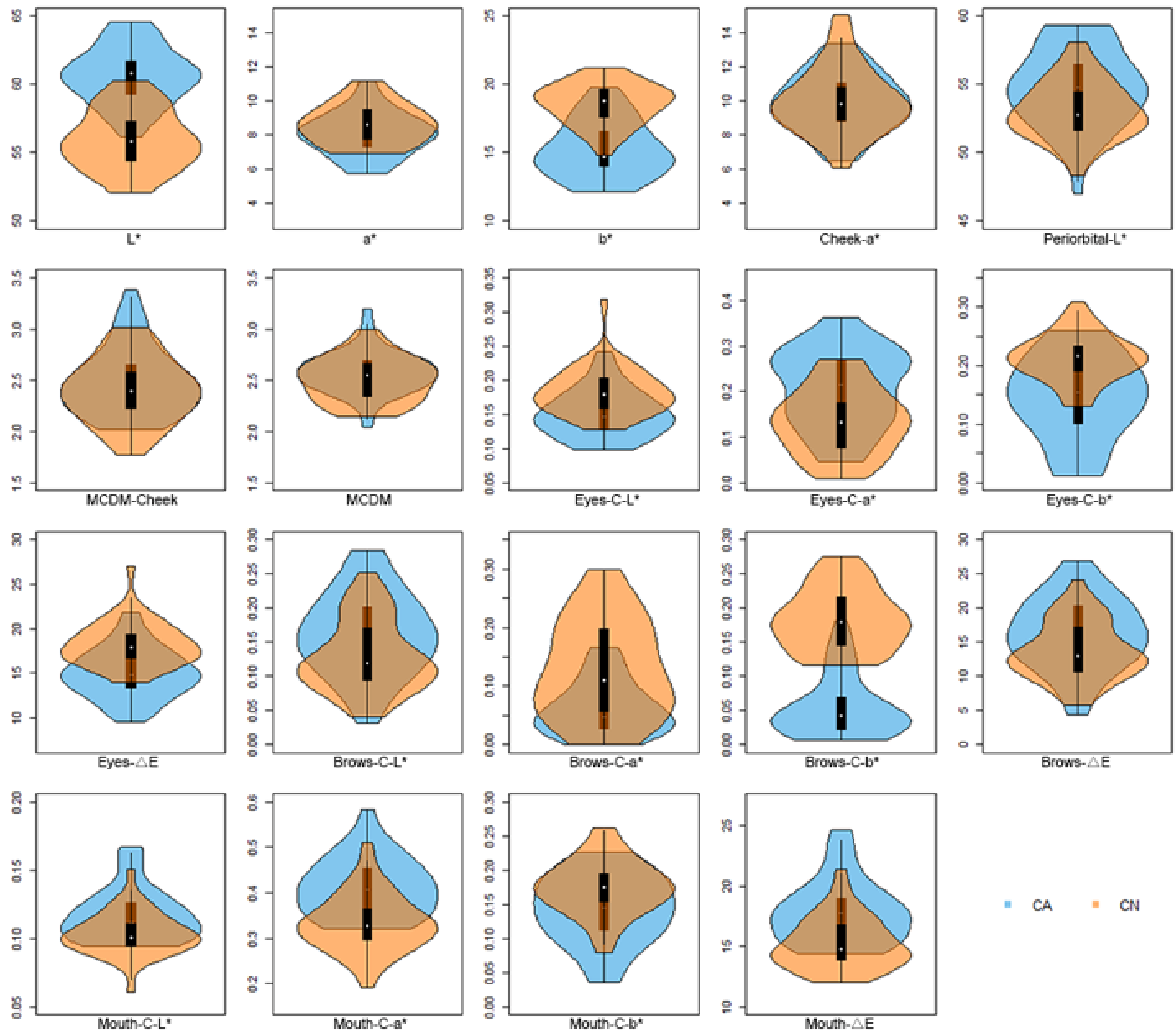

Figure 2

Violin plots showing range and variation of facial colour characteristics in CA and CN facial images.
White points indicate medians, black rectangles represent interquartile ranges.

Figure 3

The Pearson Correlations between each facial colour characteristic and facial attractiveness. Each bar chart represents the correlation coefficient (left darker bar chart: CA; right lighter bar chart: CN); all the negative coefficients are marked with (-) at the bottom of the bar charts; Asterisks above the bar charts indicate the statistical significance of each relationship: *p≤0.05, ** p≤0.01, ***p≤0.001.

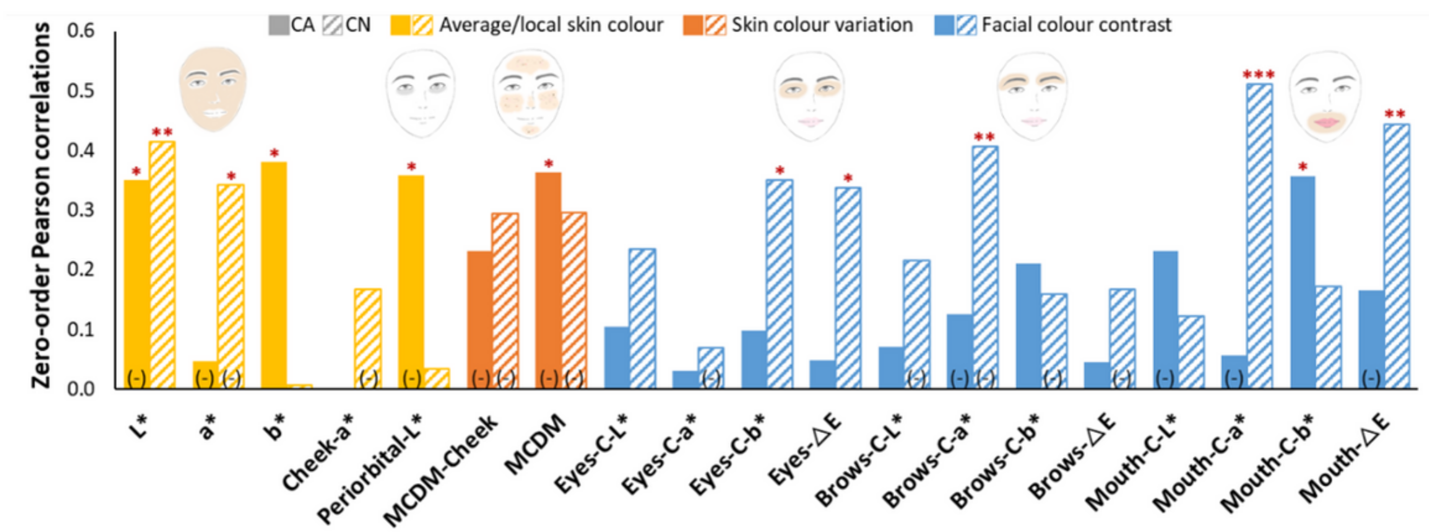

Figure 4

The Pearson Correlations between each facial colour characteristic and perceived healthiness. Each bar chart represents the correlation coefficient (left darker bar chart: CA; right lighter bar chart: CN); all the negative coefficients are marked with (-) at the bottom of the bar charts; Asterisks above the bar charts indicate the statistical significance of each relationship: *p≤0.05, ** p≤0.01, ***p≤0.001.

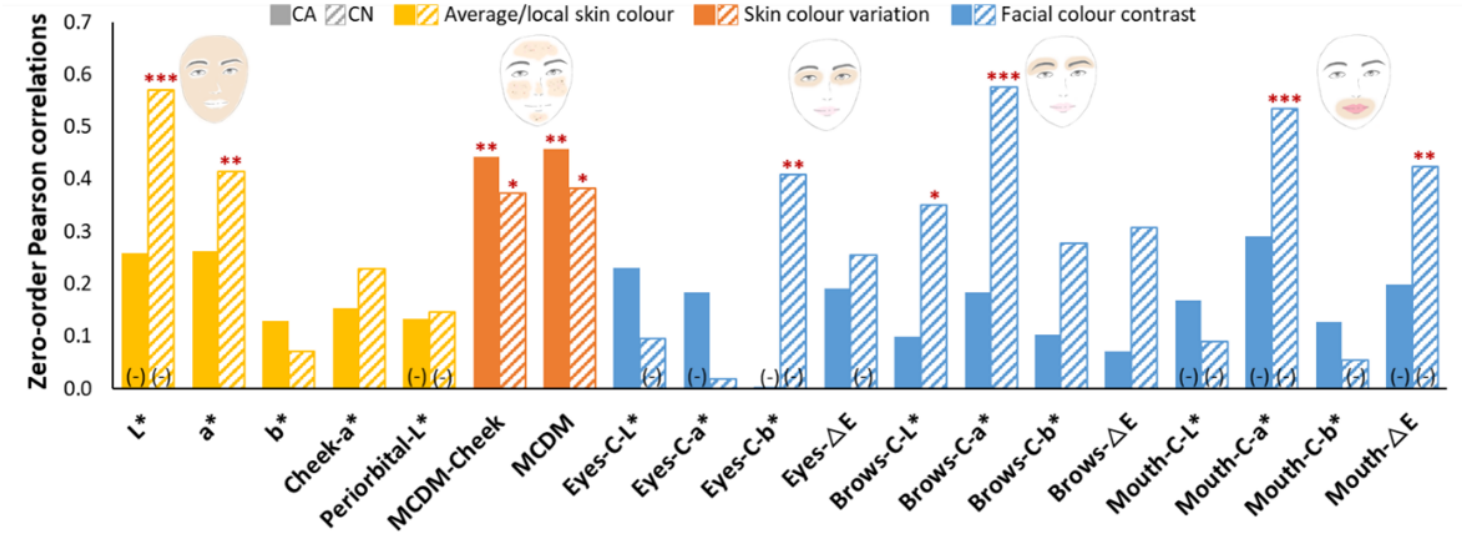

Figure 5

The Pearson Correlations between each facial colour characteristic and perceived age. Each bar chart represents the correlation coefficient (left darker bar chart: CA; right lighter bar chart: CN); all the negative coefficients are marked with (-) at the bottom of the bar charts; Asterisks above the bar charts indicate the statistical significance of each relationship: *$p \leq 0.05$, ** $p \leq 0.01$, ***$p \leq 0.001$.

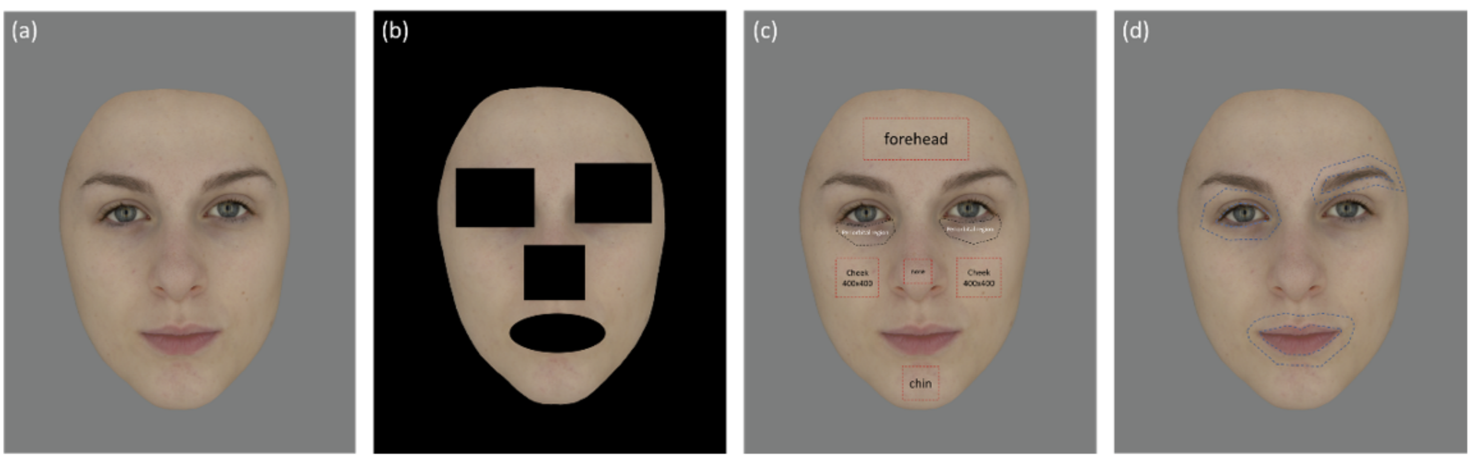

Figure 6

An example of the facial image and areas selected for calculating facial colour characteristics. (a) An example of the original facial image; (b) The facial area (the non-black area) used to calculate average facial colour; (c) Areas of interest used to calculate local skin colour and skin colour variation; (d) Areas of the features and the surrounding skin used to calculate facial colour contrast.

Supplementary Files

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- Supplementaryinformation.pdf