**Carotenoid Skin Coloration Enhances Face and Body Attractiveness: A Cross-Cultural Study**

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**Declarations of interest:** none

**Word count:** 3980

**Abstract**

Previous research has indicated that faces with higher levels of skin carotenoid-coloration are perceived as healthier and more attractive. However, it is not known whether this preference is specific to faces or reflects a more generalised preference in biological stimuli: e.g. non-face body parts. Moreover, it is not yet well-established whether the preference for carotenoid-coloration extends beyond Caucasian populations. Three studies were conducted to address these issues. In Studies 1 and 2, Caucasian and Hong Kong Chinese participants, respectively, selected the more attractive image in pairs of high and low carotenoid-coloration versions of images of Caucasian faces and body parts, and also for non-face/body-part control stimuli (scrambled faces). In Study 3, a similar study protocol was used with an independent sample of Hong Kong Chinese participants using stimuli generated from Chinese individuals. Results showed that high carotenoid-coloration was preferred across all three studies in faces and body parts, but not in the control stimuli. In addition, there was a stronger preference for high carotenoid-coloration in faces compared to body parts in Studies 1 and 2 – although this preference was not observed in Study 3. Overall, these findings demonstrate that higher levels of skin carotenoid-coloration are preferred both in face and body parts, but not in non-face stimuli, and that these preferences are evident in Caucasian and Hong Kong Chinese individuals.

Keywords: Skin colour, Cross-cultural, Facial attractiveness, Body attractiveness, Carotenoids, Health

**1. Introduction**

Physical attractiveness has important real-world implications. Attractive people tend to have better career prospects and income (Hamermesh & Biddle, 1993; Marlowe et al., 1996), higher social status (Anderson et al., 2001), greater bargaining power (Chaiken, 1979; Solnick & Schweitzer, 1999), and, virtually by definition, an advantage in mate attraction (Rhodes, 2006).

Although a range of factors are associated with physical attractiveness – including morphology (e.g. Perrett et al., 1998) and skin texture (e.g. Fink et al., 2001; Jones et al., 2004) – in recent years it has become evident that intra-ethnic variation in skin coloration is also of importance. Specifically, here we focus on ‘carotenoid-coloration’, which is associated with healthier (e.g. Foo et al., 2017; Pezdirc et al., 2018; Stephen et al., 2011) and more attractive (Foo et al., 2017; Lefevre & Perrett, 2015) facial appearance. Carotenoids are a group of yellow-red pigments contained in fruits and vegetables that when ingested in abundance are secreted in the sebum and then reabsorbed by the outer layers of skin (Alaluf et al., 2002), producing a marked increase in skin yellowness as well as minor changes in skin luminance and redness (Stephen et al., 2011). These skin colour changes have been shown to occur relatively quickly in response to dietary changes. For example, one study reported visible changes after six weeks following increased fruit and vegetable consumption (Whitehead et al., 2012b). Related work has reported similar changes following fruit smoothie consumption and beta carotene supplementation (Coetzee & Perrett, 2014; Tan, Graf, Mitra, & Stephen, 2015).

Because carotenoids are antioxidants and as such aid immune function, changes in skin carotenoid-coloration may provide a cue to current health. Indeed, plasma carotenoid levels change in response to parasite infestation (Koutsos et al., 2003) and experimentally induced acute sickness (Henderson et al., 2017). Moreover, lower carotenoid levels were also seen in individuals infected with HIV or malaria and those with elevated markers of infection (Friis et al., 2001).

The preferences for high carotenoid-coloration observed in faces may directly stem from the colour’s property as a cue to a person’s health status, rather than a more general bias toward this colour. Previous work shows that preferences are absent when carotenoid coloration is presented in a non-face stimulus (Lefevre, Ewbank, Calder, Von Dem Hagen & Perrett, 2013). Specifically, this study showed that faces that were transformed to appear high in carotenoid coloration were significantly more attractive than the same faces when transformed to appear low in carotenoid coloration. Additionally, the authors created scrambled colour-scapes that contained identical colour information to the high and low carotenoid versions of each face stimulus. These colour-scapes did not yield a preference for either high or low carotenoid coloration.

Further evidence that carotenoid-coloration preferences may be driven by the pigment’s property as a cue to current health comes from findings indicating that carotenoid coloration is preferred over melanin coloration (sun-tan) in populations who tend to think of a sun-tan as attractive. For example, Lefevre & Perrett (2015) showed that Caucasian faces with high carotenoid-coloration were found more attractive than Caucasian faces with high melanin-coloration. Similarly, Pezdirc et al. (2017) showed that in an Australian sample, participants who were asked to manipulate facial skin coloration to optimise healthy appearance typically increased carotenoid coloration but decreased melanin coloration.

Although a preference for carotenoid-coloration has now been demonstrated a number of times, some questions remain unanswered. Firstly, is this preference specific to faces or a more general target of human social perception? On the one hand models of face processing emphasise the special nature of faces (e.g. McKone et al., 2007, Wilmer et al., 2010). On the other hand, humans are clearly acutely sensitive to broader biological stimuli. For instance, infants preferentially orient to biological motion stimuli (Simion et al., 2008) and the body is routinely used as a source of social information (e.g. Aviezer et al., 2012; De Gelder, 2006). Moreover, non-face body parts also contain cues that are perceived as attractive, such as body mass, leg-to-body ratio, waist-to-hip ratio, and leg length (Furnham, Petrides & Constantinides, 2004; Kiire, 2016; Sorokowski & Pawlowski, 2008). Because skin carotenoid-coloration is likely also present outside the face, it is possible that carotenoid-coloration preferences might also be evident in non-face skin.

Secondly, does this carotenoid-coloration preference extend across cultures? To date, studies have shown that carotenoid-coloration preferences in faces are evident in Caucasian (Lefevre & Perrett, 2015; Pezdirc et al., 2017; Stephen et al., 2011), African (Coetzee et al., 2014; Stephen et al., 2012) and Malaysian Chinese (Tan, Graf, Mitra & Stephen, 2017; Tan, Tiddeman & Stephen 2018) participants, hinting at the possibility that these preferences may be universal. More recently, however, Han and colleagues (2018) examined a sample of mainland Chinese individuals living in the UK and found no preference for increased yellowness (a colour change similar to carotenoid-coloration) in either Chinese or Caucasian faces. As such, further investigation into preferences for carotenoid coloration across cultures is needed to more fully understand when and where such preferences are evident.

With these issues in mind, the current study sought to address the following questions: 1) Is high (vs low) carotenoid-coloration preferred in the face and in the body? 2) If evident, are these preferences for high carotenoid-coloration in face/body greater than those observed in a non-biological control stimulus? 3) Is the preference for high carotenoid-coloration in the face greater than this preference in the body? 4) Do these preferences exist in both Caucasian and Hong Kong Chinese individuals?

**2. Study 1**

**2.1 Method**

***2.1.1 Participants***

One hundred and thirty one Caucasian participants (45 male, 85 female, 1 ‘other’ sex; aged 18-61 years, mean age 21.08 years, SD = 6.38 years) were recruited via opportunity sampling from UK university students and their friends/family/social networks.

***2.1.2 Stimuli***

*Body Stimuli*. A Samsung EX2F digital compact smart camera was used to photograph 25 Caucasian undergraduate students (12 male, 13 female). Photographs were taken under constant indoor lighting at a distance of approximately 24 inches (60 cm) between body and camera. Settings of the camera were held constant across all acquired images. Participants were instructed to pose with their right hand, forearm, or ankle against a black background. The resultant images were then cropped and masked so that only the targeted body part was visible. If necessary, any nail polish coloration was tuned to a neutral colour using Photoshop CC 2014. Images were then set to a uniform size and the background was set to true black, to ensure a uniform background throughout. No further colour-calibration was performed. Finally, the skin colour of the body parts was transformed using PsychoMorph (Tiddeman, Burt & Perrett, 2001). Transforms were only performed on the skin portions of stimuli, leaving backgrounds and any non-skin areas unchanged.

The transform was performed along an approximated carotenoid-coloration axis measured as the average difference in skin coloration between those with high and low fruit and vegetable intake (Whitehead et al., 2012). Previous work indicates that this manipulation influences health and attractiveness perceptions (e.g. Lefevre et al., 2013; Tan et al., 2017). In order to mimic optimal carotenoid-coloration (Lefevre et al., 2013; Lefevre & Perrett, 2015), we added 9.4 (ΔE) units of carotenoid colour by adding 8.7 units of yellowness (b\* in CIELab colour-space), subtracting 2.2 units of lightness (L\*) and adding 2.8 units of redness (a\*) to all images. To mimic low, unhealthy carotenoid-coloration, we implemented the reverse manipulation (subtracted 9.4 ΔE) to all images. These transforms resulted in 25 pairs of hands, arms, and ankles (see Figure 1a for examples).

*Face Stimuli*. 25 composite faces (13 male, 12 female) were taken from previous work (Lefevre & Perrett, 2015). Composite faces are created by averaging the shape and colour of existing face photographs. Each of the composite faces used here was generated from three same-sex base images/identities taken from Caucasian undergraduate students. The base images were taken under controlled lighting conditions simulating daylight at a distance of approximately 3.2 feet (1 meter) and were subsequently colour-calibrated. Finally, these stimuli were manipulated in carotenoid coloration using the same procedure outlined above (Figure 1b).

 *Control Stimuli (Face Scramble).* Scrambled face images (Figure 1c) were used as control stimuli to examine the possibility that the high or low carotenoid preference was due to a sensory bias. Scrambled images were generated from the face stimuli described above (taken from Lefevre et al., 2013). To generate scrambled images, each RGB layer was transformed into amplitude and phase components using a Fast Fourier transform in Matlab. Noise patterns were generated by adding the same random phase spectrum to the original RGB phase spectra, leaving the relative phase between RGB layers intact. An inverse Fourier transform was then applied to the combined amplitude and phase spectra to generate the scrambled image. As a result, the relative phases of the RGB layers in the scrambled image are identical in order to their relative phases in the original image and the colour composition of the scrambled image is the same as the original image. These stimuli were used as controls as they provide identical colour information to the original face stimuli, including the skin portions but also for example colour from hair and lips. This approach controls for potential preferences stemming from colour contrast or reference effects, while ensuring that stimuli do no longer resemble faces or other biological entities.

***2.1.3 Procedure***

Participants took part in the study over the internet. Previous work shows that colour preferences between lab and online studies do not differ in statistically significant way (Lefevre et al., 2013). Participants completed 120 trials across 5 blocks: control stimuli (20 trials); body parts - hands (25 trials), forearms (25 trials), ankles (25 trials); and faces (25 trials). In each trial the high and low carotenoid version of the same image were presented side by side. Participants were required to choose the more attractive one. Since it has already been shown that people have a strong preference for high carotenoid faces, the block of faces was presented as the final (fifth) block to avoid contamination of the other blocks. Similarly, the control block was presented as the first block to obtain unbiased responses. The blocks of hands, forearms, and ankles were presented in random order in between the control and face blocks. The order of stimuli presented within blocks, and the side (left or right) on which the high and low carotenoid image appeared, were randomised for all blocks.

When data collection was completed we generated preference scores for face, body (aggregated across the three body parts as there was no a priori reason to think that any specific body part would be unique), and control stimuli. Preference scores were calculated as percent of trials in which the high carotenoid version was preferred (e.g. if a participant selected the high carotenoid face in 10 out of 20 trials, their score would be 50%).

**2.2 Results**

 The high carotenoid-coloration versions of faces, body parts, and control stimuli were preferred in 85.95% (faces), 80.54% (body parts), and 54.05% (controls) of trials. Shapiro-Wilk tests showed that the preference of the high carotenoid-coloration versions of all stimuli did not significantly deviate from normality (all p ≥ .16). One-sample t-tests with stimulus as the unit of analysis showed that the preferences for high-carotenoid coloration were significantly above chance levels (i.e. 50%): faces - *t*(24) = 36.52, *p* < .001, *d* = 7.30; body parts - *t*(74) = 26.83, *p* < .001, *d* = 3.10; controls - *t*(19) = 5.59, *p* < .001, *d* = 1.25.

We next examined whether carotenoid preferences differed across face, body, and controls using participants as the unit of analysis. The Shapiro-Wilk test showed that the carotenoid preferences significantly deviated from normality: faces (W(131) = 0.76, *p* < .001), body parts (W(131) = 0.85, *p* < .001) and controls (W(131) = 0.96, *p* < .001). Accordingly, a non-parametric Friedman test was conducted and this showed a significant difference in carotenoid preferences across faces, body parts, and controls (χ2(2) = 79.48, *p* < .001). Pairwise comparisons using Wilcoxon’s signed-rank test with Bonferroni correction showed that the preference for high carotenoid faces was significantly greater than the preference for high carotenoid body parts (*p* < .001), and that the preference for high carotenoid in both faces and body parts was significantly greater than in the controls (both *ps* < .001).

**2.3 Brief Discussion**

 In Study 1 we saw clear evidence that higher levels of carotenoid-coloration are preferred in the face and also in non-face body parts in a sample of Caucasian participants assessing Caucasian faces and body parts. These findings indicate that preferences for high carotenoid-coloration exist beyond the face, albeit to a somewhat lesser extent.

 With these findings in mind, we next sought to examine whether preferences for carotenoid-coloration in both faces and body parts extended to a Hong Kong Chinese sample of observers in light of recent work (Han et al., 2018) reporting an absence of such preferences in Chinese observers living in the UK. To this end, we used the identical stimuli set of Caucasian faces as reported above and recruited a sample of Hong Kong Chinese participants to complete the experiment.

**3. Study 2**

**3.1 Methods**

***3.1.1 Participants***

Sixty nine Chinese participants from Hong Kong (23 male, 46 female; aged 18-27 years, mean age 21.90 years, SD = 1.72 years) were recruited via opportunity sampling and took part over the Internet. None of the participants had spent longer than five consecutive months abroad.

***3.1.2 Stimuli and Procedure***

We used the identical study protocol as in Study 1 (note English is an official language in Hong Kong).

**3.2 Results**

 The high carotenoid-coloration versions of image pairs were preferred in 74.26% (faces), 67.23% (body parts), and 50.00% (control stimuli) of trials. Shapiro-Wilk tests showed that the preference of the high carotenoid-coloration versions of all stimuli did not significantly deviate from normality (all p ≥ .22). One-sample t-tests showed that carotenoid-coloration preferences were significantly above chance levels for faces - *t*(24) = 12.34, *p* < .001, *d* = 2.47, and body parts - *t*(74) = 9.95, *p* < .001, *d* = 1.15. There was no evidence for a preference in the controls - *t*(19) < 0.01, *p* > .99, *d* < .001.

We next examined whether carotenoid preferences differed across face, body, and controls using participants as the unit of analysis. The Shapiro-Wilk test showed that the carotenoid preferences were significantly non-normal: faces (W(69) = 0.89, *p* < .001), body parts (W(69) = 0.93, *p* = .001) and controls (W(69) = 0.93, *p* = .001). Accordingly, a non-parametric Friedman test was conducted and this showed a significant difference in the carotenoid preferences across faces, body parts, and controls (χ2(2) = 26.17, *p* < .001). Subsequent pairwise comparisons using Wilcoxon’s signed-rank test with Bonferroni correction indicated that the preference for high carotenoid faces was significantly higher than that for high carotenoid body parts (*p* = .02), and that the preference for high carotenoid faces and body parts were significantly greater than that for high carotenoid controls: faces vs controls (*p* < .001); body parts vs controls (*p* = .002).

**3.3 Brief Discussion**

 In Study 2 we observed that our sample of Hong Kong Chinese individuals showed a clear preference for higher levels of carotenoid-coloration in the face and also in non-face body parts. These results indicated a degree of cross-cultural generalisability of this phenomenon. However, one concern was that our Hong Kong Chinese participants would have been aware that the target stimuli were drawn from a Caucasian sample (certainly for the face stimuli, and likely for the body stimuli) and thus made their judgements in line with perceptions of Western beauty ideals. To this end, we repeated this study protocol but this time using stimuli drawn from Chinese individuals.

**4. Study 3**

**4.1 Methods**

***4.1.1 Participants***

One hundred and forty one participants from Hong Kong (64 male, 75 female, 2 other sex, aged 19-67 years, mean age 42.21 years, SD = 13.39 years) were recruited via opportunity sampling and took part over the Internet. None of the participants had spent longer than a full continuous month abroad.

***4.1.2 Stimuli and Procedure***

To generate Chinese stimuli, 26 Chinese individuals from Hong Kong and mainland China, (13 male, 13 female) took part in the same basic procedure as in Study 1. In addition, we took Chinese face stimuli (N=23, 11 male) from previous work (Stephen et al., 2018; Tan et al., 2018). These stimuli depict Chinese undergraduate students, were taken in front of a uniform grey background under daylight simulating lighting conditions and were subsequently colour calibrated. Because of an experimenter error the control stimuli were not presented to our participants in this study. As such, there were 4 blocks: 26 trials each for hands, forearms, ankles; 23 trials for faces (see Figure 2 for examples). Block order was randomised. The order of stimuli presented within blocks, and the side (left or right) on which the high and low carotenoid image appeared, were also randomised.

**4.2 Results**

The high carotenoid-coloration versions of the faces and body parts were preferred in 60.65% and 64.22% of trials respectively. Shapiro-Wilk tests showed that the preference of the high carotenoid-coloration versions of all stimuli were normally distributed (all p ≥ .36). One-sample t-tests showed that carotenoid-coloration preferences were significantly above chance level for faces (*t*(22) = 4.42, *p* < .001, *d* = 0.92) and body parts (*t*(77) = 14.38, *p* < .001, *d* = 1.63).

We next examined whether carotenoid preferences differed across faces and body-parts using participants as the unit of analysis. The Shapiro-Wilk test showed that the carotenoid preferences significantly deviated from normality: faces (W(141) = 0.95, *p* < .001) and body parts (W(141) = 0.91, *p* < .001). Accordingly, a Wilcoxon signed-rank test was conducted and this showed that the preference for high carotenoid faces did not significantly differ from this preference in body parts (*Z* = 1.85, *p* = .06).

**4.3 Brief Discussion**

 These results provided further confirmation that Hong Kong Chinese participants show a preference for face and body parts which are higher in carotenoid-coloration, and that this preference is not limited to Caucasian stimuli.

**5. General Discussion**

The three studies presented here demonstrate that high skin carotenoid-coloration in both faces and body parts is perceived as attractive compared to lower carotenoid-coloration. We also observed consistent evidence that these preferences were substantially greater than those seen for non-human colour-scapes. These findings substantiate prior work showing that preferences for high carotenoid-coloration are not a sensory bias to images with increased yellowness (Lefevre et al., 2013), but instead appear to reflect a specific preference for this coloration in skin. Of further importance, these preferences were present both for Caucasian and Hong Kong Chinese participants.

Our findings show cross-cultural consistency in skin colour preferences and are in line with previous studies that showed that Malaysian Chinese, Africans, and Caucasians perceived faces with increased skin yellowness as more attractive and healthy looking (Tan et al.,2017; Tan et al., 2018; Coetzee et al., 2012; Stephen et al., 2011; Stephen et al., 2012). Taken together, these findings point to the possibility of a universal preference for high carotenoid skin coloration as a cue to current health. Furnham and Reeves (2006) and Rhodes et al. (2001) have established intercultural commonalities in attractiveness judgements based on facial neoteny and averageness, and these commonalities pertain to health and fertility cues. Universal preferences for carotenoid-coloration, as a cue to current health, fit well with these previous results.

Our results differ from those of Han et al. (2018), who suggested that Chinese in the UK preferred faces with decreased yellowness. Importantly, however, while Han et al. (2018), manipulated images along the yellow colour axis in isolation, we manipulated images in line with an empirically derived approximation of carotenoid-coloration. This manipulation predominately affects yellowness but also increases redness and reduces lightness and is a more biologically meaningful manipulation than that of single colour axis. These methodological differences may explain the different results reported in our study compared to that of Han et al. (2018). Alternatively, it is also possible that different levels of exposure to foreign cultures or cultural diversity could lead to different results. Indeed, it has been suggested that, due to culture differences, the Malaysian Chinese and mainland Chinese focus on different facial information to recognise facial identities (Tan, Stephen, Whitehead, & Sheppard, 2012 and Blais, Jack, Scheepers, Fiset & Caldara, 2008).

In Study 1 and 2 we observed a greater preference for high carotenoid-colour in faces than in body parts. These findings are consistent with a large body of evidence arguing that the face plays a special role in interpersonal interaction. Information such as age, ethnicity, emotional states, trustworthiness, and social status (Bjornsdottir & Rule, 2017; Ekman & Friesen, 1971; Rhodes, 2009; Tanaka et al., 2004; Willis & Todorov, 2006) of a person can be perceived at a glance of the face. Faces also play a disproportionate role in overall physical attractiveness (Currie & Little, 2009; Peters et al., 2007).

Of note, however, our Hong Kong Chinese sample in Study 3 did not show greater preference for high carotenoid-coloration in faces than in body parts. It is possible that the social norms in Chinese culture favouring a fairer skin tone may have somewhat attenuated the preference for high carotenoid coloration specifically in faces in the Chinese population. Studies have suggested that males and females from Asian regions, including Hong Kong, prefer light skin tones in both the same and the opposite sex (Krishen et al., 2014; Leong, 2006; Li et al., 2008). And advertisements for face skin-whitening products or medical beauty services are ubiquitous in Hong Kong and other Asian countries. More than 70% of the models of facial skin care advertisements in China exhibit the lightest skin colour on the skin tone scale, compared to 25% of that in the US (Xie and Zhang, 2013). As such, the deep-rooted association between white skin and desirability, and the extensive exposure of white-skinned faces on advertisements may explain why Chinese showed a somewhat lower preference for high carotenoid-coloration in faces of their own race. At the same time, these observations make it all the more striking that the Hong Kong Chinese participants still showed a high carotenoid-coloration preference. It may be that the putative adaptive information stemming from carotenoid-coloration is not fully suppressed by cultural imperatives.

The current study lends support to Whitehead, Ozakinci, Stephen & Perrett (2012a), in that the findings not only enhance our understanding of the role of carotenoids in attractiveness, but also have public health implication towards healthy eating to prevent illnesses. Skin colour has been shown to respond to increased intake of fruits and vegetables relatively quickly, with visible changes occurring within six weeks (Whitehead et al., 2012b). With the benefit of improving facial and body appearance, our findings can foster the motivation of people to consume more carotenoid-rich fruits and vegetables, which have been shown to reduce risk of cancer, cardiovascular disease, cataract and skin disease (Agarwal & Rao, 2000; Reiss et al., 2012; Stahl, & Sies, 2012; Tan et al., 2008).

Tan et al. (2018) argued that studies finding significant preferences for carotenoid colour were conducted in laboratories with calibrated monitors, whereas those finding no preferences were conducted online with uncalibrated monitors. However, several studies, including the current one, have shown carotenoid coloration preferences online. Indeed, Lefevre and colleagues (2013) found no evidence for a difference in preferences between lab and online samples. Moreover, if effects were only achievable under strictly controlled lab conditions, one might question the validity of skin carotenoid-coloration as a real-world cue in social interactions where skin will be seen under many varying lighting conditions.
 One methodological limitation of the current work was that the control stimuli were not included in Study 3. A more comprehensive comparison between the two ethnicities could be achieved if the control stimuli were included. Moreover, future work may wish to assess whether carotenoid preferences are lower in Chinese than Caucasian participants. Another potential limitation concerns the fact that the control stimuli were not reflective of real-world entities and so might be encoded differently. As such, future work might want to consider using additional forms of control stimuli in order to provide a more conservative test of the claim that carotenoid coloration preferences are specific to human skin.

To conclude, high skin carotenoid-coloration in both face and body parts – but not in the control stimuli – was perceived as more attractive compared to lower carotenoid-coloration. These preferences were present both for Caucasian and Hong Kong Chinese participants – consistent with the perspective that carotenoid-coloration reflects a universal signal of health and fitness.

 **Acknowledgements:** We thank Ian Stephen for stimuli provided for study 3.

**Data availability**

The data associated with this research are available at <https://osf.io/s4z32/>.

**Funding**

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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**Figure Captions**Figure 1. Caucasian image set with (a) body stimuli, (b) face stimuli and (c) control stimuli (Fourier transformed faces). Images on the left (right) are with high (low) carotenoid skin colour.

Figure 2. Chinese image set with (a) body stimuli and (b) face stimuli. Images on the left (right) are with high (low) carotenoid skin colour.