It is all in the face: carotenoid skin coloration loses attractiveness outside the face

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Recently, the importance of skin colour for facial attractiveness has been recognized. In particular, dietary carotenoid-induced skin colour has been proposed as a signal of health and therefore attractiveness. While perceptual results are highly consistent, it is currently not clear whether carotenoid skin colour is preferred because it poses a cue to current health condition in humans or whether it is simply seen as a more aesthetically pleasing colour, independently of skin-specific signalling properties. Here, we tested this question by comparing attractiveness ratings of faces to corresponding ratings of meaningless scrambled face images matching the colours and contrasts found in the face. We produced sets of face and non-face stimuli with either healthy (high-carotenoid coloration) or unhealthy (low-carotenoid coloration) colour and asked participants for attractiveness ratings. Results showed that, while for faces increased carotenoid coloration significantly improved attractiveness, there was no equivalent effect on perception of scrambled images. These findings are consistent with a specific signalling system of current condition through skin coloration in humans and indicate that preferences are not caused by sensory biases in observers.

1. Introduction

Skin colour distribution and homogeneity affect judgements of health, age and attractiveness from faces [1–3]: more homogeneous skin is perceived as more positive. Importantly, overall skin coloration has also been shown to affect perceptions of health and attractiveness. In particular, increased skin yellowness is associated with healthier [4] and more attractive [5] appearance. This effect is thought to arise as a function of carotenoids [6,7] which, when ingested through fruit and vegetables, produce a marked increase in skin yellowness as well as minor changes in skin luminance and redness [8]. Because carotenoids are antioxidants, changes in carotenoid skin coloration may provide a cue to current health. Indeed, plasma carotenoid levels change with parasite infestation [9] and skin colour rapidly responds to dietary changes [10,11].

Carotenoids have been negatively linked to disease in humans; for example, lower carotenoid levels are seen in individuals suffering from HIV or malaria and in individuals with elevated serum α1-antichymotrypsin (an indicator of infection; [12]). Furthermore, serum carotenoid levels were inversely linked to all-cause mortality in a large US sample [13]. Conversely, carotenoid supplementation has proved beneficial for thymus gland growth in children [14] and increases T-lymphocyte number in healthy adults [15]. Accordingly, as antioxidants, carotenoids are likely to be depleted by oxidative stress, with disease reducing plasma levels and skin colour. Together these
findings indicate that carotenoid-related skin colour is attractive and healthy looking because it signals current condition and health status in humans. Indeed, from a theoretical perspective, the advantages of mate choice based on indices of current health may exceed the advantages of choice based on indices of longer term immunity [16], thus rendering cues to current health pivotal in decisions concerning attractiveness.

However, it is possible that increased skin carotenoid coloration is perceived as attractive not because it signals current health, but because this particular hue is perceived as more aesthetically pleasing compared with a less carotenoid-like colour. This hypothesis would be in line with a ‘sensory bias’ explanation for sexual signalling, whereby a particular sensory value is preferred in mate choice because the sensory systems are pre-adapted to such stimulation [17,18]. Such pre-adaptations may reflect shape, sound or—of relevance here—colour preferences [19–22]. Support for sensory bias potentially influencing human aesthetic sense comes from work on colour judgments indicating consensus preferences for particular colour (hue) and lightness combinations in the absence of any other cues [23–25]. In particular, these studies find cross-cultural preferences for light-blues and aversions to dark-yellows [23–25], yet this bias may not fit the observed attraction to carotenoid skin coloration.

If carotenoid colour preference reflects a general aesthetic colour preference, carotenoid-associated skin colour should be seen as attractive in arbitrary (non-face) patterns. Here, we tested this prediction by assessing people’s perceptions of both faces and scrambled faces (matched in spatial frequency content, luminance and hue to the faces; figure 1).

2. Material and methods

(a) Participants
Fifty-six Caucasian participants (14 male) took part. Of these, 26 participants (seven male, mean age = 30.6, age range = 16–49 years) took part in the scrambled image condition (all online) and 30 (10 male, mean age = 22.90, age range = 16–44 years) participants completed the face image condition (13 in-laboratory and 17 online).

(b) Stimuli
Stimuli were constructed from 20 Caucasian faces (10 male). Faces were photographed under standardized d65 lighting, approximating northern European daylight. Following colour calibration according to a GretagMacbeth Mini ColorChecker included in each photograph [4], images were transformed in skin colour. The transform was performed according to an approximation of carotenoid coloration determined as the difference between high and low fruit and vegetable intake [10]. Previous work indicates that this manipulation increases health and attractiveness perceptions [4,5,10]. To simulate healthy skin colour, following a pilot study assessing optimal health–colour levels (see the electronic supplementary material), we altered colour by 9.4 (ΔE) units along the carotenoid axis by adding 8.7 units of yellowness (b* in CIELab colour-space; [4]), subtracting 2.2 units of lightness (L*) and adding 2.8 units of redness (a*) to all faces. To simulate unhealthy skin colour, we performed the reverse manipulation. CIELab colour-space was used as it is modelled on the human visual system and designed to be perceptually uniform, with one unit being the same magnitude in all dimensions [26]. This created a total of 40 face stimuli (20 pairs). Images were cropped to facial boundaries. To generate scrambled images, each RGB layer was transformed into amplitude and phase components using a Fast Fourier transform. 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 (figure 1).

(c) Procedure
Participants either rated all 40 face images or all 40 scrambled stimuli on a computer. Each stimulus was presented in isolation, located centrally on a white background. For the subset of participants who completed the study in-laboratory, the stimuli were presented on a colour-calibrated CRT monitor, in a dark booth. Stimulus order was fully randomized. Participants were asked to indicate how attractive (face condition) or ‘aesthetically pleasing’ (scrambled condition) each image was on a 7-point Likert scale (1 = very unattractive/not at all aesthetically pleasing; 7 = very attractive/very aesthetically pleasing). There was no time limit for responses.

3. Results
In order to validate the use of online data for colour-based research, we compared ratings for the high- and low-carotenoid faces collected in-laboratory (M = 3.43, s.d. = 0.56) and online (M = 3.08, s.d. = 0.57). The face colour difference used here has been reported to yield reliable preferences [8] and was thus suitable for this comparison. A repeated measures ANOVA with colour as repeated measure (low-/high-carotenoid colour) and location (in-laboratory/online) as between subjects factor showed no interaction between colour and location (F(1,28) = 0.18, p = 0.66), indicating similar validity of online data compared with in-laboratory data. It also indicates that variation in colour representation across monitors used online is outweighed by the ‘signal’ of the carotenoid colour. For subsequent analyses, these data were therefore collapsed (although results were unchanged for online data only).

For each image, we collapsed ratings across participants. A mixed model by items ANOVA, with colour (high/low) as repeated measure and condition (scrambled/faces) as between item factor revealed no main effect of colour (F(1,28) = 2.77, p = 0.10, η² = 0.07) but showed a large significant interaction between condition and colour (F(1,28) = 7.67, p = 0.009, η² = 0.21; figure 2). Subsequent paired-sample t-tests indicated no difference in ratings for high- (M = 3.18, s.d. = 0.24) and low- (M = 3.23, s.d. = 0.26) carotenoid colour stimuli in the scrambled condition (t(19) = 0.74, p = 0.47). In the face condition however, high-carotenoid colour (M = 3.28, s.d. = 0.65) stimuli were rated as significantly more attractive than low-carotenoid colour (M = 3.09, s.d. = 0.65) stimuli (t(19) = 3.52, p = 0.002). Additionally, while for the face condition consistency of ratings across participants was high (Cronbach’s α = 0.93; online-only: α = 0.89), there was low agreement in the scrambled condition (α = 0.08), suggesting no consistent preference for scrambled images.

4. Discussion
Here, we demonstrate context dependency of preferences for carotenoid-linked skin colour. When healthy high-carotenoid colour was presented as skin colour in faces, participants rated the faces as more attractive compared with faces with unhealthy (low-carotenoid) skin colour. However, when the same faces were presented as scrambled images that no longer resembled faces, participants showed no preference for either healthy-colour or unhealthy-colour versions. These results indicate that healthy skin colour is found attractive because it signals current condition, not because of a sensory bias towards yellow colours. Sensory biases are thought to evolve independently of mate choice preferences. They may, for example, evolve to enable an individual to recognize particular stimuli (e.g. food and predators) or as a function of specific physiological properties of the organism’s sensory system. Subsequently, the sensory bias may lead to preferences for opposite sex signals that exploit the salience and behavioural orientation to particular colours, sounds or movements [19–22]. Although there was no significant difference in our data with respect to preferences for high- or low-carotenoid colour in scrambled images, previous research suggests that in the absence of context, dark yellow hues (similar to healthy high-carotenoid skin colour) are often found unappealing, perhaps because they are associated with bodily secretion and excretion products, and rotten foods [24].

The current findings then, render a sensory bias explanation of our data unlikely and provide evidence consistent with the existence of mechanisms attuned to current health cues. Our evidence provides no information on the ontogeny of such mechanisms but we note there is opportunity for learning about the associations between health and skin colour, much as there is for learning associations between fruit colour and ripeness. Work indicating that these skin colour preferences exist cross culturally and even in dark-skinned (e.g. African) individuals [8] provides further support for an evolved mechanism. Good current health is of great importance not only for mates [16] but also in social interactions involving trust and cooperation. In conclusion, we provide evidence for a signalling system of current condition through carotenoid-linked skin coloration in humans.

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References


