Fruit over sunbed: Carotenoid skin colouration is found more attractive than melanin colouration

Carmen E. Lefevre & David I. Perrett

a Centre for Decision Research, Leeds University Business School, United Kingdom
b School of Psychology and Neuroscience, University of St Andrews, Fife, United Kingdom

Accepted author version posted online: 11 Jul 2014. Published online: 10 Sep 2014.

To cite this article: Carmen E. Lefevre & David I. Perrett (2014): Fruit over sunbed: Carotenoid skin colouration is found more attractive than melanin colouration, The Quarterly Journal of Experimental Psychology, DOI: 10.1080/17470218.2014.944194

To link to this article: http://dx.doi.org/10.1080/17470218.2014.944194
Fruit over sunbed: Carotenoid skin colouration is found more attractive than melanin colouration

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1Centre for Decision Research, Leeds University Business School, United Kingdom
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Skin colouration appears to play a pivotal part in facial attractiveness. Skin yellowness contributes to an attractive appearance and is influenced both by dietary carotenoids and by melanin. While both increased carotenoid colouration and increased melanin colouration enhance apparent health in Caucasian faces by increasing skin yellowness, it remains unclear, firstly, whether both pigments contribute to attractiveness judgements, secondly, whether one pigment is clearly preferred over the other, and thirdly, whether these effects depend on the sex of the face. Here, in three studies, we examine these questions using controlled facial stimuli transformed to be either high or low in (a) carotenoid colouration, or (b) melanin colouration. We show, firstly, that both increased carotenoid colouration and increased melanin colouration are found attractive compared to lower levels of these pigments. Secondly, we show that carotenoid colouration is consistently preferred over melanin colouration when levels of colouration are matched. In addition, we find an effect of the sex of stimuli with stronger preferences for carotenoids over melanin in female compared to male faces, irrespective of the sex of the observer. These results are interpreted as reflecting preferences for sex-typical skin colouration: men have darker skin than women and high melanization in male faces may further enhance this masculine trait, thus carotenoid colouration is not less desirable, but melanin colouration is relatively more desirable in males compared to females. Taken together, our findings provide further support for a carotenoid-linked health-signalling system that is highly important in mate choice.

Keywords: Carotenoids; Skin colour; Skin yellowness; Melanin; Attractiveness; Health; Sex differences

A number of factors have been established as influencing facial attractiveness. While most research on factors influencing attractiveness has focused on facial shape (for a review, see, for example, Rhodes, 2006) with averageness, symmetry, and sexual dimorphism being the most prominent examples, more recent work has highlighted the importance of skin attributes in the perception of attractiveness. In particular, the colour and texture of the skin have been found to influence perceptions of attractiveness (Coetzee et al., 2012; Fink, Grammer, & Matts, 2006; Fink, Grammer, & Thornhill, 2001; Matts, Fink, Grammer, & Burquest, 2007; Stephen et al., 2012). Increased skin yellowness is perceived as healthy looking (Scott, Pound, Stephen, Clark, & Penton-Voak, 2010; Stephen, Coetzee, Law-Smith, & Perrett, 2009; Stephen, Coetzee, & Perrett, 2011; Stephen et al., 2012; Stephen, Law-Smith, Stirrat, & Perrett, 2009), yet changes in skin yellowness can arise as a result of at least two distinct processes: melanization (tanning) and carotenoid ingestion (Edwards & Duntley, 1939; Stamatas, Zmudzka, Kollias, & Beer, 2004). Previous work...
indicates that the isolated yellowness component of skin (b* in the CIELab colour system) as well as both melanin-associated colouration and carotenoid-associated colouration, increase perceptions of health (Stephen et al., 2011; Stephen, Law-Smith et al., 2009). Furthermore, there is some evidence for a greater impact of carotenoid than melanin colouration, at least for health perceptions (Stephen et al., 2011; Whitehead, Ozakinci, & Perrett, 2012), but it remains unclear whether attractiveness attributions follow a similar pattern. Here we test, first, whether both carotenoid colouration and melanin colouration affect attractiveness perception, and second, whether carotenoid colouration is preferred over melanin colouration in judgements of facial attractiveness.

Previous work assessing the perceptual importance of skin colour and texture homogeneity indicates that these properties contribute to the perception of traits such as attractiveness, health, and age (Fink et al., 2001, 2006; Matts et al., 2007). Fink et al. (2001) report that a more homogenous skin colour distribution is associated with higher levels of attractiveness. A more detailed assessment of colour distributions indicated that homogenous melanin and haemoglobin chromophore distributions positively enhance ratings of health, youthfulness, and attractiveness when assessing full-face images of females (Fink et al., 2006) and patches of skin in isolation (Matts et al., 2007). Additionally, in a sample of male faces, Jones et al. (2004) showed that health ratings of skin patches positively correlated with attractiveness ratings of the corresponding full-face images, indicating an influence of skin colour and texture on attractiveness perception in male faces.

While these studies demonstrate the importance of skin colour distribution and homogeneity, a growing body of work has also assessed the influence of overall skin colouration. In particular, participants enhanced both skin redness (as measured by the CIELab a* axis) and skin yellowness (as measured by the CIELab b* axis) when asked to maximize the healthy appearance of faces (Stephen, Law-Smith et al., 2009). Similarly, recent work assessing both European and African males, as well as African females, found that skin yellowness (b*) significantly predicted attractiveness perception in un-manipulated images, and showed that skin colour was a more influential predictor of attractiveness than sexual dimorphism in face shape (Coetzee et al., 2012; Scott et al., 2010; Stephen et al., 2012). While these studies were performed assessing pure colour levels (i.e., the yellowness or redness axis in isolation), other research has linked health perceptions to naturally occurring skin pigments: within the domain of skin redness, participants increased the amount of oxygenated blood colour more than deoxygenated blood colour, to maximize the appearance of health in faces (Stephen, Coetzee et al., 2009). These findings are in line with previous work showing positive links between levels of blood oxygenation and cardiovascular fitness (Armstrong & Welsman, 2001; Johnson, 1998) and between blood deoxygenation and ill health (Ponsonby, Dwyer, & Couper, 1997).

Similarly, and of importance here, skin yellowness is influenced by two major pigments: melanin and carotenoids. While melanin is produced by the melanocytes, cells contained within the skin, mainly in response to exposure to UV light (Hearing, 1997), carotenoids are obtained through fruit and vegetable consumption and are deposited onto the skin (Alaluf, Heinrich, Stahl, Tronnier, & Wiseman, 2002). When asking participants to manipulate either a beta-carotene-associated colouration axis or a melanin-associated colouration axis to maximize the healthy appearance of Caucasian faces, Stephen et al. (2011) found that although both pigments were increased, carotenoid colouration was increased relatively more than melanin colouration. Importantly, when participants were given the option to change both carotenoid colouration and melanin colouration within the same trial, they predominantly added carotenoid colouration to the presented faces, with only a small amount of melanin colouration being added. Similar results were also obtained in a more recent study assessing the effect of a broader range of carotenoid colours on healthy appearance by using empirically derived skin tones associated with high fruit and vegetable consumption (Whitehead, Re, Xiao, Ozakinci, & Perrett, 2012).
Taken together, these results indicate that carotenoid colouration is a more important factor in healthy appearance than melanin colouration. These findings are in line with the assumption that carotenoid levels provide an accurate cue for current health. For example, plasma carotenoid levels can change within days in response to dietary changes (Stahl et al., 1998) and parasite infestation (Koutsos, Christopher Calvert, & Klasing, 2003) and skin colour has been shown to respond to dietary changes within a few weeks (Whitehead, Re et al., 2012). Furthermore, lower carotenoid levels are seen in individuals suffering from HIV or malaria and in individuals with elevated serum α1-antichymotrypsin (an indicator of infection; see Friis et al., 2001). Similarly, serum carotenoid levels were inversely linked to all-cause mortality in a large US sample (Shardell et al., 2011). Carotenoid supplementation, on the other hand, has been shown to increase T-lymphocyte counts in healthy adults (Alexander, Newmark, & Miller, 1985) and has beneficial effects for thymus gland growth in children (Seifter, Rettura, & Levenson, 1981). Since carotenoids act as antioxidants, they are likely to be depleted by oxidative stress, reducing plasma levels and skin yellowness in times of disease.

While the work on carotenoids to date has been intriguing, it remains unclear whether carotenoid colouration is preferred over melanin colouration in attractiveness judgements. In Western countries, tanning is popular and tanned skin is seen as attractive (Smith, Cornelissen, & Tovée, 2007), perhaps because it indicates status and wealth (ability to spend time tanning and holidaying; see Etcoff, 1999). It is also possible that carotenoid colouration or melanin colouration is liked because the effects of the pigments mimic each other. For example, a suntan might be attractive in Caucasian skin because raised skin melanization simulates the effect of raised skin carotenoid levels. Therefore, in order to establish the likely direction of this possible mimicry, here we directly compare preferences for melanin and carotenoid colouration. First, in two studies we establish whether high carotenoid (Study 1) and high melanin (Study 2) colouration are indeed found to be more attractive than low levels of these pigments. In our third study we then directly compare attractiveness of high carotenoid and high melanin colouration.

STUDY 1: CAROTENOID PREFERENCES

Methods

Participants
A total of 60 participants (45 female, mean age = 23.9 years, age range = 16–66 years) took part in the experiment. All participants were recruited over the Internet via the website http://www.perceptionlab.com. Of the participants, 78% self-identified as white, with the remaining reporting a range of ethnicities (7% mixed, 5% Hispanic, 5% East Asian, 5% other).

Stimuli
A total of 27 (15 female) base faces were created, each combining 3 individual facial images of Caucasian students (for details, see Tiddeman, Burt, & Perrett, 2001). The blending together of several faces to create a composite or base face for testing the effects of a given cue is a process that has been adopted in several studies of attractiveness. The process eliminates the possibility that a real individual will be recognized, and removes any idiosyncratic features from individual faces that may influence preferences in a non-generalizable manner. Original digital images used to create the base faces were taken under standardized d65 lighting conditions, approximating northern European daylight. All images were additionally colour-calibrated according to a Gretag Macbeth mini colour checker that was included in each image. The skin areas of each of the 27 base faces were then transformed in carotenoid-associated skin colour.

Carotenoid associated skin colour was previously determined by comparing the skin colour of a group of 15 individuals with high fruit and vegetable intake with that of a matched control group of 15 individuals with low fruit and vegetable intake. The two groups did not differ on gender, age,
BMI, or exercise behaviour and all individuals were Caucasian. Skin colour was measured on the forearm using spectrophotometry (for details, see Whitehead, Re et al., 2012). Next, using MATLAB, we created two face-shaped uniform colour masks representing the average high and low carotenoid skin colouration as measured. These masks were created by uniformly applying the colour difference between high and low carotenoid skin colouration in CIELab values to a generic face-shaped starting mask. These masks then allowed us to transform the skin areas of the base face images along the carotenoid colour axis using Psychomorph (Tiddeman et al., 2001). In detail, the high and low pigment masks were warped in shape to align with the target face, and then the colour of the pixels in the skin areas of the target face were modified along the colour difference between high and low pigment masks.

To simulate an increase in carotenoid colouration we added 4.35 units of yellowness (b* in the CIELab colour space, see Stephen, Law-Smith et al., 2009 for details), subtracted 1.1 units of lightness (L*) and added 1.4 units of redness (a*) to the skin areas of all face images. To simulate a decrease in carotenoid colouration we performed the reverse colour manipulations. These changes each reflect a ΔE of 9.4 (Euclidian distance in CIELab colour space). The transforms created a total of 54 face stimuli (27 pairs). The level of positive transform was derived from a pilot experiment, which indicated that on average, this amount of colour change was applied to Caucasian faces to make them appear most healthy (see Lefevre, Ewbank, Calder, von dem Hagen, & Perrett, 2013). Images were cropped to the outer boundaries of the face (see Figure 1).

In order to assess the effect of the starting colour of each stimulus on preferences, we additionally measured the average colour of all skin areas (excluding lips, and eyebrows). To this end, first a binary colour mask in the shape of a face was created, with skin areas being coloured white and non-skin areas, including eyes, eyebrows, lips, and hair being coloured in black. Each stimulus face was then shape warped to fit the outline of the generic mask using Psychomorph. Subsequently, using MATLAB, all pixels in face areas that fell within the white area of the mask were analysed for their average colour (L*, a*, b*) in CIELab colour space.

Procedure
The experiment took place over the Internet. The validity of Internet-based studies for colour research has previously been demonstrated (Lefevre et al., 2013). High and low carotenoid-coloured versions of each identity were presented as pairs on the participant’s computer screen in random order and with the presentation side counterbalanced. In a forced-choice paradigm, participants were told to choose the face they thought was more attractive for each of the 27 pairs. They were additionally instructed: “You will see faces of both sexes. For faces of a sex you are not sexually attracted to, please make attractiveness judgements with respect to who you would recommend to someone with the relevant sexual orientation”. For each participant we computed the percentage of male faces and the percentage of female faces with raised carotenoid colour that were selected as most attractive.

Results
The high carotenoid version of each face was preferred in 86.0% of trials. This was significantly above the chance value of 50% for all faces (t(59) = 15.36, p < .001, d = 4.0) and for both male (m = 88%, SD = 16%; t(59) = 17.67, p < .001, d = 4.6) and female (m = 84%, SD = 21%; t(59) = 12.53, p < .001, d = 3.26) faces, separately. A repeated measures ANOVA with sex of stimulus face as repeated measure and sex of rater as between-subjects factor revealed a marginally stronger preference for carotenoids in male as compared to female faces (F(1,58) = 3.59, p = .06, $\eta_p^2 = .06$). There was no main effect of participant sex (F(1,58) = 2.22, p = .14, $\eta_p^2 = .04$) and no interaction between sex of face and sex of participant (F(1,58) = 0.06, p = .81, $\eta_p^2 = .001$).
In an additional analysis we investigated the variation in choice across stimuli. To this end we measured the starting skin colour by computing the average L*, a*, and b* from the original images (see the Methods section and Stephen et al., 2011). We found a negative correlation between the average starting skin yellowness (b*) in the original untransformed image and the proportion of high carotenoid versions chosen, $r = -0.49, p = 0.01$, which remained marginally significant after controlling for sex of face ($p = 0.06$). Neither starting face redness (a*) nor starting face lightness (L*) were significantly associated with preferences (both $p > 0.4$). Such dependency on

Figure 1. Example stimuli. Top row: low (left) and high (right) carotenoid colouration stimuli used in Study 1. Bottom row: low (left) and high (right) melanin colouration stimuli used in Study 2. For Study 3, high versions of both carotenoid and melanin colouration were pitched against each other.
starting image colour is expected from previous studies (e.g., Stephen et al., 2011).

STUDY 2: MELANIN PREFERENCES

Methods

Participants
A total of 60 new participants (41 female, mean age = 27.0 years, age range = 16–59 years) took part over the Internet. All participants were recruited via the website http://www.perceptionlab.com and received no credit for participation. Of the participants, 66% self-identified as white, with the remaining participants reporting a range of ethnicities (12% Hispanic, 7% Afro-Caribbean, 5% mixed, 10% other).

Stimuli
We used the same 27 base faces as in Study 1. Skin areas of these base faces were colour-transformed along the axis of melanin (suntan) colouration previously determined (Stephen et al., 2011). Colour values were derived by calculating the difference in skin colour between high sun-exposed and low sun-exposed areas on the forearms of Caucasian participants (Stephen et al., 2011). Uniform face-shaped colour masks representing high and low melanin colouration were created using MATLAB. For each face, a high and low melanin version was created by changing the colour of skin areas according to the colour difference between the two colour masks using Psychomorph (Tiddeman et al., 2001). To increase melanin colouration, we subtracted 2.7 units of L* and 0.6 units of a* but added 3.7 units of b*. The reverse was performed to reduce melanin colouration. The total colour difference was matched to the Carotenoid transform (i.e., ΔE = 9.4). This procedure resulted in 27 pairs of images, differing only in their melanin colouration.

Procedure
High and low melanin-coloured versions of each face were presented as pairs on a computer screen in random order and with presentation side counterbalanced. In a forced-choice paradigm, participants were told to choose the face they thought was more attractive. The instructions were identical to those of Study 1.

Results
Participants preferred the high melanin face in 78.5% of cases. This was significantly higher than chance for all images (t(59) = 11.25, p < .001, d = 2.93) and for both male (m = 86%, SD = 17%; t(59) = 16.53, p < .001, d = 4.30) and female (m = 73%, SD = 25%; t(59) = 7.04, p < .001, d = 1.83) faces, separately. A repeated measures ANOVA with sex of stimulus face as repeated measure and sex of rater as between-subjects factor revealed that preferences for high melanin versions of faces were significantly more pronounced for male compared to female faces (F(1,56) = 18.52, p < .001, η² = .25). There was no main effect of rater sex (F(1,56) = 1.21, p = .28, η² = .02) and no interaction between stimulus sex and rater sex (F(1,56) = 1.2, p = .28, η² = .02). Furthermore, stimulus starting colour affected the proportion of high melanin faces chosen: there was a negative correlation between starting b* and proportion of high melanin choices (r = −.41, p = .04) as well as a negative correlation between starting L* and proportion of high melanin choices (r = −.53, p = .005).

Cross comparison of carotenoid and melanin colouration preferences by sex
Because sex-specific effects of both carotenoid and melanin colouration were observed, we next assessed whether these effects differed between carotenoid and melanin colouration. To this end we collapsed data from Studies 1 and 2 and performed a 2 × 2 × 2 (face sex × participant sex × pigment) mixed measures ANOVA. This test showed a significant effect of face sex (F(1,114) = 20.96, p < .001) as well as an interaction between face sex and pigment (F(1,114) = 5.48, p = .02), caused by a greater effect of sex on the preference for melanin colouration than the carotenoid
colouration (see Figure 2). No further effects were significant (all $p > .1$).

**STUDY 3: CAROTENOID VS MELANIN PREFERENCES**

**Participants**

A total of 60 new participants (39 female, mean age = 27.3 years, age range 16–56 years) took part over the Internet. All participants were recruited via [http://www.perceptionlab.com](http://www.perceptionlab.com) and did not receive reimbursement for participation. Of the participants, 77% self-identified as white, with the remaining participants reporting a range of ethnicities (5% East Asian, 5% Hispanic, 5% mixed, 8% other).

**Stimuli**

A total of 24 (12 female) stimuli pairs were created by combining the high melanin and high carotenoid faces of the transforms performed in Studies 1 and 2.

**Procedure**

The procedure was identical to that of Study 1 and Study 2.

**RESULTS**

Participants preferred the high carotenoid face to the high melanin face in 75.9% of trials. This was significantly above chance level for all images ($t(59) = 10.73$, $p < .001$, $d = 2.79$) and for both male ($m = 74\%$, $SD = 23\%$; $t(59) = 7.79$, $p < .001$, $d = 2.03$) and female ($m = 78\%$, $SD = 18\%$; $t(59) = 11.89$, $p < .001$, $d = 3.10$) images, separately. A repeated measures ANOVA with sex of stimulus face as the repeated measure and participant sex as between-subjects factor indicated a marginally stronger preference for carotenoid over melanin colour in female faces compared to male faces ($F(1,58) = 3.51$, $p = .066$, $\eta^2_p = .06$). There was no main effect of participant sex ($F(1,58) = 1.00$, $p = .32$, $\eta^2_p = .02$) and no interaction between stimulus sex and participant sex ($F(1,58) = 0.05$, $p = .82$, $\eta^2_p = .001$). Additionally, the starting colour of the face stimuli did not affect choices (all $p > .25$).

**DISCUSSION**

Here we tested whether participants find high levels of both carotenoid and melanin colouration attractive in Caucasian faces, and whether participants show a preference for carotenoid colouration over melanin colouration. Across three studies, we present strong evidence for a skin colour preference aligning with carotenoid colouration, likely as a cue to current health. When comparing high and low carotenoid-colour faces (Study 1), participants consistently chose the high carotenoid version as more attractive. Similarly, when comparing high and low melanin colouration, participants consistently chose the high melanin face as more attractive (Study 2). Importantly, however, when high carotenoid and high melanin faces were pitched against each other in attractiveness judgements, participants showed strong preferences for the high carotenoid over the high melanin face (Study 3). These results are in line with our hypothesis that increased skin yellowness, induced through either melanin or carotenoids, is preferred to a less yellow complexion, but that the melanin...
preferences are likely, at least in part, driven by melanin colouration mimicking the highly desirable carotenoid colour.

The current findings align well with previous work using interactive tasks. In these studies participants were asked to maximize the healthy appearance of a stimulus face by simultaneously increasing or decreasing both the melanin and the carotenoid content in the skin. On average, participants added relatively larger amounts of carotenoid and smaller amounts of melanin colouration to the skin (Stephen et al., 2011; Whitehead, Ozakinci, & Perrett, 2012). While these studies established the importance of carotenoid colouration for a healthy appearance, they did not show whether carotenoid colouration is preferred to melanin colouration in absolute terms and, in particular, whether these preferences are present when judging the attractiveness of a face. The present work (Study 3) clarifies this issue by showing a direct preference for carotenoid colouration over melanin colouration. These results are consistent with a health detection mechanism influencing people’s attractiveness perceptions. Carotenoid colouration of the skin is likely to be a direct signal of current condition (e.g., Koutsos et al., 2003; Stahl et al., 1998) and as such may be of pivotal importance to mate choice and other social judgements.

In addition, we found novel sex-specific pigment effects, namely that both melanin and carotenoid colouration were preferred more in male compared to female faces. There was no interaction with the sex of the observer, indicating that the preferences found here are likely to be independent of sex-specific mate choice mechanisms. Alternatively, it is possible that men and women are aware of what constitutes a skin colour in their own sex that is desirable to the opposite sex. Additionally, we tested for interactions between skin pigment (carotenoid or melanin) and sex of face, finding a greater sex specificity of preferences for melanin as compared to carotenoids. Taken together, these findings may be accounted for by preferences for sex-typical skin colour. Men are typically found to have darker, as well as somewhat redder skin than women across ethnicities (e.g., Frost, 1994; Jablonski & Chaplin, 2000; Mesa, 1983; Van den Berghe & Frost, 1986). While carotenoids predominantly increase skin yellowness, increased melanin additionally significantly darkens skin, shifting it towards a typical male colouration. Some work indicates a preference for sex-typical skin colouration (e.g., Frost, 1994), in turn suggesting that perhaps, in the current study, the high pigment (high melanin and high carotenoid) versions of Caucasian male faces were seen as doubly attractive: healthy and sex-typical looking. For female faces, preferences may then have been conflicted between sex typicality and healthy colouration. This conflict may be particularly pronounced for high melanin colouration, which provides less of the health benefit cues compared to high carotenoid colouration and deviates from female sex-typical skin colour due to its darkening properties.

Similarly, the sex differences observed in Study 3, namely a stronger preference for carotenoid colouration over melanin colouration in female faces compared to male faces, is in line with an increased melanin preference in male faces. This preference may reduce the preference for carotenoid colouration in our specific study set-up. In males, both carotenoid colouration and melanin colouration may be highly preferred and thus the differential effect between those two pigments is diminished. In females, on the other hand, the preference for carotenoid colouration far outweighs that for melanin colouration, leading to strong preferences for this colour.

There are a number of potential limitations that deserve discussion. First, although we matched the amount of transform between carotenoid and melanin images in delta E units, recent work has suggested that humans may be more attuned to seeing differences in yellowness compared to luminance (Tan & Stephen, 2013). While it is possible then that the high and low melanin images are perceptually more similar than the high and low carotenoid images, both of our skin–colour transforms are clearly distinguishable, considering that research indicates that differences as small as 0.9 delta E are enough to accurately distinguish the attractiveness of two facial images (Whitehead, Re et al., 2012) and the differences reported here were around 10 times as large. It should also be noted that while we
matched our stimuli to be of the same magnitude in colour transform, this transform was based on ideal levels of carotenoid colouration and might not reflect ideal levels of melanin colouration. As such, it is possible that when matching ideal levels of melanin with ideal levels of carotenoid, the preference for carotenoids may be less pronounced. Future research should address this question. Similarly, here we tested the effect of relatively high levels of pigmentation; further research may wish to address the reverse effect, i.e. whether low levels of carotenoid are more detrimental to attractiveness than low levels of melanin. Finally, when transforming our stimuli in colour, we transformed the eyebrow and lip region alongside the regular skin regions. This was done in order to avoid artefacts such as sharp lines around these features that may cause a mask-like appearance of the transformed faces. We note that previous studies indicate that both the colour of these features as well as their contrast to the surrounding skin play a role in attractiveness (e.g., Porcheron, Mauger, & Russell, 2013; Stephen & McKeegan, 2010). Future research into the relative attractiveness of melanin and carotenoid pigments will be necessary to establish the independent roles of these pigments within the lip and eyebrow regions and their contrast with facial skin.

In summary, here we present strong evidence for the importance of skin colouration in attractiveness perception and highlight a differential preference for carotenoid over melanin colouration. We also present novel sex-specific effects perhaps indicating preferences for sex-typical skin colour in addition to preferences for carotenoid colouration. These results underline the importance of skin colour and specifically of carotenoid colouration as a cue to current health and consequently attractiveness.

Original manuscript received 4 February 2014
Accepted revision received 19 June 2014

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