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

Carmen E. Lefevre[1]* & David I. Perrett[2]

1. Centre for Decision Research, Leeds University Business School, Leeds LS2 9JT, United Kingdom.
2. School of Psychology and Neuroscience, University of St Andrews, St Andrews KY16 9JP.

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Word count (inc references): 4483

*Corresponding author
email: carmenlefevre@me.com
phone: 07595305424
address: Leeds University Business School, Maurice Keyworth Building, Moorland Road, Leeds, LS2 9JT

Abstract

Skin colouration appears to play a pivotal part in facial attractiveness. Skin yellowness contributes to an attractive appearance and is influenced by dietary carotenoids, and melanin. While both increased carotenoid colouration and increased melanin colouration enhance apparent health in Caucasian faces, it remains unclear firstly, whether both pigments contribute to attractiveness, 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 that both increased carotenoid colouration and increased melanin colouration are found attractive compared to lower levels of these pigments, and, importantly, 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 melanisation 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

Introduction

A number of factors have been established as influencing facial attractiveness. While most attractiveness factors concern facial shape (for review see e.g. 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 skin have been found to influence perception of attractiveness (Coetzee et al., 2012; Fink, Grammer, & Thornhill, 2001; Fink, Grammer, & Matts, 2006; Matts, Fink, Grammer, & Burquest, 2007; Stephen et al., 2012). Increased skin yellowness is perceived as healthy looking (Scott et al., 2010; Stephen et al., 2009a,b; 2011; 2012), yet changes in skin yellowness can arise as a result of at least two distinct processes: melanisation (tanning) and carotenoid ingestion (Edwards & Duntley 1939; Stamatas et al., 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 perception of health (Stephen et al., 2009a; 2011). Furthermore, there is some evidence implying a higher impact for carotenoid over melanin colouration, at least for health perception (Stephen et al., 2011; Whitehead et al., 2012a), 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 and colleagues (2001) report that a more homogenous skin colour distribution is associated with higher levels of attractiveness. A more detailed assessment of colour distribution indicated that both 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 only (Matts et al., 2007). Additionally, in a sample of male faces, Jones and colleagues (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 indicate the importance of skin colour distribution and homogeneity, a growing body of work has also assessed the influence of overall 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 maximise the health appearance of faces (Stephen et al., 2009a). 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. yellowness or redness axis in isolation), other research has linked health perception to naturally occurring skin pigments: for skin redness, participants increased the amount of oxygenated blood colour more than deoxygenated blood colour, to maximise the appearance of health in faces (Stephen et al., 2009b). These findings are inline 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 et al., 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 in the skin (Alaluf et al., 2002). When asking participants to manipulate either a beta-carotene-associated colouration axis or a melanin colouration axis to maximise the healthy appearance of Caucasian faces, Stephen and colleagues (2011) found that both pigments were increased, although carotenoid colouration was increased relatively more than melanin. 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 faces, with only a small amount of melanin 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 et al., 2012b).

These results may indicate that carotenoid colouration is a more important factor in health appearance than melanin colouration and are in line with carotenoids providing a cue to current health. For example, plasma carotenoid levels can change within days in response to dietary changes (Stahl et al., 1998) and parasite infestation (Koutsos et al., 2003) and skin colour has been shown to respond to dietary changes within weeks (Whitehead et al., 2012b). 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, 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 et al., 1985) and has beneficial effects for thymus gland growth in children (Seifter, et al., 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 et al., 2007), perhaps because it indicates status and wealth (ability to spend time tanning and holidaying; 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 melanisation 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

Sixty participants (45 female, mean age = 23.9 years, age range = 16-66 years) took part in the experiment. All participants were recruited across the internet via the website www.perceptionlab.com. Seventy-eight per cent of participants self-identified as white with the remaining reporting a range of ethnicities (7% mixed, 5% Hispanic, 5% East Asian, 5% other).

Stimuli

Twenty-seven (15 female) base faces were created, each combining 3 individual facial images of Caucasian students (for details see Tiddeman et al., 2001). This procedure was implemented to remove any idiosyncratic features from individual faces that may influence preferences in a non-generalizable manner. 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 chance that a real individual will be recognised, and creates stimuli that are somewhat more representative than particular individuals with the possibility of idiosyncrasies in for example hair colour or face shape. Original digital images used in the composites were taken under standardised 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. Skin colour was measured on the forearm using spectrophotometry (for details see Whitehead et al., 2012b). Using Matlab, we created two face-shaped uniform colour masks representing high and low carotenoid coloration. These masks were created by uniformly applying the empirically derived colour difference in CIELab values between high and low carotenoid skin colouration to a uniform neutral skin-coloured face-shaped starting mask. These masks then allowed us to transform the skin areas of face images along the carotenoid colour axis using Psychomorph (Tiddeman et al., 2001). In detail the masks high and low pigment masks were warped in shape to align with the target face, and then the colour of the pixels in the target face were modified by a difference of 9.4 CIE ΔE 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 et al., 2009a 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 CIE 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 et al., 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. Subsequently, each stimulus face was 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 across 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 presentation side counter balanced. 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.

--------- Insert Figure 1 about here ----------

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, η_p^2 = .06). There was no main effect of participant sex (F(1,58) = 2.22, p = .81, η_p^2 = .04) and no interaction between sex of face and sex of participant (F(1,58) = 0.06, p = .81. η_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 originals image (see methods and Stephen et al. 2010). 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 = -.49, p = .01, which remained marginally significant after controlling for sex of face (p=.06). Neither starting face redness (a*) nor starting face lightness (L*) were significantly associated with preferences (both p > .4). Such dependency on starting image colour is expected from previous studies (e.g. Stephen et al 2010).

Study 2 – Melanin Preferences

Methods

Participants

Sixty new participants (41 female, mean age = 27.0 years, age range = 16-59 years) took part across the internet. All participants were recruited via the website www.perceptionlab.com and received no credit for participation. Sixty-six per cent of participants 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 coloration were created using Matlab. For each face a high-melanin and a low-melanin version were 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. $\Delta E = 9.4$). 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 counter balanced. In a forced-choice paradigm, participants were told to choose the face they thought was more attractive. Instructions were identical to 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 ($F(1,56) = 18.52$, $p < .001$, $\eta_p^2 = .25$). There was no main effect of rater sex ($F(1,56) = 1.21$, $p = .28$, $\eta_p^2 = .02$) and no interaction between stimulus sex and rater sex ($F(1,56) = 1.2$, $p = .28$, $\eta_p^2 = .02$). 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 2x2x2 (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 $p > .1$).

--------- Insert Figure 2 about here ----------

Study 3 – Carotenoid vs Melanin preferences

Participants

Sixty new participants (39 female, mean age = 27.3 years, age range 16-56 years) took part across the internet. All participants were recruited via www.perceptionlab.com and did not receive reimbursement for participation. Seventy-seven per cent of participants self-identified as white with the remaining participants reporting a range of ethnicities (5% East Asian, 5% Hispanic, 5% Mixed, 8% Other).

Stimuli

Twenty-four (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 ($F(1,58) = 3.51$, $p = .066$, $\eta_p^2 = .06$). There was no main effect of participant sex ($F(1,58) = 1.00$, $p = .32$, $\eta_p^2 = .02$) and no interaction between stimulus sex and participant sex ($F(1,58) = 0.05$, $p = .819$, $\eta_p^2 = .001$). Additionally, starting colour of the face stimuli did not affect choices (all $p > .25$).

Discussion

Here we tested whether participants find high levels of both carotenoids and melanin colouration attractive in Caucasian faces, and whether participants show a preference for carotenoid colouration over melanin colouration. Across the 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 maximise 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 to the skin (Stephen et al., 2011; Whitehead et al., 2012a). 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, the generality of colour preferences may reflect that both sexes are aware of the skin colour desirable in men and women. 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. Mesa, 1983; Frost, 1994; Jablonski & Chaplin, 2000; Van den Berghe & Frost, 1986). While carotenoids predominantly increase skin yellowness, added melanin additionally significantly darkens skin, shifting it towards a male typical 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 were 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 inline with a 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 research indicates that differences as small as 0.9 delta E are enough to accurately distinguish attractiveness of two facial images (Whitehead et al., 2012b) 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 pigmentation 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.

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Figure Captions:

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.

Figure 2. Interaction between sex of face and skin pigment, indicating reduced preferences for melanin colouration in female faces as compared to all other conditions. Error bars represent standard error of the mean.