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

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**Abstract**

22 Skin colouration appears to play a pivotal part in facial attractiveness. Skin yellowness  
23 contributes to an attractive appearance and is influenced by dietary carotenoids, and  
24 melanin. While both increased carotenoid colouration and increased melanin colouration  
25 enhance apparent health in Caucasian faces, it remains unclear firstly, whether both  
26 pigments contribute to attractiveness, secondly, whether one pigment is clearly preferred  
27 over the other, and thirdly, whether these effects depend on the sex of the face. Here, in  
28 three studies, we examine these questions using controlled facial stimuli transformed to  
29 be either high or low in (a) carotenoid colouration, or (b) melanin colouration. We show  
30 that both increased carotenoid colouration and increased melanin colouration are found  
31 attractive compared to lower levels of these pigments, and, importantly, that carotenoid  
32 colouration is consistently preferred over melanin colouration when levels of colouration  
33 are matched. In addition, we find an effect of the sex of stimuli with stronger preferences  
34 for carotenoids over melanin in female compared to male faces, irrespective of the sex of  
35 the observer. These results are interpreted as reflecting preferences for sex-typical skin  
36 colouration: men have darker skin than women and high melanisation in male faces may  
37 further enhance this masculine trait, thus carotenoid colouration is not less desirable, but  
38 melanin colouration is relatively more desirable in males compared to females. Taken  
39 together, our findings provide further support for a carotenoid-linked health-signalling  
40 system that is highly important in mate choice.  
41

42

43 Keywords: carotenoids, skin colour, skin yellowness, melanin, attractiveness, health, sex  
44 differences

## 45        **Introduction**

46            A number of factors have been established as influencing facial attractiveness. While  
47 most attractiveness factors concern facial shape (for review see e.g. Rhodes 2006) with  
48 averageness, symmetry and sexual dimorphism being the most prominent examples, more  
49 recent work has highlighted the importance of skin attributes in the perception of  
50 attractiveness. In particular the colour and texture of skin have been found to influence  
51 perception of attractiveness (Coetzee et al., 2012; Fink, Grammer, & Thornhill, 2001; Fink,  
52 Grammer, & Matts, 2006; Matts, Fink, Grammer, & Burquest, 2007; Stephen et al., 2012).  
53 Increased skin yellowness is perceived as healthy looking (Scott et al., 2010; Stephen et al.,  
54 2009a,b; 2011; 2012), yet changes in skin yellowness can arise as a result of at least two  
55 distinct processes: melanisation (tanning) and carotenoid ingestion (Edwards & Duntley  
56 1939; Stamatas et al., 2004). Previous work indicates that the isolated yellowness component  
57 of skin ( $b^*$  in the CIELab colour system) as well as both melanin-associated colouration and  
58 carotenoid-associated colouration, increase perception of health (Stephen et al., 2009a; 2011).  
59 Furthermore, there is some evidence implying a higher impact for carotenoid over melanin  
60 colouration, at least for health perception (Stephen et al., 2011; Whitehead et al., 2012a), but  
61 it remains unclear whether attractiveness attributions follow a similar pattern. Here we test  
62 first, whether both carotenoid colouration and melanin colouration affect attractiveness  
63 perception and second, whether carotenoid colouration is preferred over melanin colouration  
64 in judgements of facial attractiveness.

65            Previous work assessing the perceptual importance of skin colour and texture  
66 homogeneity indicates that these properties contribute to the perception of traits such as  
67 attractiveness, health and age (Fink et al., 2001, 2006; Matts, et al., 2007). Fink and  
68 colleagues (2001) report that a more homogenous skin colour distribution is associated with  
69 higher levels of attractiveness. A more detailed assessment of colour distribution indicated

70 that both homogenous melanin and haemoglobin chromophore distributions positively  
71 enhance ratings of health, youthfulness, and attractiveness when assessing full-face images of  
72 females (Fink et al., 2006) and patches of skin only (Matts et al., 2007). Additionally, in a  
73 sample of male faces, Jones and colleagues (2004) showed that health ratings of skin patches  
74 positively correlated with attractiveness ratings of the corresponding full-face images,  
75 indicating an influence of skin colour and texture on attractiveness perception in male faces.

76         While these studies indicate the importance of skin colour distribution and  
77 homogeneity, a growing body of work has also assessed the influence of overall colouration.  
78 In particular, participants enhanced both skin redness (as measured by the CIELab a\* axis)  
79 and skin yellowness (as measured by the CIELab b\* axis) when asked to maximise the health  
80 appearance of faces (Stephen et al., 2009a). Similarly, recent work assessing both European  
81 and African males as well as African females found that skin yellowness (b\*) significantly  
82 predicted attractiveness perception in un-manipulated images, and showed that skin colour  
83 was a more influential predictor of attractiveness than sexual dimorphism in face shape  
84 (Coetzee et al., 2012; Scott et al., 2010; Stephen et al., 2012). While these studies were  
85 performed assessing pure colour levels (i.e. yellowness or redness axis in isolation), other  
86 research has linked health perception to naturally occurring skin pigments: for skin redness,  
87 participants increased the amount of oxygenated blood colour more than deoxygenated blood  
88 colour, to maximise the appearance of health in faces (Stephen et al., 2009b). These findings  
89 are inline with previous work showing positive links between levels of blood oxygenation  
90 and cardiovascular fitness (Armstrong & Welsman, 2001; Johnson, 1998) and between blood  
91 deoxygenation and ill health (Ponsonby et al., 1997).

92         Similarly, and of importance here, skin yellowness is influenced by two major  
93 pigments: melanin and carotenoids. While melanin is produced by the melanocytes, cells  
94 contained within the skin, mainly in response to exposure to UV light (Hearing, 1997),

95 carotenoids are obtained through fruit and vegetable consumption and are deposited in the  
96 skin (Alaluf et al., 2002). When asking participants to manipulate either a beta-carotene-  
97 associated colouration axis or a melanin colouration axis to maximise the healthy appearance  
98 of Caucasian faces, Stephen and colleagues (2011) found that both pigments were increased,  
99 although carotenoid colouration was increased relatively more than melanin. Importantly,  
100 when participants were given the option to change both carotenoid colouration and melanin  
101 colouration within the same trial, they predominantly added carotenoid colouration to the  
102 faces, with only a small amount of melanin being added. Similar results were also obtained in  
103 a more recent study assessing the effect of a broader range of carotenoid colours on healthy  
104 appearance by using empirically derived skin tones associated with high fruit and vegetable  
105 consumption (Whitehead et al., 2012b).

106         These results may indicate that carotenoid colouration is a more important factor in  
107 health appearance than melanin colouration and are in line with carotenoids providing a cue  
108 to current health. For example, plasma carotenoid levels can change within days in response  
109 to dietary changes (Stahl et al., 1998) and parasite infestation (Koutsos et al., 2003) and skin  
110 colour has been shown to respond to dietary changes within weeks (Whitehead et al., 2012b).  
111 Furthermore, lower carotenoid levels are seen in individuals suffering from HIV or malaria  
112 and in individuals with elevated serum  $\alpha$ 1-antichymotrypsin (an indicator of infection, Friis et  
113 al., 2001). Similarly, serum carotenoid levels were inversely linked to all-cause mortality in a  
114 large US sample (Shardell et al., 2011). Carotenoid supplementation, on the other hand, has  
115 been shown to increase T-lymphocyte counts in healthy adults (Alexander et al., 1985) and  
116 has beneficial effects for thymus gland growth in children (Seifter, et al., 1981). Since  
117 carotenoids act as antioxidants, they are likely to be depleted by oxidative stress, reducing  
118 plasma levels and skin yellowness in times of disease.

119           While the work on carotenoids to date has been intriguing, it remains unclear whether  
120 carotenoid colouration is preferred over melanin colouration in attractiveness judgements. In  
121 Western countries, tanning is popular and tanned skin is seen as attractive (Smith et al.,  
122 2007), perhaps because it indicates status and wealth (ability to spend time tanning and  
123 holidaying; Etcoff, 1999). It is also possible that carotenoid colouration or melanin  
124 colouration is liked because the effects of the pigments mimic each other. For example, a  
125 suntan might be attractive in Caucasian skin because raised skin melanisation simulates the  
126 effect of raised skin carotenoid levels. Therefore, in order to establish the likely direction of  
127 this possible mimicry, here we directly compare preferences for melanin and carotenoid  
128 colouration. First, in two studies we establish whether high carotenoid (Study 1) and high  
129 melanin (Study 2) colouration are indeed found to be more attractive than low levels of these  
130 pigments. In our third study we then directly compare attractiveness of high carotenoid and  
131 high melanin colouration.

## 132 **Study 1 – Carotenoid Preferences**

### 133 **Methods**

#### 134 *Participants*

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

140

141 *Stimuli*

142           Twenty-seven (15 female) base faces were created, each combining 3 individual facial  
143 images of Caucasian students (for details see Tiddeman et al., 2001). This procedure was  
144 implemented to remove any idiosyncratic features from individual faces that may influence  
145 preferences in a non-generalizable manner. The blending together of several faces to create a  
146 composite or base face for testing the effects of a given cue is a process that has been adopted  
147 in several studies of attractiveness. The process eliminates the chance that a real individual  
148 will be recognised, and creates stimuli that are somewhat more representative than particular  
149 individuals with the possibility of idiosyncrasies in for example hair colour or face shape.  
150 Original digital images used in the composites were taken under standardised d65 lighting  
151 conditions, approximating northern European daylight. All images were additionally colour-  
152 calibrated according to a Gretag Macbeth mini colour checker that was included in each  
153 image. The skin areas of each of the 27 base faces were then transformed in carotenoid-  
154 associated skin colour. Carotenoid associated skin colour was previously determined by  
155 comparing the skin colour of a group of 15 individuals with high fruit and vegetable intake  
156 with that of a matched control group of 15 individuals with low fruit and vegetable intake.  
157 The two groups did not differ on gender, age, BMI, or exercise behaviour. Skin colour was  
158 measured on the forearm using spectrophotometry (for details see Whitehead et al., 2012b).  
159 Using Matlab, we created two face-shaped uniform colour masks representing high and low  
160 carotenoid coloration. These masks were created by uniformly applying the empirically  
161 derived colour difference in CIELab values between high and low carotenoid skin colouration  
162 to a uniform neutral skin-coloured face-shaped starting mask. These masks then allowed us to  
163 transform the skin areas of face images along the carotenoid colour axis using Psychomorph  
164 (Tiddeman et al., 2001). In detail the masks high and low pigment masks were warped in

165 shape to align with the target face, and then the colour of the pixels in the target face were  
166 modified by a difference of 9.4 CIE  $\Delta E$  between high and low pigment masks.

167 To simulate an increase in carotenoid colouration we added 4.35 units of yellowness  
168 ( $b^*$  in the CIELab colour space, see Stephen et al., 2009a for details), subtracted 1.1 units of  
169 lightness ( $L^*$ ) and added 1.4 units of redness ( $a^*$ ) to the skin areas of all face images. To  
170 simulate a decrease in carotenoid colouration we performed the reverse colour manipulations.  
171 These changes each reflect a  $\Delta E$  of 9.4 (Euclidian distance in CIE colour space). The  
172 transforms created a total of 54 face stimuli (27 pairs). The level of positive transform was  
173 derived from a pilot experiment, which indicated that on average, this amount of colour  
174 change was applied to Caucasian faces to make them appear most healthy (see Lefevre et al.,  
175 2013). Images were cropped to the outer boundaries of the face (see Figure 1).

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

#### 184 *Procedure*

185 The experiment took place across the internet. The validity of internet-based studies  
186 for colour research has previously been demonstrated (Lefevre et al., 2013). High and low  
187 carotenoid-coloured versions of each identity were presented as pairs on the participant's  
188 computer screen in random order and with presentation side counter balanced. In a forced-



189 choice paradigm, participants were told to choose the face they thought was more attractive  
190 for each of the 27 pairs. They were additionally instructed: “You will see faces of both sexes.  
191 For faces of a sex you are not sexually attracted to, please make attractiveness judgements  
192 with respect to who you would recommend to someone with the relevant sexual orientation.”  
193 For each participant we computed the percentage of male faces and the percentage of female  
194 faces with raised carotenoid colour that were selected as most attractive.

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

## 196 **Results**

197 The high carotenoid version of each face was preferred in 86.0 % of trials. This was  
198 significantly above the chance value of 50% for all faces ( $t(59) = 15.36$ ,  $p < .001$ ,  $d = 4.0$ )  
199 and for both male ( $m = 88\%$ ,  $SD = 16\%$ ;  $t(59) = 17.67$ ,  $p < .001$ ,  $d = 4.6$ ) and female ( $m =$   
200  $84\%$ ,  $SD = 21\%$ ;  $t(59) = 12.53$ ,  $p < .001$ ,  $d = 3.26$ ) faces, separately. A repeated measures  
201 ANOVA with sex of stimulus face as repeated measure and sex of rater as between subjects  
202 factor revealed a marginally stronger preference for carotenoids in male as compared to  
203 female faces ( $F(1,58) = 3.59$ ,  $p = .06$ ,  $\eta_p^2 = .06$ ). There was no main effect of participant sex  
204 ( $F(1,58) = 2.22$ ,  $p = .81$ ,  $\eta_p^2 = .04$ ) and no interaction between sex of face and sex of  
205 participant ( $F(1,58) = 0.06$ ,  $p = .81$ ,  $\eta_p^2 = .001$ ).

206 In an additional analysis we investigated the variation in choice across stimuli. To this end we  
207 measured the starting skin colour by computing the average  $L^*$ ,  $a^*$ , and  $b^*$  from the originals  
208 image (see methods and Stephen et al. 2010). We found a negative correlation between the  
209 average starting skin yellowness ( $b^*$ ) in the original untransformed image and the proportion  
210 of high carotenoid versions chosen,  $r = -.49$ ,  $p = .01$ , which remained marginally significant  
211 after controlling for sex of face ( $p = .06$ ). Neither starting face redness ( $a^*$ ) nor starting face

212 lightness ( $L^*$ ) were significantly associated with preferences (both  $p > .4$ ). Such dependency  
213 on starting image colour is expected from previous studies (e.g. Stephen et al 2010).

## 214 **Study 2 – Melanin Preferences**

### 215 **Methods**

#### 216 *Participants*

217 Sixty new participants (41 female, mean age = 27.0 years, age range = 16-59 years)  
218 took part across the internet. All participants were recruited via the website  
219 www.perceptionlab.com and received no credit for participation. Sixty-six per cent of  
220 participants self-identified as white with the remaining participants reporting a range of  
221 ethnicities (12% Hispanic, 7% Afro-Caribbean, 5% Mixed, 10% Other).

#### 222 *Stimuli*

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

235 *Procedure*

236 High and low melanin-coloured versions of each face were presented as pairs on a  
237 computer screen in random order and with presentation side counter balanced. In a forced-  
238 choice paradigm, participants were told to choose the face they thought was more attractive.  
239 Instructions were identical to Study 1.

240 **Results**

241 Participants preferred the high melanin face in 78.5% of cases. This was significantly  
242 higher than chance for all images ( $t(59) = 11.25, p < .001, d = 2.93$ ) and for both male ( $m =$   
243  $86\%, SD = 17\%; t(59) = 16.53, p < .001, d = 4.30$ ) and female ( $m = 73\%, SD = 25\%; t(59) =$   
244  $7.04, p < .001, d = 1.83$ ) faces, separately. A repeated measures ANOVA with sex of stimulus  
245 face as repeated measure and sex of rater as between subjects factor revealed that preferences  
246 for high melanin versions of faces were significantly more pronounced for male compared to  
247 female faces ( $F(1,56) = 18.52, p < .001, \eta_p^2 = .25$ ). There was no main effect of rater sex  
248 ( $F(1,56) = 1.21, p = .28, \eta_p^2 = .02$ ) and no interaction between stimulus sex and rater sex  
249 ( $F(1,56) = 1.2, p = .28, \eta_p^2 = .02$ ). Furthermore, stimulus starting colour affected the  
250 proportion of high melanin faces chosen: there was a negative correlation between starting  $b^*$   
251 and proportion of high melanin choices ( $r = -.41, p = .04$ ) as well as a negative correlation  
252 between starting  $L^*$  and proportion of high melanin choices ( $r = -.53, p = .005$ ).

253 *Cross comparison of carotenoid and melanin colouration preferences by sex*

254 Because sex-specific effects of both carotenoid and melanin colouration were  
255 observed, we next assessed whether these effects differed between carotenoid and melanin  
256 colouration. To this end we collapsed data from Studies 1 and 2 and performed a  $2 \times 2 \times 2$  (face  
257 sex  $\times$  participant sex  $\times$  pigment) mixed measures ANOVA. This test showed a significant

258 effect of face sex ( $F(1,114) = 20.96, p < .001$ ) as well as an interaction between face sex and  
259 pigment ( $F(1,114) = 5.48, p = .02$ ), caused by a greater effect of sex on the preference for  
260 melanin colouration than the carotenoid colouration (see Figure 2). No further effects were  
261 significant (all  $p > .1$ ).

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

### 263 **Study 3 – Carotenoid vs Melanin preferences**

#### 264 *Participants*

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

#### 270 *Stimuli*

271 Twenty-four (12 female) stimuli pairs were created by combining the high melanin  
272 and high carotenoid faces of the transforms performed in Studies 1 and 2.

#### 273 *Procedure*

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

### 275 **Results**

276 Participants preferred the high carotenoid face to the high melanin face in 75.9 % of  
277 trials. This was significantly above chance level for all images ( $t(59) = 10.73, p < .001, d =$   
278  $2.79$ ) and for both male ( $m = 74\%, SD = 23\%; t(59) = 7.79, p < .001, d = 2.03$ ) and female  
279 ( $m = 78\%, SD = 18\%; t(59) = 11.89, p < .001, d = 3.10$ ) images, separately. A repeated

280 measures ANOVA with sex of stimulus face as the repeated measure and participant sex as  
281 between subjects factor indicated a marginally stronger preference for carotenoid over  
282 melanin colour in female faces compared to male faces ( $F(1,58) = 3.51, p = .066, \eta_p^2 = .06$ ).  
283 There was no main effect of participant sex ( $F(1,58) = 1.00, p = .32, \eta_p^2 = .02$ ) and no  
284 interaction between stimulus sex and participant sex ( $F(1,58) = 0.05, p = .819, \eta_p^2 = .001$ ).  
285 Additionally, starting colour of the face stimuli did not affect choices (all  $p > .25$ ).

286

## 287 **Discussion**

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

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

316           In addition, we found novel sex-specific pigment effects, namely that both melanin  
317 and carotenoid colouration were preferred more in male compared to female faces. There was  
318 no interaction with the sex of the observer, indicating that the preferences found here are  
319 likely to be independent of sex-specific mate choice mechanisms. Alternatively, the  
320 generality of colour preferences may reflect that both sexes are aware of the skin colour  
321 desirable in men and women. Additionally, we tested for interactions between skin pigment  
322 (carotenoid or melanin) and sex of face, finding a greater sex specificity of preferences for  
323 melanin as compared to carotenoids. Taken together, these findings may be accounted for by  
324 preferences for sex-typical skin colour. Men are typically found to have darker, as well as  
325 somewhat redder skin than women across ethnicities (e.g. Mesa, 1983; Frost, 1994; Jablonski  
326 & Chaplin, 2000; Van den Berghe & Frost, 1986). While carotenoids predominantly increase

327 skin yellowness, added melanin additionally significantly darkens skin, shifting it towards a  
328 male typical colouration. Some work indicates a preference for sex-typical skin colouration  
329 (e.g. Frost, 1994), in turn suggesting that perhaps, in the current study, the high pigment (high  
330 melanin and high carotenoid) versions of Caucasian male faces were seen as doubly  
331 attractive: healthy and sex typical looking. For female faces preferences were conflicted  
332 between sex typicality and healthy colouration. This conflict may be particularly pronounced  
333 for high melanin colouration, which provides less of the health benefit cues compared to high  
334 carotenoid colouration and deviates from female sex-typical skin colour due to its darkening  
335 properties.

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

344 There are a number of potential limitations that deserve discussion. First, although we  
345 matched the amount of transform between carotenoid and melanin images in delta E units,  
346 recent work has suggested that humans may be more attuned to seeing differences in  
347 yellowness compared to luminance (Tan & Stephen, 2013). While it is possible then that the  
348 high and low melanin images are perceptually more similar than the high and low carotenoid  
349 images, both of our skin colour transforms are clearly distinguishable, considering research  
350 indicates that differences as small as 0.9 delta E are enough to accurately distinguish  
351 attractiveness of two facial images (Whitehead et al., 2012b) and the differences reported

352 here were around 10 times as large. It should also be noted, that while we matched our  
353 stimuli to be of the same magnitude in colour transform, this transform was based on ideal  
354 levels of carotenoid colouration and might not reflect ideal levels of melanin colouration. As  
355 such, it is possible that when matching ideal levels of melanin with ideal levels of carotenoid  
356 the preference for carotenoids may be less pronounced. Future research should address this  
357 question. Similarly, here we tested the effect of relatively high levels of pigmentation; further  
358 research may wish to address the reverse effect, i.e. whether low levels of carotenoid are  
359 more detrimental to attractiveness than low levels of melanin. Finally, when transforming our  
360 stimuli in colour, we transformed the eyebrow and lip region alongside the regular skin  
361 regions. This was done in order to avoid artefacts such as sharp lines around these features  
362 that may cause a mask-like appearance of the transformed faces. We note that previous  
363 studies indicate that both the colour of these features as well as their contrast to the  
364 surrounding skin play a role in attractiveness (e.g. Porcheron, Mauger, & Russell, 2013;  
365 Stephen & McKeegan, 2010). Future research into the relative attractiveness of melanin and  
366 carotenoid pigments will be necessary to establish the independent roles of these pigments  
367 within the lip and eyebrow regions and their contrast with facial skin.

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

374



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484 Figure Captions:

485 Figure 1. Example stimuli. Top row: low (left) and high (right) carotenoid colouration stimuli  
486 used in Study 1. Bottom row: low (left) and high (right) melanin colouration stimuli used in  
487 Study 2. For Study 3 high versions of both carotenoid and melanin colouration were pitched  
488 against each other.

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

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