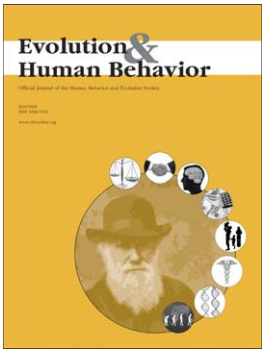

The role of sexually dimorphic skin colour and shape in attractiveness of male faces

M.L. Carrito, I.M. Santos, C.E. Lefevre, R.D. Whitehead, C.F. Silva, D.I. Perrett

PII: S1090-5138(15)00085-9
DOI: doi: 10.1016/j.evolhumbehav.2015.09.006
Reference: ENS 6013

To appear in: *Evolution and Human Behavior*

Received date: 28 November 2014
Revised date: 17 September 2015
Accepted date: 21 September 2015

Please cite this article as: Carrito, M.L., Santos, I.M., Lefevre, C.E., Whitehead, R.D., Silva, C.F. & Perrett, D.I., The role of sexually dimorphic skin colour and shape in attractiveness of male faces, *Evolution and Human Behavior* (2015), doi: 10.1016/j.evolhumbehav.2015.09.006

The Role of Sexually Dimorphic Skin Colour and Shape in Attractiveness of Male Faces

M. L. Carrito [a, b, c, *], I. M. Santos [a, b, *], C.E. Lefevre [c], R. D. Whitehead [c], C. F. Silva [a, b], D. I. Perrett [c]

[a] Center for Health Technology and Services Research (CINTESIS), Department of Education, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro Portugal.

[b] Institute for Biomedical Imaging and Life Sciences (IBILI), Faculty of Medicine, University of Coimbra, 3000-548 Coimbra, Portugal.

[c] School of Psychology and Neuroscience, University of St Andrews, St Mary's Quad, South Street, St Andrews, Fife, KY16 9JP, Scotland, United Kingdom

Number of Words: 6,330 (excluding references)

* Corresponding authors:
Isabel M. Santos / Mariana L. Carrito
Universidade de Aveiro
Departamento de Educação
Campus Universitário de Santiago
3810-193 Aveiro
PORTUGAL
+351.234.370.353 (phone)
+351.234.370.640 (fax)
E-mail: isabel.m.b.santos@gmail.com / mariana.carrito@gmail.com

The Role of Sexually Dimorphic Skin Colour and Shape in Attractiveness of Male Faces

Abstract

Evidence for attraction to sexually dimorphic features in male faces is inconsistent in the literature. Mixed results regarding facial masculinity and male attractiveness may arise partly from different influences of face shape and face colouration depending on whether colour was controlled. Recent research suggests that masculinity in face colour, namely darker skin, and femininity in shape are attractive in male faces. Here we examine the influence of sexual dimorphism in skin colour and face shape on attractiveness in 3 experiments. We allowed female participants to manipulate male and female face images along axes of sexual dimorphism in skin colour and/or shape in order to optimise attractiveness. Participants searching for the most attractive appearance chose to masculinise the colour of male faces more than the colour of female faces (although not reaching significance in Experiment 3; $p = .16$). We found a clear preference for feminine shape in male faces supporting predictions of recent research. These results help to clarify the influence of facial masculinity in women's attractiveness preferences.

Keywords: face perception; attractiveness; sexual dimorphism; face shape; skin colour; masculinity

The Role of Sexually Dimorphic Skin Colour and Shape in Attractiveness of Male Faces

1. Introduction

The role of sexual dimorphism in male facial attractiveness is still equivocal (DeBruine et al., 2010). While some work shows positive associations between masculinity and attractiveness (DeBruine et al., 2006; Little & Mannion, 2006), other findings suggest a negative (Little & Hancock, 2002; Perrett et al., 1998) or no association (Scott et al., 2010). However, most research to date has failed to address the possible independent effects of sexual dimorphism in facial shape and facial skin colour on attractiveness perception, despite findings indicating the importance of skin colour on attractiveness judgements (Matts et al., 2007; Russell, 2003; Scott et al., 2010; Stephen et al., 2012b). Moreover a lack of preference for masculinity in male faces may be observed by virtue of conflicting preferences for relatively feminine shape but also relatively masculine skin colour (Said & Todorov, 2011). Here we investigated this idea formally, addressing two questions: 1) Is masculinity in face colour attractive when judging male faces? 2) How does sexually dimorphic colour relate to attraction to sexually dimorphic shape? To answer these questions we examined preferences for colour and shape separately and simultaneously.

1.1 Women's preferences and sexual dimorphism

Sexual dimorphism is believed to signal health and contribute to attractiveness of male faces. This position has been justified by the association between both baseline and reactive testosterone and masculine facial appearance (Lefevre et al., 2013; Pound et al., 2009) and by the immunosuppressive effects of testosterone (Grossman, 1985; Wedekind, 1992; Zahavi, 1975; but see Roberts, 2004; Scott et al., 2010). According to

the immunocompetence handicap hypothesis, since only males with relatively high genetic quality are able to sustain the immunosuppression associated with high levels of testosterone and remain healthy, masculinity may therefore signal mate value (Little et al., 2011). It follows that women should benefit from choosing a partner with sexually dimorphic masculine features as these would indicate long-term healthiness and ability to provide direct and indirect genetic benefits to her offspring (Kirkpatrick & Ryan, 1991; Little et al., 2011).

An alternative conceptualization regarding the value of facial masculinity relies on the possibility that masculine traits may signal intra-sexual competitiveness and dominance. In fact, owners of masculine faces are perceived as dominant (Boothroyd et al., 2007; Perrett et al., 1998; Stirrat & Perrett, 2010) and aggressive (Lefevre & Lewis, 2013; Stirrat et al., 2012). Perceived facial dominance is associated with status in some human hierarchies (Muller & Mazur, 1997). Masculine facial traits could be a cue for competitive status-seeking behaviours (Scott et al., 2013) and are therefore attractive to women that desire a dominant mate who will ensure access to resources and protection (Puts, 2010).

There are a number of factors influencing women's preferences for facial masculinity including women's own attractiveness and the relationship context of hypothetical unions. Women who regard themselves as attractive (Little et al., 2001; Little & Mannion, 2006) and women who are rated as more attractive by others (Penton-Voak et al., 2003) prefer more masculine and symmetrical faces than less attractive women. This difference is seen in the context of a long- but not a short-term relationship.

Although high partner masculinity may confer benefits (health, good genes), masculinity may also have potential costs because it is related to reduced paternal skills,

cooperativeness and trustworthiness (Perrett et al., 1998). Less attractive women may prefer a male with a more feminine face for a long-term relationship because such a man may invest more in the relationship and be less likely to desert (Penton-Voak et al., 2003). Conversely, attractive women may prefer more masculine male faces because they can cope with their lower parental ability and may even persuade them to invest more (Little et al., 2001). This assumption is featured in the Trade-off Theory (Gangestad & Simpson, 2000; Gross, 1996) which suggests that women may trade heritable immunity benefits against the costs of lack of paternal investment.

1.2 Colour as a sexually dimorphic cue

Recent research has suggested that face colour has an impact on attractiveness that may be more pronounced than face shape (Said & Todorov, 2011; Stephen et al., 2012b) as it may be a more reliable index of current health compared to shape (Scott et al., 2010). Overall, skin colour (Stephen et al., 2009a; Whitehead et al., 2012b) and colour distribution (Fink et al., 2006; Matts et al., 2007) have strong effects on apparent health and attractiveness in human faces.

The CIE L*a*b* colour space is commonly used in human perceptual studies and includes 3 main axes: L*(0 = dark, 100 = light), a* (negative = green, positive = red) and b* (negative = blue, positive = yellow). For Caucasian skin colour, the redness component (a*) is formed primarily by haemoglobin in the blood vessels (Stephen et al., 2009a), and the yellowness component (b*) by the presence of carotenoid and melanin pigments (Alaluf et al., 2002; Stephen et al., 2009b). Skin lightness (L* values) is decreased primarily by the presence of melanin in the skin (Stamatas et al., 2004).

Skin CIE L*a*b* values have been associated with human health but also appear to be sexually dimorphic and related with reproductive health and dominance (Little et al., 2011). Carotenoid levels are reduced in infertile men and carotenoid supplements

can improve men's fertility (Eskenazi et al., 2005). For female faces, light skin may be taken as a sign of fecundity (Aoki, 2002; van den Berghe & Frost, 1986) and skin lightness affects attractiveness (Russell, 2003). Skin colour varies considerably between people from different regions of the globe but is sexually dimorphic within a specific region, with men having darker (lower L*) and redder (higher a*) skin compared to women (Jablonski & Chaplin, 2000; Russell, 2003; van den Berghe & Frost, 1986). Madrigal and Kelly (2007) analysing the prevalence of sexual dimorphic colour in different areas with different solar radiation, concluded that hormonal factors may be more reliable explanation of differences between sexes. Indeed, according to Hill et al. (1995), discrimination of human sexes relies more on colour information than on face shape.

Red stimuli in general are associated with increased perceived dominance, an advantage in intra-sexual competition and access to resources (Stephen et al., 2012a). Men wearing red are more likely to win physical competitions even when controlling for ability and are perceived as more aggressive and more dominant (Feltman & Elliot, 2011; Hill and Barton., 2005; Little & Hill, 2007). Red colour is associated with attractiveness, and women perceive men to be more attractive and sexually desirable when seen on a red background or in red clothing (Elliot et al., 2010).

The effect of sexual dimorphism in skin colour on attractiveness has not been investigated directly but differences in skin lightness and redness (components of dimorphism) have pervasive roles in perception and preliminary research indicated that a darker photograph contributed to male facial attractiveness (Frost, 1994). Therefore, skin colour seems to be sexually dimorphic, providing cues to health and, possibly, to dominance. While skin colour has clear effects on attractiveness, the effect of sexual dimorphism in skin colour on attractiveness is not known.

1.3 Current study

This study aims to define the influences of sexually dimorphic skin colour and face shape on women's attractiveness judgments. Said & Todorov (2011) developed a model of attractiveness in which, by determining the position of each face in a face space, it was possible to predict its attractiveness. Their face space incorporated 25 shape dimensions and 25 colour dimensions. According to the authors, the mixed results of previous studies regarding masculinity and male attractiveness may reflect competing effects of shape and colour. After analysing the separate contributions of these sexually dimorphic dimensions, the authors concluded that, for male faces, masculinity is attractive in colour properties whereas femininity is attractive in shape. Their model predicts that, compared to the average male face, "attractive male faces have darker skin, more beard, darker brows and eye lines and less bulk around the cheeks and upper neck" (Said & Todorov, 2011, p. 1186). The authors also reported that attractive female faces were feminine in both face shape and colour.

Said & Todorov (2011) used artificial facial stimuli (synthetic models with bald heads) and noted that it is possible that real faces' attractiveness is rated differently. Since colour properties of the face stimuli were encoded in 25 principal component dimensions, it was not possible within their approach to resolve the contribution of any single sexually dimorphic feature such as a specific skin hue or the presence of a beard.

In the present study, we aimed to test predictions for the attractiveness of sexually dimorphic face shape and colour using composites of real human faces. Note that even though computer graphic techniques were used to manipulate sexual dimorphic traits in faces, this work aimed to use more ecologically valid stimuli than Said and Todorov (2011). Furthermore, we integrate attractiveness preferences in a

mating context to ensure that perceptive mechanisms involved are related to sexual selection.

Our goal was to understand how the two dimensions of sexual dimorphism, skin colour and shape, contribute to women's judgments of male facial attractiveness. Following the conclusions of previous studies, we hypothesised that relative femininity in face shape will be attractive in both male and female faces, and that masculinity in skin colour will be attractive for male faces. Additionally, we expect our participants to feminise male faces less than female faces in shape, and masculinise them more than female faces in colour. The prediction for attractiveness of female facial colour is unclear[1].

Although preferences for feminine traits in male faces have been reported as mentioned previously, when it comes to other sexually dimorphic characteristics, such as the voice, women who perceive masculine male voices as more dominant prefer them compared to more feminine male voices (Vukovic et al., 2008). The reason why face shape behaves differently from other sexually dimorphic variables is not known but it may be due to the relationship between masculinity and facial expressions of emotion. Angrier faces are perceived as more masculine and happier faces are perceived as more feminine (Hess et al., 2009). Hence, feminine shape faces may be more attractive since happier faces are also more attractive (Mueser et al., 1984). Other sexually dimorphic characteristics are less related to emotion so preferences for male masculinity can prevail.

In the first experiment we investigated women's preferences for sexually dimorphic colour in male faces. In the second experiment, participants manipulated

[1] Said & Todorov's (2011) model predicted that feminisation of 25 dimensional colour (reflectance) makes female faces more attractive but they also found that attractive female faces had darkened skin.

faces in either sexually dimorphic skin colour or shape in different tasks. In the last experiment, participants were able to manipulate both sexually dimorphic variables simultaneously while considering short- or long-term relationship contexts. In this experiment, we included a 'friendship' control condition with female faces. In all 3 experiments, we also examined the effect of self-perceived attractiveness on face preferences. We predict that women who rate themselves high in attractiveness will prefer male faces that are more masculinised in shape and skin colour in virtue of their ability to deal with partner's lower parental investment.

2. Experiment 1

2.1 Method

2.1.1 Participants

One hundred and forty-two Caucasian students, 101 women and 41 men, from St Andrews University, UK volunteered for the skin colour measurements (M_{age} = 20.29, *SD* = 1.79). Another 72 Caucasian students from St Andrews University, UK, 36 women and 36 men, were photographed voluntarily (M_{age} = 20.28, *SD* = 1.69) (see Whitehead et al. (2012b) for procedures). Lastly, 48 heterosexual Caucasian female participants (M_{age} = 22.65, *SD* = 6.60) voluntarily took part in the online experiment that is described in the procedure.

2.1.2 Colour Measurement

For details of colour measurement procedures see Whitehead et al. (2012b).

From a total of 142 participants, 103 that reported no use of a solarium, fake tan or sun bathing in the previous month and had skin colour values that lay within 3 standard deviations of the mean were selected for analysis. After exclusions, there were 75 women and 28 men left to calculate mean CIE L*a*b* face skin values (across the 3 face regions) for the male and female faces. Average male face skin colour was L*=

63.39, a*= 13.53 and b*= 15.06 and average female colour was L*= 66.81, a*= 11.48 and b*= 13.91. Average male face skin luminance (L*) was significantly different from female average (Z = -6.23, p < .001), and the same was true for a* (Z = -5.63, p < .001) and b* (Z = -3.99, p < .001) parameters.

2.1.3 Stimuli

Individual photographed faces were colour calibrated prior to manipulation (see Whitehead et al. (2012b) for detailed procedures). Twelve composite female faces and 12 composite male faces were used for perceptual judgements; each composite face was an average of 3 photographed faces of different individuals. These groups of three faces were randomly selected from the 36 photographs of the same sex individuals mentioned in 2.1.1. Different combinations were used for short- and long-term stimuli. The averaging procedure aimed to reduce individual differences in colour and shape of the face stimuli without the need to use other procedures that would increase the artificiality of the faces. One hundred and ninety two landmarks were marked on each face image to delineate the facial features that would be transformed.

Two face uniform colour masks were created in Psychomorph (Tiddeman et al., 2001) to represent the average male and female skin colour from the L*a*b* values reported above. The skin portions including lips and eyebrows but excluding eyes (sclera, iris and pupil) of the composite faces were manipulated according to the colour difference between the two endpoint colour masks in order to obtain a set of 21 images for each face, ranging from -200% masculinised to 200% masculinised, with the middle image being the original composite face. The colour continua represented a total range of +/-1.710 L* units, +/-1.024 a* units and +/-0.577 b* units. Finally, the hair, neck, ears and background were occluded from view (see Figure 1).

<INSERT FIGURE 1>

2.1.4 Procedure

Participants were asked to answer a short computer-based questionnaire with demographic information including a 7-point scale for self-rated attractiveness. Participants then performed two facial manipulation tasks, where they were asked to "make the face look as attractive as possible". The tasks consisted in manipulating face images along colour masculinity to maximize the attractiveness of the faces from the range available. Horizontal mouse movement allowed participants to change the colour of the presented face, similar to previous studies (Little et al., 2002b; Penton-Voak et al., 2003; Perrett et al., 1998).

Faces were presented in random order in two counterbalanced blocks of 12 male and 12 female faces. Participants selected, via horizontal movements of a mouse cursor, the position along the colour axis. Direction of movement, axis centre location and axis arrangement (left movement increasing or decreasing masculine colour) were randomized.

2.2 Results

2.2.1 Colour masculinity preferences. For each participant the mean degree of masculinisation considered to be maximally attractive, was calculated for male and female faces independently. Distributions were normal (Kolmogorov-Smirnov tests $p > 0.2$). A significant preference for masculinity was found for male faces (M = 81.74%, SD = 69.23, one sample t-test against no change in masculinity, t (47) = 8.18, $p < .001$, d = 1.18) and for female faces (M = 59.27%, SD = 83.5, t (47) = 4.92, $p < .001$, d = .71). Participants masculinised male faces more than female faces (t (47) = -2.47, p = .017, d = 0.36) (Figure 2).

<INSERT FIGURE 2>

2.2.2 Self-rated attractiveness. Self-reported attractiveness of women did not correlate with the level of colour masculinity chosen for the male faces (Spearman's rank correlation (r_s) = .005, p = .974) or the female faces (r_s = -.074, p = .619).

2.3 Discussion

In Experiment 1, we found a preference for more masculine colour in male faces compared to female faces. While participants choose to masculinise both male and female faces, this tendency was exaggerated in male faces. This outcome may reflect skin colour acting as a signal of mate quality through the owner's health or status (Scott et al., 2010; Whitehead et al., 2012b).

Our colour measurements indicate that men have darker (lower L*), redder (higher a*) and yellower (higher b*) facial skin colouration compared to women. Frost (1994) suggests that in our ancestral environment, the darker faces of men might be perceived as stronger potential rivals for other men and hence better future mates for women. Lightness is more attractive in female faces compared to male faces and is more naturally pronounced in women's faces than in men's (Frost, 1988; van den Berghe & Frost, 1986). Redness of male facial skin is related to important traits including perceived dominance and attractiveness (Matts et al., 2007; Re et al., 2011) and, along with yellowness, might signal mate quality (Stephen et al., 2012b). Hence males with colour masculinised faces may be more attractive because their colour is associated with health or dominance and ability to access resources (Puts, 2010).

Female faces had less masculine colour applied than male faces but were still subject to an increase in masculinisation of skin colour for optimal attractiveness. This

is likely to reflect the fact that skin colour cues convey similar health information in men and women. Blood flow to the skin and hence skin redness is linked with health and cardiovascular fitness (Re et al., 2011). Skin yellowness depends on carotenoids from a healthy diet and lifestyle (Alaluf et al., 2002; Whitehead et al., 2012a; 2012b).

3. Experiment 2

The aim of this experiment was to explore preferences for sexual dimorphism in skin colour (as Experiment 1) and in face shape from the same participants. We explored preferences for sexual dimorphism in skin colour with an extended colour range. It is possible that in Experiment 1, face colour preferences were limited by the truncated range available to participants. Experiment 2, therefore, tested whether an increased range of face colour would affect the masculinity level preferred by participants.

3.1 Method

3.1.1 Participants

Sixty-one volunteer female participants (M_{age} = 20.11, SD = 4.26) took part in the experiments online. All participants reported heterosexual orientation and Caucasian ethnicity.

3.1.2 Stimuli

The 24 base images (12 female) from Experiment 1 were used.

3.1.2.1 Shape Manipulation. The facial shape of each of the 24 faces was manipulated according to the shape difference between Penton-Voak and colleagues' (2003) average male and average female face shapes. A continuum of 11 images was created for each face ranging from -100% masculinised to 100% masculinised (see Figure 3).

<INSERT FIGURE 3>

3.1.2.2 Colour Manipulation. The skin portions of the same 24 faces were manipulated according to the colour difference between the two endpoint colour masks from Experiment 1 in order to obtain a set of 21 images each, ranging from -300% to 300% masculinised.

3.1.3 Procedure

Participants performed two facial manipulation tasks where they were asked to "make the face look as attractive as possible", with appearance varying either in either colour or shape continua. As in Experiment 1, horizontal mouse movement allowed participants to manipulate the colour (or shape) of the test face. Faces were presented in random order and shape and colour blocks were counterbalanced.

3.2 Results

3.2.1 Preferences for masculinity in male and female faces. For each participant the mean preferences for sexually dimorphic colour and shape across male and female faces were calculated. Values were normally distributed (Kolmogorov-Smirnov, $p > .05$) except male colour which showed acceptable skewness of -.75 (SE = .31) and kurtosis of .17 (SE = 0.60). A significant preference for colour masculinity was found in male faces (M = 121.27%, SD = 81.2, t (60) = 11.66, $p < .001$, d = 1.49) and in female faces (M = 103.77%, SD =85.58, t (60) = 9.74, $p < .001$, d = 1.21) (Figure 4).

<INSERT FIGURE 4>

Furthermore, a significant preference for femininity in shape was found in male faces (M = -11.83%, SD =33.75, t (60) = -2.74, $p < .001$, d = -.35) and in female faces (M = -43.28%, SD = 19.21, t (60) = -17.60, $p < .001$, d = -2.25) (Figure 5).

<INSERT FIGURE 5>

There was a significant effect of face gender on colour preferences, (paired t (60) = -2.10, p = .04, Figure 4) reflecting greater masculinity preferences in male faces. There was also a significant effect of face gender on shape preferences (t (60) = -6.8, p < .001, Figure 5) reflecting greater femininity preferences in female faces.

Preferences for sexually dimorphic shape did not correlate with preferences for sexually dimorphic colour across individuals, neither for female faces (r = .06, p = .648) nor male faces (r = .17, p = .191).

3.2.2 Self-rated attractiveness. Self-rated attractiveness did not correlate with the levels of skin colour masculinity chosen for female faces (r_s = -.01, p = .936) or male faces (r_s = .017, p = .891). Self-rated attractiveness also did not correlate with the levels of shape masculinity preferred for female faces (r_s = -.114, p = .345) or male faces (r_s = .178, p = .137).

3.3 Discussion

Experiment 2 tested skin colour preferences with an extended colour range. The increased manipulation range (-300% to +300%) allowed participants to indicate preferences for slightly higher degrees of colour masculinisation. Since preferences fell below +150%, there did not seem to be a ceiling effect. Therefore, it is not possible to draw conclusions about the absolute level of preferred sexual dimorphism in skin colour since this may depend on the colour range available. However, it is noteworthy that participants in Experiments 1 and 2 preferred a similar difference of colour masculinity between female and male faces, which indicates that participants prefer different skin

colour in men and women. Indeed the preferred level of skin colour masculinisation tended to be 20% greater for men's faces than for women's faces.

Women chose to feminise the shape of both female and male faces to maximise their attractiveness. Such preferences for a feminised male face shape have been reported in several studies (DeBruine et al., 2010; Little et al., 2001; 2002b; Perrett et al., 1998). Said & Todorov (2011) also found that male facial attractiveness was associated with feminisation in shape but masculinisation was preferred in terms of colour.

4. Experiment 3

Experiment 3 permitted simultaneous manipulation of sexual dimorphism in both skin colour and face shape. This allowed participants to search for an optimal combination of the two cues and could potentially reveal interactions in attraction to the sexually dimorphic traits. Face colour range was restricted to +/-200% (as in Experiment 1) since in Experiment 2, participants maintained preferences below +/-150%.

Experiment 3 also investigated between-subjects the influence of short- or long-term relationship context. We predicted a preference for higher levels of masculinisation in the short-term context and that own attractiveness would correlate with masculinity preferences in the long-term context.

4.1 Method

4.1.1 Participants

Fifty-two female undergraduate students at the University of Aveiro, Portugal (M_{age} = 20.39, *SD* = 2.95) participated in the experiment, 26 in each experimental condition (short- and long-term relationship contexts). All participants were Caucasian and reported being heterosexual.

4.1.2 Stimuli

We employed the 24 composite base faces (12 female) from the previous two experiments.

4.1.2.1 Shape Manipulation and Colour Manipulation. Psychomorph (Tiddeman et al., 2001) was used to construct the average shape of 36 women and 36 men. These averages were used for shape transforms (as described in Experiment 2) to obtain 11 images for each base face ranging from -100% to 100% shape masculinised. The colour masks from Experiment 1 were used for colour transformation. The skin portions of each of the 11 shape transformed images per face were manipulated to obtain 21 images ranging from -200% to 200% colour masculinised. Thus 231 images (11 x 21 images) varying in shape and colour were prepared for each base face (see Figure 6).

<INSERT FIGURE 6>

4.1.3 Procedure

Participants answered a short questionnaire and then performed the face manipulation tasks. On each trial participants were able to manipulate both face colour and shape, from the range available, in order to maximize its attractiveness.

When manipulating the 12 male faces, participants were instructed to assume either a short-term or a long-term relationship context as defined previously (Penton-Voak et al., 2003). Participants judged male faces in only one of the two relationship contexts, and in addition judged 12 female faces in a friendship condition. For the different conditions, the instruction was respectively: “Please alter the face until you think it is the closest to the appearance you would find attractive for a partner in a short-term (or long-term) relationship / for a friendship”.

The order of presentation of stimuli blocks (female or male) was counterbalanced across participants and trials order was randomized. Mouse movement direction was also randomized, where horizontal movement could alter the shape and vertical movement could alter the colour of the face randomly from masculine to feminine or from feminine to masculine.

4.2 Results

4.2.1 Preferences for masculinity in male and female faces. Initial analyses examined preferences for male facial masculinity in male or female faces, collapsing data across short- and long-term relationship contexts for the male faces. A significant preference for colour masculinity was found in male faces (M = 108.85%, SD = 56.94, t (51) = 13.79, $p < .001$, d = 1.91) and in female faces (M = 92.92%, SD = 59.3, t (51) = 11.30, $p < .001$, d = 1.57).

Furthermore, a significant preference for shape femininity was found in male faces (M = - 40.67%, SD = 27.05, t (51) = -10.84, $p < .001$, d = -1.5) and in female faces (M = -48.30%, SD = 29.85, t (51) = - 11.67, $p < .001$, d = -1.62).

As in experiment 1 and 2, participants masculinised male faces more than female faces but this time, the results did not reach statistical significance for colour preferences (paired t (51) = -1.43, p = .16) or shape preferences (t (60) = -1.45, p = .15) (Figure 7).

<INSERT FIGURE 7>

Preferences for colour masculinisation correlated negatively with preferences for shape masculinisation in female faces (r = - .414, p = .002). However, this correlation was not significant for male faces (r = - .136, p = .336).

4.2.2 Relationship context. T-tests for independent samples examined the association between each sexually dimorphic dimension (colour and shape) and relationship context (short- or long-term) for male faces. The effect of relationship context was not significant for male colour (t (50) = 2.12, p = .152) or male shape (t (50) = 0.52, p = .82) (Figure 8).

<INSERT FIGURE 8>

4.2.3 Self-rated attractiveness. When considering the short-term context group, self-rated attractiveness was not correlated with shape or colour masculinisation of the male faces (r_s = -.151, p = .462; r_s = .103, p = .617). By contrast, when considering the long-term context group, self-rated attractiveness was positively correlated with shape masculinisation of the male faces (r_s = .482, p = .013) but not with colour masculinisation of the male faces (r_s = -.093, p = .652). Self-rated attractiveness did not correlate with the chosen level of masculinity in shape (r_s = -.022, p = .877) or colour (r_s = -.172, p = .223) for female faces.

4.3 Discussion

As in the two previous experiments, results indicate that masculinisation is generally preferred in face skin colour and feminisation is desirable in face shape. Moreover, in line with the hypothesis that reproductive strategy and mate choice depend on own-condition (Gross, 1996; Penton-Voak et al., 2003), there was a significant positive association between preferred masculinity in face shape and self-rated attractiveness for long-term relationships, such that participants who considered themselves more attractive preferred more masculine-shaped male faces. This may happen because attractive females are more able to compete more successfully for

markers of quality or dominance in men (Penton-Voak et al., 2003). As expected, the influence of self-rated attractiveness only emerged for participants who considered a long-term relationship: a context that requires investment from the male partner. However, an association with self-rated attractiveness was not present when considering face skin colour.

5. General Discussion

5.1 Masculinity preferences

Previous research by Said & Todorov (2011) suggested that masculinity in male faces is attractive in terms of colour properties but that femininity is attractive in shape properties. Here we investigated sexual dimorphism in skin colour along with face shape to understand how each variable may influence female mate choice.

Based on the latest models of face attractiveness, we expected to find a preference for masculine colouration of male faces. That was the case since, in all three experiments, participants increased colour masculinity of faces to make them look more attractive. The advantage of preferring a masculine colour, which is darker, yellower and redder, may be linked with a preference for health and/or personality traits such as dominance (Stephen et al., 2012a). Masculine traits, including a deep voice and muscular build may have evolved in the context of intra-sexual competition, and secondarily become sexually attractive to women (Puts, 2010). Hence, women's preferences for masculine male skin colour may also underlie the pursuit of a dominant mate.

Our participants also showed a preference for masculine skin colour in female faces. This is at first surprising, but it is not without precedent. Indeed Said & Todorov's (2011) figure 4a shows that direction of maximal increase in attractiveness from the average female face includes a darkening of the facial skin. Men have higher

skin melanin than women (Jablonski & Chaplin, 2000), yet Stephen et al. (2009) and Lefevre & Perrett (2015) found that increased melanin levels in both male and female faces makes them look more healthy. Indeed, raised a* and b* levels, which are components of masculinity in skin colour, are attractive in both sexes since both increase perceived health (Stephen et al., 2011; Stephen et al., 2009a). Therefore, participants may enhance skin colour masculinity in female faces to increase perceived health. Importantly, the preferred colour masculinity level for female faces was lower than the masculinity level preferred for male faces (although this effect did not reach significance in Experiment 3); hence participants amplify sex differences in skin colour when maximizing attractiveness in male and female faces.

For face shape, following Said and Todorov's (2011) findings, we expected our participants to prefer feminine-shaped male faces as potential partners. Indeed, as predicted, our participants did consider feminised male faces as more attractive (Experiment 2 and 3). Consistent with this model, we also found a preference for masculinisation in the colour component relative to the shape component for male faces. Moreover, preferences in colour and shape masculinisation did not correlate for male faces, which may support the claim that shape and colour have different weights on attractiveness (Said & Todorov, 2011).

If dimorphism in skin colour contributes to judgments of masculinity in male or female faces, colour variation can lead to discrepant conclusions about the contribution of masculinity to male facial attractiveness. The majority of studies using natural images (varying in intensity and colouration) report a positive correlation between attractiveness and perceived masculinity (Rhodes, 2006). Studies manipulating face shape while keeping colour constant are less consistent in reporting masculinity contributing to male facial attractiveness (Rhodes, 2006). Studies of natural image allow

preferences for masculinity in male skin colouration to be manifest, while studies manipulating or measuring masculinity in face shape cannot reflect attraction to masculine skin colouration.

5.2 Own attractiveness

According to the Trade-off Theory (Gross, 1996; Little et al., 2001; Penton-Voak et al., 2003) we expected that participants who rated themselves as more attractive would show preferences for more masculinised faces, especially when considering a long-term mate. The absence of significance for the effect of self-rated attractiveness on preferred masculine face shape and colour in Experiment 1 and 2 may be because a relationship context was not specified (although in Experiment 2 there was non-significant, but positive, correlation between self-attractiveness and shape masculinisation). Experiment 3 did show the expected correlation between self-rated attractiveness and preference for shape masculinisation in the long-term partnership contexts. This effect, however, was not apparent in preferences for male face colour in long- or short-term contexts.

5.3 Limitations and future studies

A limitation of the current research is that we did not control variations in participant's own skin colour (beyond restricting analysis to those reporting ethnicity as 'White'). Melanin levels vary considerably with latitude and population. Individuals used to a darker-skinned population may have higher preferences for masculinised skin colour (in both male and female faces). Such variation can potentially disrupt detection of relationships between preferred masculinity in skin colour and other variables including self-rated attractiveness.

Comparing the results across the three experiments, we found different mean values of preferred face masculinity for each group of participants. Such variation could

be due to the stimulus range or the experimental setting, i.e., participation online or in the lab, since online participants were worldwide, whereas attendees in the lab had perhaps more similar cultural backgrounds. Differences between Experiments 1 and 3 could also reflect a trade-off between masculinity cues, with higher colour masculinity selected for faces with low shape masculinity.

Nonetheless, the goal of the present studies was not to determine an absolute value of masculinity for optimal attractiveness but to explore the roles of sexual dimorphism in skin colour and face shape in attractiveness judgments. We confirmed a preference amongst Caucasian women for masculinity of skin colour in men's faces. Additionally, we found that the attraction to masculinisation of skin colour co-exists with a preference for femininity in face shape.

Future research is required to resolve the question of why femininity is found attractive in one trait (male face shape) while preference for masculinity is evident in other traits such as skin colour. Further research will also be necessary to establish the impact of sexually dimorphic skin colour on: (a) social attributions, (b) attractiveness in different populations and (c) individual differences in attraction more generally, as a result of partnership status, menstrual cycle, other-rated attractiveness, sexual orientation and hormonal contraceptive use.

6. Conclusion

This work is the first to investigate the attractiveness of skin colour, as a sexually dimorphic variable, in composites of real faces, and it sheds light on the reasons for the equivocal results in the role of sexual dimorphism in male facial attractiveness. The divergent results found in previous studies may, at least in part, be explained by the apparent trade-off between preferences for masculine facial colouration but feminine facial shape.

This study highlights the importance of analysing face skin colour along with shape when studying the attractiveness of faces. We show that when women are given the opportunity to adjust sexually dimorphic skin colour and shape of a male face to maximise attractiveness, masculine skin colour and feminine face shape are the preferred traits.

7. Acknowledgments:

This research was supported by funding from Foundation for Science and Technology (FCT) and the POPH/FSE Program (grant reference SFRH/BD/77592/2011). The funding agency had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

References

Alaluf, S., Heinrich, U., Stahl, W., Tronnier, H., & Wiseman, S. (2002). Dietary carotenoids contribute to normal human skin color and UV photosensitivity. *The Journal of Nutrition, 132*(3), 399-403.

Aoki, K. (2002). Sexual selection as a cause of human skin colour variation: Darwin's hypothesis revisited. *Annals of Human Biology, 29*(6), 589-608. doi: 10.1080/03014460210000191 44.

Boothroyd, L. G., Jones, B. C., Burt, D. M., & Perrett, D. I. (2007). Partner characteristics associated with masculinity, health and maturity in male faces. *Personality and Individual Differences, 43*(5), 1161-1173. doi: 10.1016/j.paid.2007.03.008.

DeBruine, L. M., Jones, B. C., Little, A. C., Boothroyd, L. G., Perrett, D. I., Penton-Voak, I. S., . . . Tiddeman, B. P. (2006). Correlated preferences for facial masculinity and ideal or actual partner's masculinity. *Proceedings of the Royal Society B: Biological Sciences, 273*(1592), 1355-1360. doi: 10.1098/rspb.2005.3445.

DeBruine, L. M., Jones, B. C., Smith, F. G., & Little, A. C. (2010). Are attractive men's faces masculine or feminine? The importance of controlling confounds in face stimuli. *Journal of Experimental Psychology: Human Perception and Performance, 36*(3), 751. doi: 10.1037/a0016457.

Elliot, A. J., Niesta Kayser, D., Greitemeyer, T., Lichtenfeld, S., Gramzow, R. H., Maier, M. A., & Liu, H. (2010). Red, rank, and romance in women viewing men. *Journal of Experimental Psychology: General, 139*(3), 399. doi: 10.1037/a0019689.

Eskenazi, B., Kidd, S. A., Marks, A. R., Sloter, E., Block, G., & Wyrobek, A. J. (2005). Antioxidant intake is associated with semen quality in healthy men. *Human Reproduction, 20*(4), 1006-1012. doi: 10.1093/humrep/deh725.

Feltman, R., & Elliot, A. J. (2011). The influence of red on perceptions of relative dominance and threat in a competitive context. *Journal of Sport & Exercise Psychology, 33*(2), 308-314.

Fink, B., Grammer, K., & Matts, P. J. (2006). Visible skin color distribution plays a role in the perception of age, attractiveness, and health in female faces. *Evolution and Human Behavior, 27*(6), 433-442. doi: 10.1016/j.evolhumbehav.2006.08.007.

Frost, P. (1988). Human skin color: A possible relationship between its sexual dimorphism and its social perception. *Perspectives in Biology and Medicine, 32*(1), 38-58.

Frost, P. (1994). Preference for darker faces in photographs at different phases of the menstrual cycle: preliminary assessment of evidence for a hormonal relationship. *Perceptual and Motor Skills, 79*(1), 507-514. doi: 10.2466/pms.1994.79.1.507.

Gangestad, S. W., & Simpson, J. A. (2000). The evolution of human mating: Trade-offs and strategic pluralism. *Behavioral and Brain Sciences, 23*(04), 573-587.

Gross, M. R. (1996). Alternative reproductive strategies and tactics: diversity within sexes. *Trends in Ecology & Evolution, 11*(2), 92-98. doi: 10.1016/0169-5347(96)81050-0.

Grossman, C. J. (1985). Interactions between the gonadal steroids and the immune system. *Science, 227*(4684), 257-261. doi: 10.1126/science.3871252.

Hess, U., Adams, R. B., Grammer, K., & Kleck, R. E. (2009). Face gender and emotion expression: Are angry women more like men?. *Journal of Vision*, *9*(12), 19.

Hill, R. A., & Barton, R. A. (2005). Psychology: red enhances human performance in contests. *Nature*, *435*(7040), 293-293.

Hill, H., Bruce, V., & Akamatsu, S. (1995). Perceiving the sex and race of faces: The role of shape and colour. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *261*(1362), 367-373. doi: 10.1098/rspb.1995.0161.

Jablonski, N. G., & Chaplin, G. (2000). The evolution of Human Skin Coloration. *Journal of Human Evolution*, *39*(1), 57-106.

Kirkpatrick, M., & Ryan, M. J. (1991). The evolution of mating preferences and the paradox of the lek. *Nature*, *350*(6313), 33-38.

Lefevre, C. E., & Lewis, G. J. (2013). Perceiving Aggression from Facial Structure: Further Evidence for a Positive Association with Facial Width-to-Height Ratio and Masculinity, but not for Moderation by Self-Reported Dominance. *European Journal of Personality*, *28*(6), 530-537. doi: 10.1002/per.1942.

Lefevre, C. E., Lewis, G. J., Perrett, D. I., & Penke, L. (2013). Telling facial metrics: facial width is associated with testosterone levels in men. *Evolution and Human Behavior*, *34*(4), 273-279.

Little, A. C., Burt, D. M., Penton-Voak, I. S., & Perrett, D. I. (2001). Self-perceived attractiveness influences human female preferences for sexual dimorphism and symmetry in male faces. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *268*(1462), 39-44. doi: 10.1098/rspb.2000.1327.

Little, A. C., & Hancock, P. J. B. (2002a). The role of masculinity and distinctiveness in judgments of human male facial attractiveness. *British Journal of Psychology*, *93*(4), 451-464. doi: 10.1348/000712602761381349.

Little, A. C., & Hill, R. A. (2007). Attribution to red suggests special role in dominance signalling. *Journal of Evolutionary Psychology, 5*(1), 161-168. doi: 10.1556/JEP.2007.1008.

Little, A. C., Jones, B. C., & DeBruine, L. M. (2011). Facial attractiveness: evolutionary based research. *Philosophical Transactions of the Royal Society B: Biological Sciences, 366*(1571), 1638-1659. doi: 10.1098/rstb.2010.0404.

Little, A. C., Jones, B. C., Penton-Voak, I. S., Burt, D. M., & Perrett, D. I. (2002b). Partnership status and the temporal context of relationships influence human female preferences for sexual dimorphism in male face shape. *Proceedings of the Royal Society of London. Series B: Biological Sciences, 269*(1496), 1095-1100. doi: 10.1098/rspb.2002.1984.

Little, A. C., & Mannion, H. (2006). Viewing attractive or unattractive same-sex individuals changes self-rated attractiveness and face preferences in women. *Animal Behaviour, 72*(5), 981-987. doi: 10.1016/j.anbehav.2006.01.026.

Madrigal, L., & Kelly, W. (2007). Human skin-color sexual dimorphism: A test of the sexual selection hypothesis. *American Journal of Physical Anthropology, 132*(3), 470-482.

Matts, P. J., Fink, B., Grammer, K., & Burquest, M. (2007). Color homogeneity and visual perception of age, health, and attractiveness of female facial skin. *Journal of the American Academy of Dermatology, 57*(6), 977-984. doi: 10.1016/j.jaad.2007.07.040.

Mueser, K. T., Grau, B. W., Sussman, S., & Rosen, A. J. (1984). You're only as pretty as you feel: facial expression as a determinant of physical attractiveness. *Journal of Personality and Social Psychology, 46*(2), 469.

Muller, U., & Mazur, A. (1997). Facial dominance in Homo sapiens as honest signaling of male quality. *Behavioral Ecology, 8*(5), 569-579. doi: 10.1093/beheco/8.5.569.

Penton-Voak, I. S., Little, A. C., Jones, B. C., Burt, D. M., Tiddeman, B. P., & Perrett, D. I. (2003). Female condition influences preferences for sexual dimorphism in faces of male humans (*Homo sapiens*). *Journal of Comparative Psychology, 117*(3), 264. doi: 10.1037/0735-7036.117.3.264.

Perrett, D. I., Lee, K. J., Penton-Voak, I. S., Rowland, D., Yoshikawa, S., Burt, D. M., . . . Akamatsu, S. (1998). Effects of sexual dimorphism on facial attractiveness. *Nature, 394*(6696), 884-887. doi: 10.1038/29772.

Pound, N., Penton-Voak, I. S., & Surridge, A. K. (2009). Testosterone responses to competition in men are related to facial masculinity. *Proceedings of the Royal Society B: Biological Sciences, 276*(1654), 153-159. doi: 10.1098/rspb.2008.0990.

Puts, D. (2010). Beauty and the beast: mechanisms of sexual selection in humans. *Evolution and Human Behavior, 31*(3), 157-175. doi: 10.1016/j.evolhumbehav.2010.02.005.

Re, D. E., Whitehead, R. D., Xiao, D., & Perrett, D. I. (2011). Oxygenated-blood colour change thresholds for perceived facial redness, health, and attractiveness. *PLoS One, 6*(3), e17859. doi: 10.1371/journal.pone.0017859.

Rhodes, G. (2006). The evolutionary psychology of facial beauty. *Annu. Rev. Psychol., 57*, 199-226. doi: 10.1146/annurev.psych.57.102904.190208.

Roberts, M. L. (2004). Testing the immunocompetence handicap hypothesis: a review of the evidence. *Animal Behaviour, 68*(2), 227-239. doi: 10.1016/j.anbehav.2004.05.001.

Russell, R. (2003). Sex, beauty, and the relative luminance of facial features. *Perception, 32*(9). doi: 10.1068/p5101.

Said, C. P., & Todorov, A. (2011). A statistical model of facial attractiveness. *Psychological Science, 22*(9), 1183-1190. doi: 10.1177/0956797611419169.

Scott, I. M. L., Clark, A. P., Boothroyd, L. G., & Penton-Voak, I. S. (2013). Do men's faces really signal heritable immunocompetence? *Behavioral Ecology, 24*(3), 579-589. doi: 10.1093/beheco/ars092.

Scott, I. M. L., Pound, N., Stephen, I. D., Clark, A. P., & Penton-Voak, I. S. (2010). Does masculinity matter? The contribution of masculine face shape to male attractiveness in humans. *PLoS One, 5*(10), e13585. doi: 10.1371/journal.pone.0013585.

Stamatas, G. N., Zmudzka, B. Z., Kollias, N., & Beer, J. Z. (2004). Non-Invasive Measurements of Skin Pigmentation In Situ. *Pigment Cell Research, 17*(6), 618-626. doi: 10.1111/j.1600-0749.2004.00204.x.

Stephen, I. D., Coetzee, V., & Perrett, D. I. (2011). Carotenoid and melanin pigment coloration affect perceived human health. *Evolution and Human Behavior, 32*(3), 216-227. doi: 10.1016/j.evolhumbehav.2010.09.003.

Stephen, I. D., Coetzee, V., Smith, M. L., & Perrett, D. I. (2009a). Skin blood perfusion and oxygenation colour affect perceived human health. *PLoS One, 4*(4), e5083. doi: 10.1371/journal.pone.0005083.

Stephen, I. D., Oldham, F. H., Perrett, D. I., & Barton, R. A. (2012a). Redness enhances perceived aggression, dominance and attractiveness in men's faces. *Evolutionary Psychology, 10*(3), 562-572.

Stephen, I. D., Scott, I. M. L., Coetzee, V., Pound, N., Perrett, D. I., & Penton-Voak, I. S. (2012b). Cross-cultural effects of color, but not morphological masculinity,

on perceived attractiveness of men's faces. *Evolution and Human Behavior, 33*(4), 260-267. doi: 10.1016/j.evolhumbehav.2011.10.003.

Stephen, I. D., Smith, M. J. L., Stirrat, M. R., & Perrett, D. I. (2009b). Facial skin coloration affects perceived health of human faces. *International Journal of Primatology, 30*(6), 845-857. doi: 10.1007/s10764-009-9380-z.

Stirrat, M., & Perrett, D. I. (2010). Valid Facial Cues to Cooperation and Trust Male Facial Width and Trustworthiness. *Psychological Science, 21*(3), 349-354. doi: 10.1177/0956797610362647.

Stirrat, M., Stulp, G., & Pollet, T. V. (2012). Male facial width is associated with death by contact violence: narrow-faced males are more likely to die from contact violence. *Evolution and Human Behavior, 33*(5), 551-556. doi: 10.1016/j.evolhumbehav.2012.02.002.

Tiddeman, B., Burt, M., & Perrett, D. (2001). Prototyping and transforming facial textures for perception research. *Computer Graphics and Applications, IEEE, 21*(5), 42-50. doi: 10.1109/38.946630.

van den Berghe, P. L., & Frost, P. (1986). Skin color preference, sexual dimorphism and sexual selection: A case of gene culture co-evolution?*. *Ethnic and Racial Studies, 9*(1), 87-113. doi: 10.1080/01419870.1986.9993516.

Vukovic, J., Feinberg, D. R., Jones, B. C., DeBruine, L. M., Welling, L. L. M., Little, A. C., & Smith, F. G. (2008). Self-rated attractiveness predicts individual differences in women's preferences for masculine men's voices. *Personality and Individual Differences, 45*(6), 451-456. doi: 10.1016/j.paid.2008.05.013.

Wedekind, C. (1992). Detailed information about parasites revealed by sexual ornamentation. *Proceedings of the Royal Society of London. Series B: Biological Sciences, 247*(1320), 169-174. doi: 10.1098/rspb.1992.0024.

Whitehead, R. D., Ozakinci, G., & Perrett, D. I. (2012). Attractive skin coloration: harnessing sexual selection to improve diet and health. *Evolutionary Psychology: an International Journal of Evolutionary Approaches to Psychology and Behavior, 10*(5), 842.

Whitehead, R. D., Re, D., Xiao, D., Ozakinci, G., & Perrett, D. I. (2012). You are what you eat: Within-subject increases in fruit and vegetable consumption confer beneficial skin-color changes. *PLoS One, 7*(3), e32988. doi: 10.1371/journal.pone.0032988.

Zahavi, A. (1975). Mate selection—a selection for a handicap. *Journal of Theoretical Biology, 53*(1), 205-214.

FIGURE CAPTIONS

Figure 1. Coloration applied to faces along sexually dimorphic colour axis in Experiment 1. A represents low masculinisation (-200%), B is the original image and C represents high masculinisation (+200%).

Figure 2. Mean masculinity level preferred in colour according to the gender of the face stimuli in Experiment 1. Error bars show standard errors of the mean.

Figure 3. Shape transform applied to faces along sexually dimorphic shape axis in Experiment 2. A represents low masculinisation (-100%), B is the original image and C represents high masculinisation (+100%).

Figure 4. Mean masculinity level preferred in colour according to the gender of the face stimuli in Experiment 2. Error bars show standard errors of the mean.

Figure 5. Mean masculinity level preferred in shape according to the gender of the face stimuli in Experiment 2. Error bars show standard errors of the mean.

Figure 6. Sexually dimorphic shape and colour transforms of male facial appearance in Experiment 3. A represents high masculinisation of colour (+200%) and low masculinisation in shape (-100%), B represents high masculinisation of colour (+200%) and high masculinisation in shape (+100%); C represents low masculinisation of colour (-200%) and low masculinisation in shape (-100%); D represents low masculinisation of colour (-200%) and high masculinisation in shape (+100%).

Figure 7. Mean masculinity level preferred (in colour and shape) according to the gender of the presented stimuli in Experiment 3. For male faces, preferences for a short-term and for long-term relationships are combined. For female faces, preferences are for friendship. Error bars show standard errors of the mean.

Figure 8. Mean masculinity level preferred (in colour and shape) for male faces according to long- and short-term relationship contexts considered by female participants in Experiment 3. Error bars show standard errors of the mean.

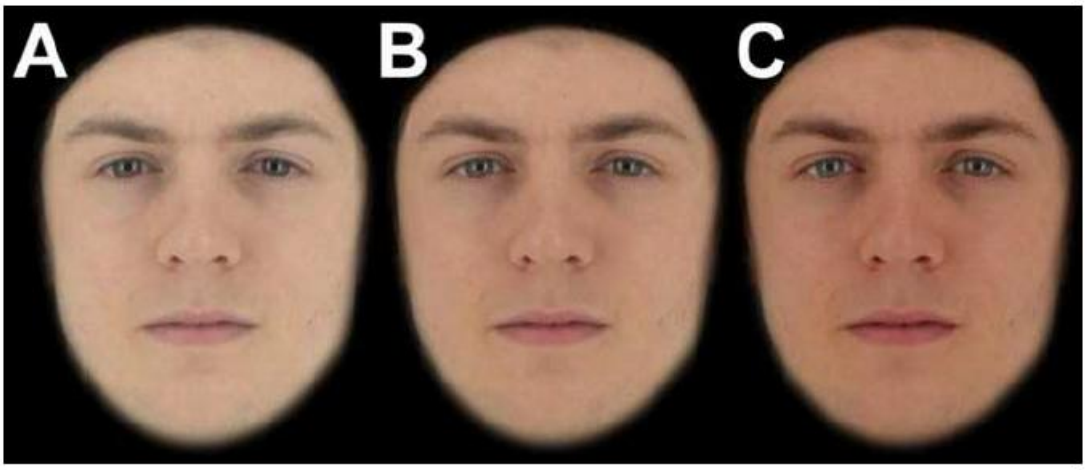

Figure 1

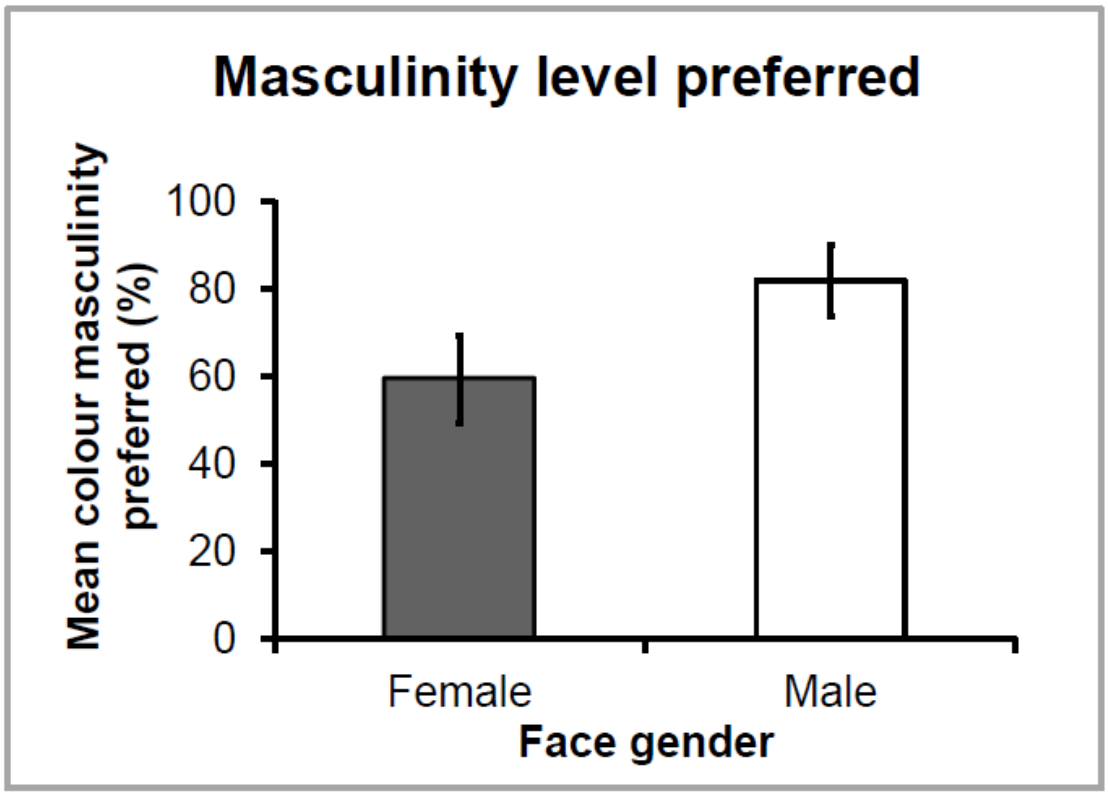

Figure 2

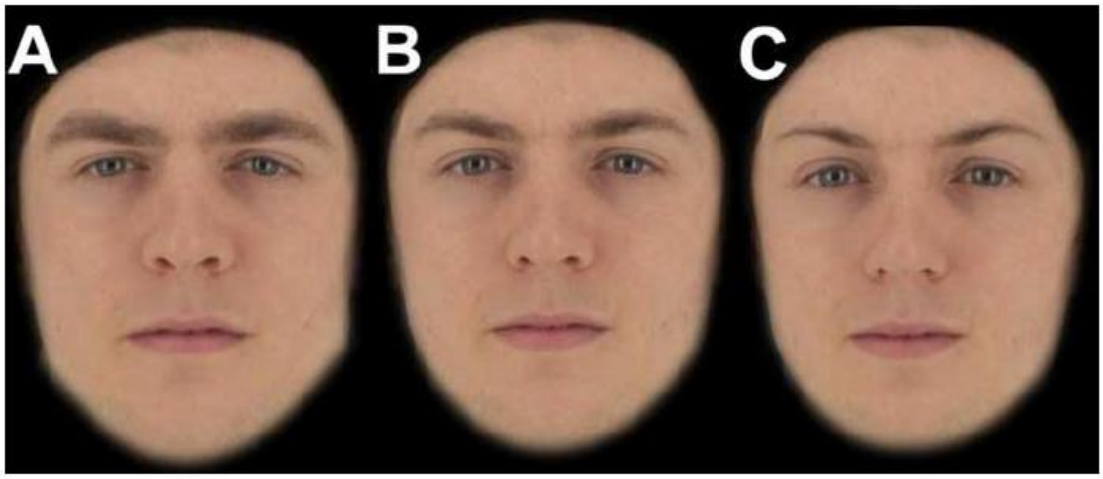

Figure 3

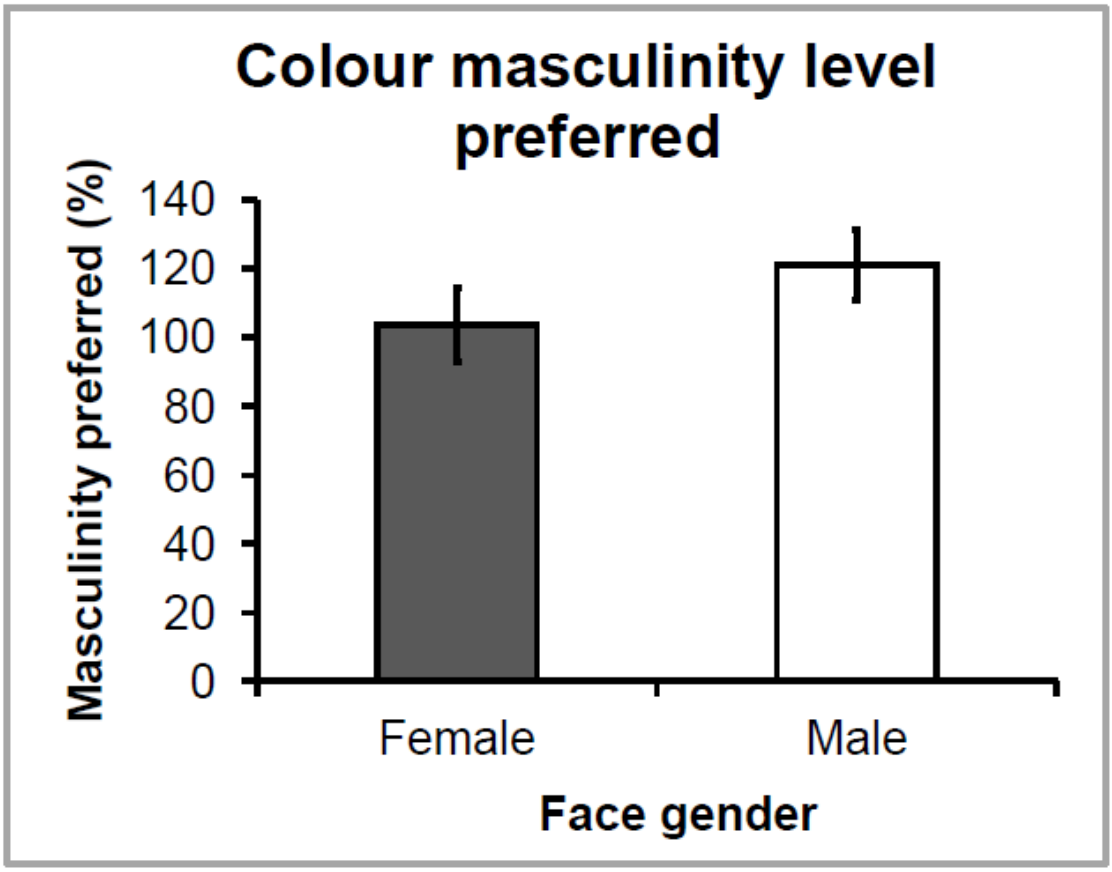

Figure 4

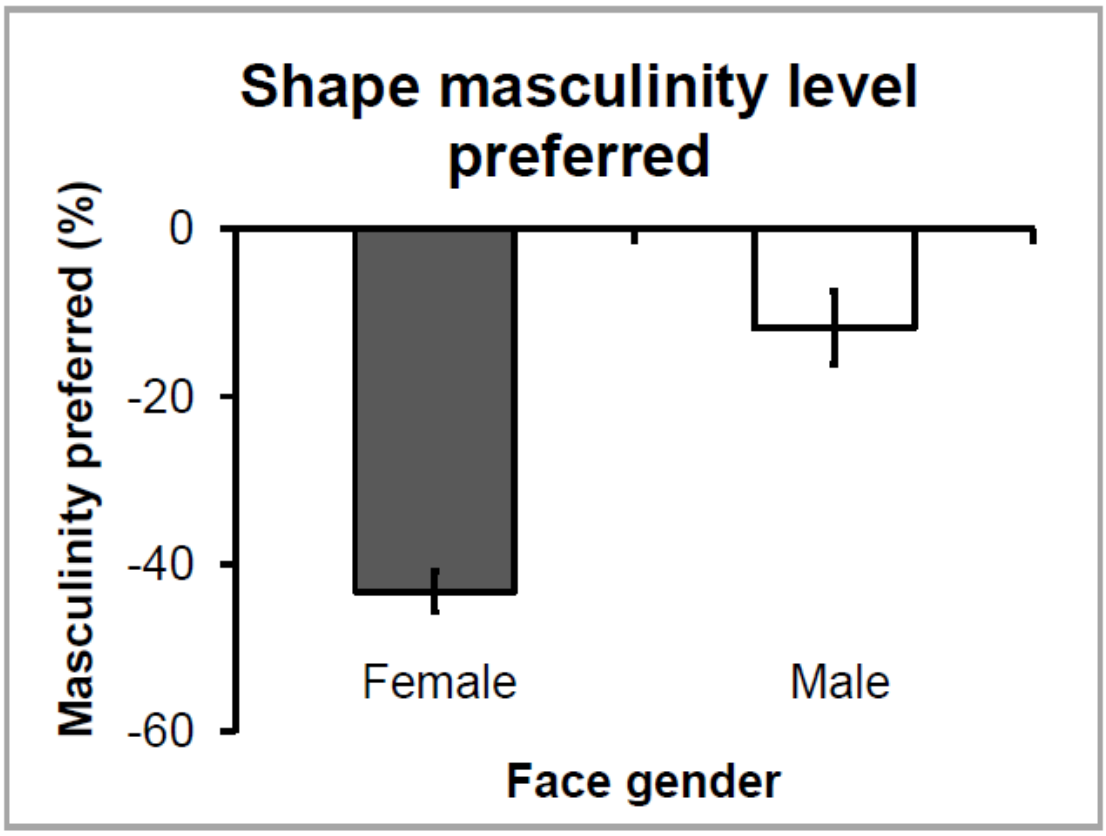

Figure 5

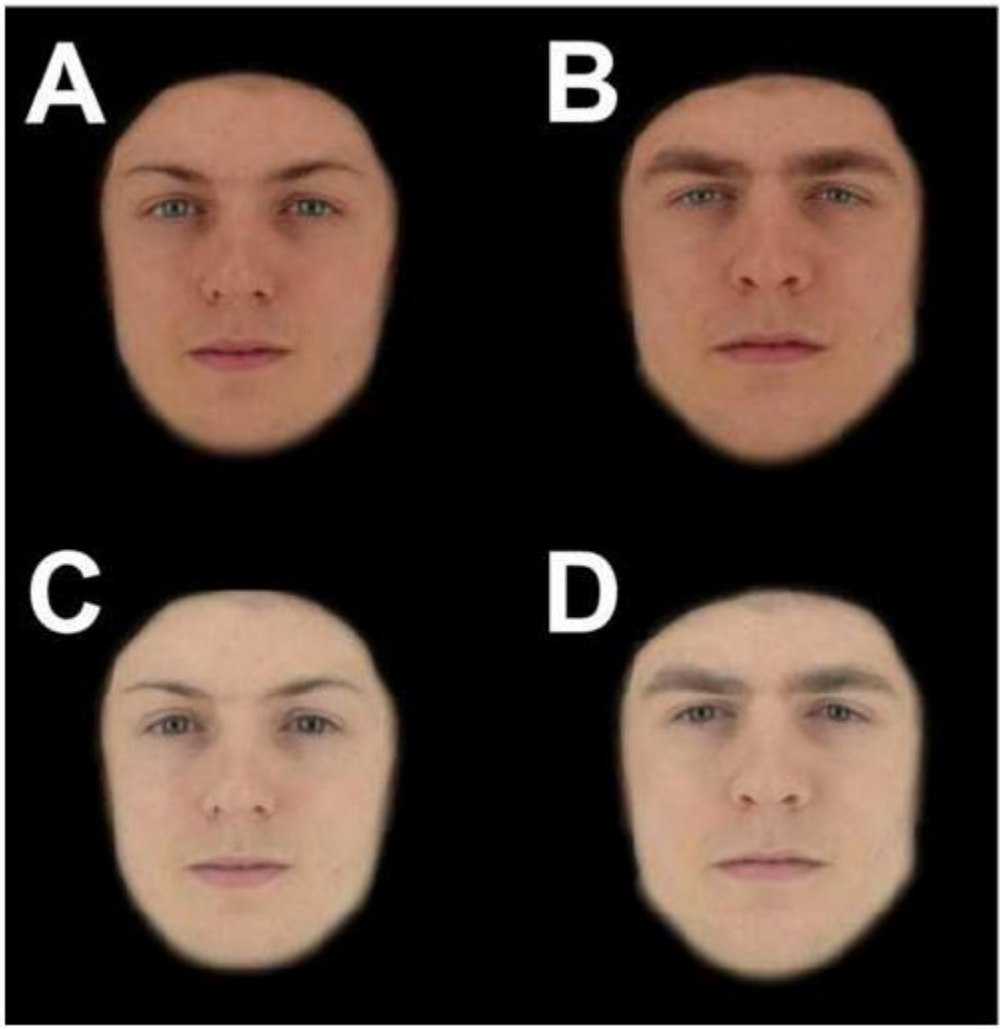

Figure 6

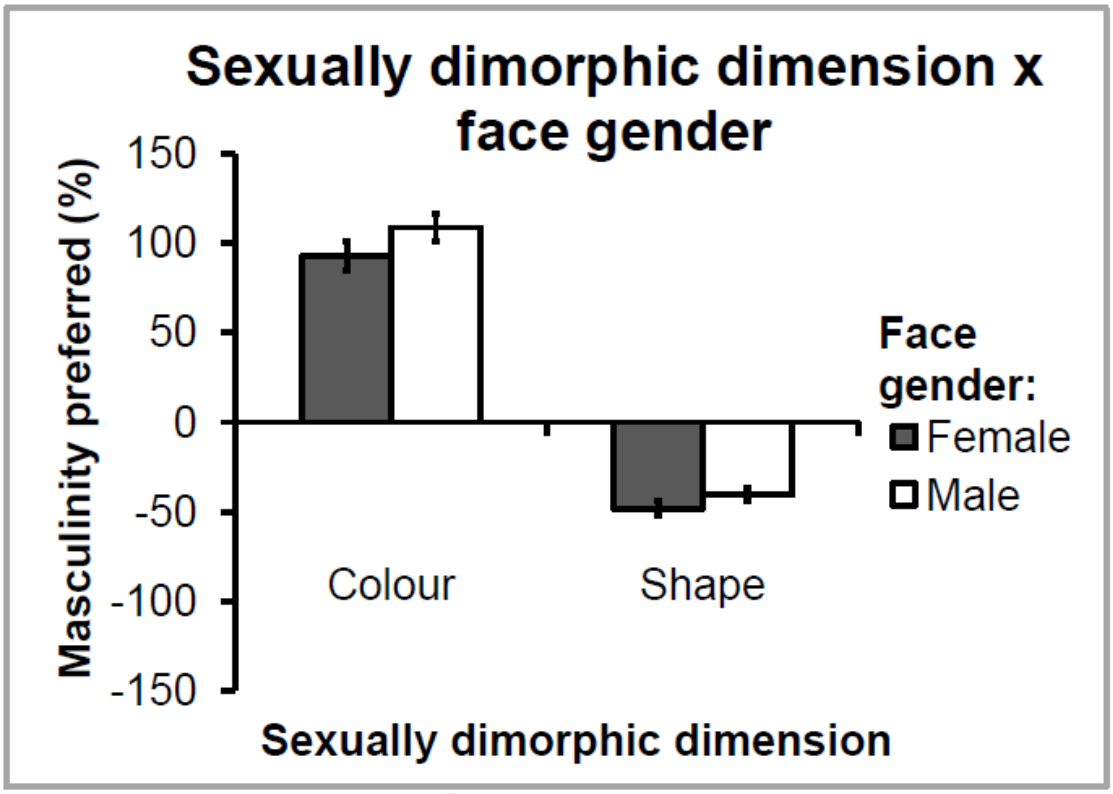

Figure 7

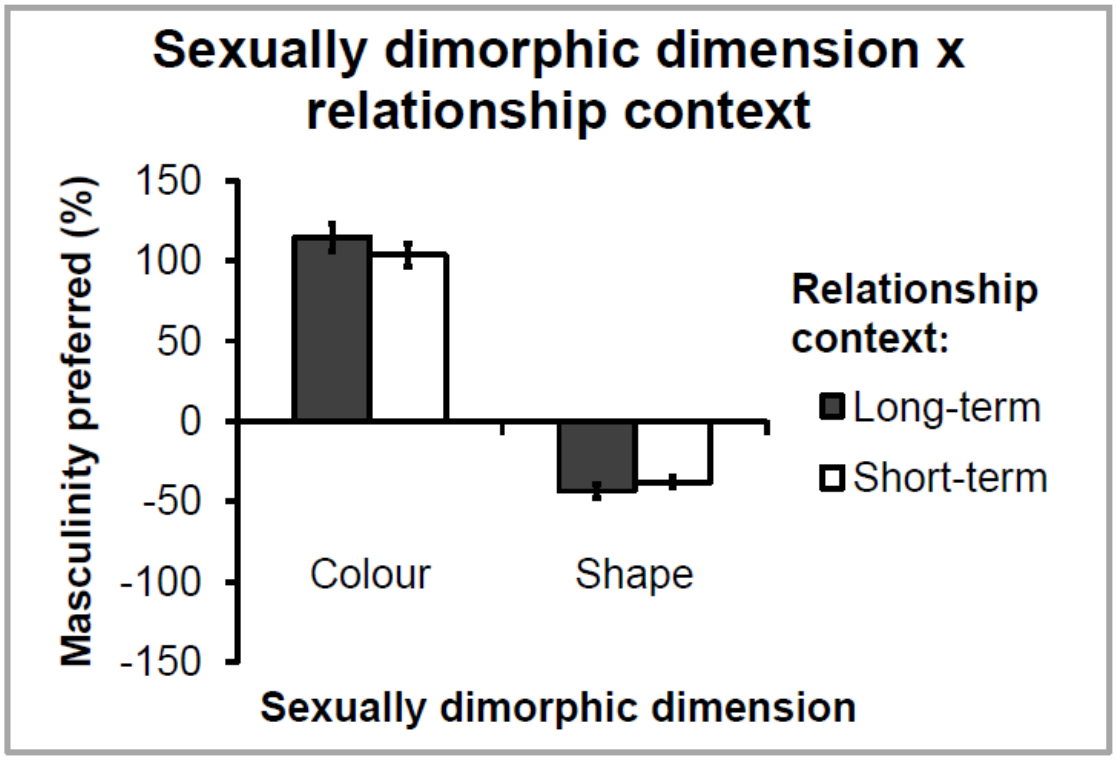

Figure 8