Chemical Senses, 2017, Vol 42, 269–275
doi:10.1093/chemse/bjx004
Original Article
Advance Access publication February 11, 2017

Original Article

Do Masculine Men Smell Better? An Association Between Skin Color Masculinity and Female Preferences for Body Odor

Mariana L. Carrito[1,2,3], Isabel M. Santos[1], Laura Alho[1,2,4], Jacqueline Ferreira[1,2], Sandra C. Soares[1,5,6], Pedro Bem-Haja[1,2], Carlos F. Silva[1] and David I. Perrett[3]

[1]Department of Education and Psychology, Centre for Health Technology and Services Research (CINTESIS), University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal, [2]Institute for Biomedical Imaging and Life Sciences (IBILI), Faculty of Medicine, University of Coimbra, 3000-548 Coimbra, Portugal, [3]School of Psychology and Neuroscience, University of St Andrews, St Mary's Quad, South Street, St Andrews, Fife KY16 9JP, Scotland, UK, [4]Lusófona University of Humanities and Technology, Lisbon, Portugal, [5]Department of Clinical Neuroscience, Division for Psychology, Karolinska Institutet, Stockholm, Sweden and [6]William James Center for Research, ISPA-Instituto Universitário, Lisbon, Portugal

Correspondence to be sent to Isabel M. Santos, Departamento de Educação e Psicologia, Universidade de Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal. e-mail: isabel.m.b.santos@gmail.com

Editorial Decision 1 January 2017.

Abstract

A recent study claimed face skin color as a sexually dimorphic variable that influences attractiveness preferences in mate choice. Thereby, skin color may assume the role of a mate quality signal influencing attractiveness preferences. As body odor is linked to attractiveness, this study aimed to explore whether the odors of men with more masculine facial skin color would be evaluated more positively than odors from less masculine men. Female raters were presented with body odors of 18 men and were asked to rate them in various characteristics. Multilevel modeling revealed that the odors of the donors with more masculine color were rated not only as more attractive, more pleasant, and sexier, but also healthier. This indicates that odor associated with men with more masculine skin color is attractive, just as other sexually dimorphic traits. Furthermore, we found a negative relation between skin color masculinity and perceived odor maleness. Regarding this last finding, a new discussion is introduced with respect to the influence of cognitive stereotypes in odor judgments. Altogether, the study supports the possibility that chemosensory signals may be communicating signs of mate quality associated with masculinity.

Keywords: attractiveness, male coloration, mate preferences, olfaction, scent, sexual dimorphism.

Introduction

Several studies have demonstrated that olfactory cues seem to have an important role in human sexual behavior (Kohl et al. 2001; Lübke and Pause 2015), especially in women's mate choice (Herz and Cahill 1997; Herz and Inzlicht 2002; Havlíček et al. 2008). Women show superiority in sensitivity-detection and recognition-identification body odor tasks compared to men (Brand and Millot 2001) and seem to be more sensitive to the influence of body scents in their sexual interest (Herz and Cahill 1997). In fact, female participants seem to prefer the odors of men that are more dominant (Havlíček et al. 2005) and more symmetric (Thornhill and Gangestad 1999). During puberty, when sexually dimorphic traits begin to emerge, the development of sebaceous and apocrine skin glands occurs which suggests that masculinity may be imprinted in human odor (Wyatt 2015).

Heterosexual women might feel attracted to masculine traits in men, namely scent cues, since masculinity is believed to signal genetic fitness and/or intrasexual competitiveness. The preference for masculinity traits in sexual partners might lower the risk of infection for women, since masculine healthy males may be less likely to contract and spread diseases (Kirkpatrick and Ryan 1991), or at least ensure protection and resources for them and their offspring (Puts 2010). Several studies have reported that preferences for masculinity, especially in odor cues, are dependent on the menstrual cycle of the female participants (Havlíček et al. 2005; Thornhill and Gangestad 1999). Those studies report that women prefer the scent of more masculine males only near ovulation, and this occurs only for non-pill users. However, other studies have failed to find differences across the ovulatory cycle (Rantala et al. 2006).

To our knowledge, Allen et al. (2016), while studying the effect of artificial fragrances on preferences for human body odors, were the first to investigate how perceived facial masculinity correlates with perceived body odor masculinity. They found a positive correlation between face masculinity ratings given by both sex participants with odor masculinity ratings given by female participants. Other studies explored the preference for masculinity in odor cues relying on men's testosterone levels (Thornhill et al. 2013), second-to-fourth digit ratio (2D:4D) (Roberts et al. 2011), or women's exposure to androstenone (Grammer 1993; Cornwell et al. 2004), androstenol (Savic and Berglund 2010), or androstadienone (Cornwell et al. 2004). Acknowledging the debate on whether these last chemicals do in fact represent real human pheromones (Wyatt 2015) and the inconsistent results regarding the attractiveness level of face shape masculinity, with some studies reporting preferences for femininity (e.g. Perrett et al. 1998; Little and Hancock 2002; DeBruine et al. 2010) and others suggesting a preference for masculinity (e.g. DeBruine et al. 2006; Little and Mannion 2006) in male faces, it becomes important to consider other measures of masculinity when investigating odor preferences for sexually dimorphic cues. In this study, we measured masculinity through a new trait which has received little attention: sexually dimorphic skin color.

One of the most typical sexual dimorphic traits that distinguish males and females throughout the animal kingdom is phenotypic color. Sexual dichromatism is frequent between species of birds (Bortolotti et al. 1996; Dale et al. 2015), amphibians (Bell and Zamudio 2012) and fish (Kodric-Brown 1998). Human skin color, apart from being an important indicator of current health (Stephen et al. 2009b; Re et al. 2011; Fink et al. 2012; Whitehead et al. 2012), has been shown to be different between human females and males (Van den Berghe and Frost 1986) but also to be considered attractive in mate preferences (Carrito et al. 2016). The multi-million industry of facial cosmetics is itself a proof of how much skin color influences the perception of facial beauty, and much of cosmetics use seems to serve the purpose of exaggerating sexual dimorphic differences (Russell 2009). A recent proposal claimed skin color, as an indicator of current health condition, to be a stronger determinant of perceived attractiveness than shape masculinity (Scott et al. 2010; Stephen et al. 2012). In a previous study of Carrito et al. (2016), participants chose to masculinize the color of male faces more than the color of female faces when asked to modify the faces to define the most attractive appearance. A masculine skin color that is darker, yellower, and redder than a more feminine skin color, might represent direct benefits to the female partner and hence be attractive for women.

Accordingly, the goal of our study was to investigate whether the odor of men with more masculine facial skin color would be more attractive to heterosexual women. We expected odors of donors with more masculine skin color to be preferred by female raters compared to the ones from men with less masculine skin color. Along with attractiveness, women were asked to rate other characteristics of the odors: pleasantness, sexiness, health, familiarity, intensity, arousal, masculinity, and dominance.

Method

Participants

Detailed written informed consent was obtained from all participants prior to enrolment, and all aspects of the study were performed in accordance with the Declaration of Helsinki for experimentation with human subjects. The study was part of a project that was approved by the Scientific Council of the University of Aveiro, which assesses its ethical, formal, and scientific aspects. A socio-demographic questionnaire open to the academic community was available online, in order to recruit female participants for the experimental task. Forty-two women, aged between 18 and 39 (M = 24.24 years, SD = 6.43), from a total of 116, were selected to participate in the study.

The inclusion criteria were ethnicity (Caucasian), age (between 18 and 40 years old), health status (not reporting any physical, neurological or mental disease), not being pregnant and not currently taking any medication. The upper limit in age was a deliberate choice aiming to avoid the possible influence of hormonal effects related with participants' menopause (Jones et al. 2011; Cobey et al. 2015). The absence of use of hormonal contraceptives was also a requirement since it has been shown that hormonal contraceptives influence sensitivity to olfactory stimuli (Lundström et al. 2006; Renfro and Hoffmann 2013) and also attractiveness judgments in other domains (Little et al. 2013; Roberts et al. 2014). All participants reported having regular menstrual cycles (28–40 days). Participants were asked about the date of the onset of their last menstruation (day 1). Fertile women were considered when being on days 9–15 of their cycle at the time of the experiment (N = 10) while others were considered to be in non-fertile phases of the cycle (N = 31) (Havlicek and Lenochova 2006). One participant could not recall the date of the onset of her last menstruation and her fertility status was not considered.

Participants were asked to refrain from eating (e.g., gum, candies), drinking coffee, or using any scented products that could interfere with their olfactory ability for 1 hour before testing.

Materials

Skin color measurements

The first phase of this work focused on trying to establish a measure of facial skin color sexual dimorphism for the young adult Portuguese population. To do so, it was necessary to collect a sample of skin color measurements of men and women in order to calculate a representative skin color average, according to the International Commission on Illumination (CIE) L*a*b* values, typical of the male and female population. The CIELab color space is defined by L*, a*, and b* values (L* reflects degrees of lightness, and positive values of a* and b* reflect degrees of redness and yellowness, respectively) (Whitehead et al. 2012) and is designed to be perceptually uniform, with a change of one unit appearing to be of approximately the same magnitude regardless of its dimension (Martinkauppi 2002). Therefore, skin color measurements were taken from 100 Caucasian university students, 50 women (aged between 18 and 37; M = 21.14, SD = 3.89) and 50 men (aged between 19 and 31; M = 22.98, SD = 2.65) who volunteered for skin color measurements. Exclusion criteria included the use of self-tanning products, recent physical effort, skin or

infectious disease. The experimenter cleaned the skin on the forehead of each student with cotton and alcohol. Skin color was measured using a Konica Minolta Chroma Meter CR-400. The aperture of the Chroma meter was lightly held against the skin, in order to minimize pressure-induced blanching. White-point calibration was conducted before recording sessions. Recordings were repeated 3 times on the participant's forehead, and the most divergent value of the 3 was excluded from the analyses. Two men and 3 women were later excluded from the sample since the Euclidean (ΔE^*) distance between their 2 remaining skin color measurements was larger than 2. Finally, we averaged the 2 remaining values to obtain a unique L* a* b* set of values for each participant.

Through this process of skin color measurement, average CIE L*a*b* values were assessed for male (n = 48) and female (n = 47) participants. Average male face skin color was L*= 65.37, a*= 12.52 and b*= 17.05 and average female color was L*= 67.82, a*= 11.02 and b*= 15.85. Average male face skin luminance (L*) was significantly different from female average (t (93) = −4.51, P < 0.001), and the same was true for a* (t (93) = 3.77, P < 0.001) and b* (t (93) = 3.08, P < 0.001) color axes. A logistic regression was conducted in order to posteriorly calculate skin color masculinity scores of the male body odor donors. To do so, we considered the L* a* b* values as predictors and the sex of participant as the outcome (men were scored as 1 and women as 0). The resulting model was significant, χ^2 (3) = 26.96, P < 0.01, R^2 (Nagelkerke) = 0.329, and was represented by the following equation: Sex = constant + $B1$ x L* + $B2$ x a* + $B3$ x b*, in which the constant = 7.2, $B1$ = −0.22, $B2$ = 0.25 and $B3$ = 0.27. Logistic regression analyses revealed that skin color (L*, a* and b*) predicted the sex correctly for 69.5% of participants.

A similar skin color measurement procedure was adopted to collect skin color measurements of the male body odor donors. Thirty-two male students volunteered, 14 of them being later excluded based on several criteria as described below. Male volunteers filled a socio-demographic questionnaire and 2 Visual Analogue Scales (VAS, 0–100 mm) that measured their own perceived stress and anxiety levels during the tasks. Only participants that reported low levels of stress or anxiety (<50 in the stress/anxiety scales) were selected. Additional inclusion criteria were: ethnicity (Caucasian), age (over 18 but under 40 years old), avoidance of sun-tanning activities, health status (not reporting physical, mental or neurological diseases) and not currently taking any medication. The 18 male volunteers that fulfilled all requirements (aged between 18 and 34; M = 23.83, SD = 3.94) were selected for subsequent skin color measurements and body odor sampling. Regarding the skin color measurements, CIE L*a*b* values of participants' forehead skin were used to estimate the degree of skin color masculinity of each of the 18 donors. Based on the model presented previously, we calculated the masculinity score of each of the body odor donors (M = 1.63, SD = 1.08, Range: −0.31 to 3.86).

Sampling of donors' body odor

For the body odor sampling procedure, donors were given a kit with 2 cotton pads (Mercurochrome) and medical adhesive tape in a zip bag, a white cotton *t*-shirt, a towel and a hypoallergenic scent free gel wash (*Lactacyd Derma Gel*). Donors were instructed to refrain from using fragrant hygiene products (e.g., perfume, body lotions), smoking, eating spicy foods, garlic, and drinking alcohol, the day before the body odor sampling and until the end of the sampling, in order to avoid alterations of their natural body odor (Alho et al. 2015).

Donors were instructed to bathe early in the morning with the *Lactacyd Derma Gel* and to put in place the cotton pads under both armpits. After they had put on the white cotton t-shirt supplied, donors could also wear their personal clothes if they were clean (and fragrance free). Body odors were collected on the cotton pads attached to their armpits (Mitro et al. 2012; Alho et al. 2015). Donors wore the *t*-shirts for periods of 4 h. The cotton pads were then collected, divided into equal size quadrants, stored in a closed zip-locked bag and frozen at −20 °C.

The samples were thawed 1 h before the experimental task. Four pad quadrants were placed separately in wide-mouthed glass jars with lids and were used as body odor samples. To prevent contamination, odor samples were always handled with surgical gloves. Also, the time interval between storage and the last defrosting was less than 6 months (Lenochova et al. 2009).

Procedure

In the odor rating task, participants smelled each body odor sample for 3 s and rated them on their perceived attractiveness, sexiness, healthiness, familiarity, intensity, pleasantness, masculinity, dominance, and arousal using a VAS (0–100 mm). The anchor points for the ratings were *not attractive* and *very attractive* for "attractiveness", and the same format was applied to the rest of the traits. The specific instructions were as follows: "Place a mark on the lines below in order to indicate your judgement about the various characteristics of this odor". The order of presentation of the traits to be rated was randomized between trials for each sample for each participant. Also, the order of presentation of the 18 odors was randomized and different for each participant. This task was repeated 18 times (one time for each odor sample).

Results

Notes on data analysis

All the analyses were performed using SPSS with Amos (v.22). Primary descriptive and correlational analyses considered male body odor donors as units of analyses, averaging the scores given by all female participants. However, because this methodology does not take into account the variability stemming from individual differences between raters, further analyses were performed taking into account the absolute values of the ratings given by each female rater for each odor sample. Multilevel analyses allowed the consideration of both the effect of female raters (n = 42; level 1) and the effect of male body odor donors (n = 18; level 2) to be analyzed simultaneously rather than aggregating data by either one of them (Gildersleeve et al. 2012). This test was repeated for each of the dependent variables considered, addressing how the skin color masculinity score predicted each one of the ratings.

In order to avoid repeating conceptually similar evaluations and increasing the probability of one of the judgments becoming significant by chance, the ratings considered in all analyses were previously submitted to a dimension reduction procedure. Exploratory factor analyses allowed the extraction of 2 factors and the model was posteriorly improved using confirmatory factor analyses. Hence, the dependent variables considered in the previously mentioned multilevel analyses were not the individual ratings initially collected but the dimensions determined by the latter model.

Descriptive statistics and correlations between ratings

In the first analyses performed, body odor donors were considered as units of analysis (n = 18), to investigate possible associations between the collected ratings. Table 1 shows descriptive statistics for all the rated traits.

Since the rating values were normally distributed (Shapiro-Wilk, $P > 0.05$), except for pleasantness, which showed acceptable skewness of 0.96 (SE = 0.54) and kurtosis of –0.11 (SE = 1.04), Pearson correlations were performed. As observed in Table 2, there are multiple significant correlations between the ratings.

Ratings: dimension reduction

Analyses were performed considering both body odor donors and female raters as units of analysis. Exploratory factor analysis, with Principal Component Analysis (PCA) as extraction method and varimax rotation with suppression of small coefficients (<0.40), allowed the extraction of 2 main components: one including attractiveness, pleasantness, sexiness, and health ratings; the other including masculinity, dominance, intensity, and arousal ratings. To confirm the validity of these latent factors and to verify if the observed variables are legitimate representations of their latent factors, we conducted a confirmatory factor analysis. A new model, excluding both health and arousal, showed higher factor weights and individual reliabilities. Following the procedure used by Gildersleeve et al. (2012), we have grouped the attractiveness, pleasantness, and sexiness ratings in a single latent factor which was called "Likeability". In addition, we grouped the masculinity, dominance and intensity ratings in a factor called "Maleness". The 2-factor model (see Figure 1) revealed a good goodness-of-fit index (GFI = 0.901). Additionally, all the items of the 2 factors obtained high factor weights ($\lambda \geq 0.5$) and appropriate individual reliabilities ($R^2 \geq 0.25$) showing good local adjustment and factorial validity (Figure 1).

The discriminant validity (which assesses whether the items/variables present in a particular factor are not correlated with other factors) was calculated by comparing the Average Variance Extracted (AVE) of each factor with the square of the correlation between the 2 factors (Anderson and Gerbing 1988). AVEs were evaluated as described by Fornell and Larcker (1981). The resulting value (0.0081) was far below that of the AVE values ($AVE_{Likeability} = 0.83$; $AVE_{Maleness} = 0.58$), confirming discriminant validity.

The Cronbach alpha was calculated to assess the internal consistency of the items in each factor. The values obtained for the 2 factors were above 0.7 (Nunnally 1975) indicating an appropriate reliability (Cronbach $\alpha_{Likeability} = 0.929$; Cronbach $\alpha_{Maleness} = 0.793$). Thus, the values of likeability and maleness were calculated taking into account

Table 1. Descriptive statistics of the male odor ratings

	Mean	SD	Range
Attractiveness	27.13	10.27	8.85–45.83
Pleasantness	33.84	13.56	7.26–53.29
Sexiness	25.35	9.20	9.70–43.55
Health	45.17	8.86	28.57–57.29
Masculinity	51.68	15.58	32.21–77.22
Dominance	36.44	9.48	24.12–53.45
Intensity	46.83	21.54	17.71–83.52
Arousal	34.78	9.73	20.14–51.62
Familiarity	27.90	6.66	20.02–46.83

Table 2. Correlations between odor ratings when considering male body donors as units of analysis

	ATTR	PLEA	SEXI	HEAL	MASC	DOMI	INTE	AROU	FAMI
ATTR	—								
PLEA	0.899**	—							
SEXI	0.948**	0.783**	—						
HEAL	0.880**	0.926**	0.806**	—					
MASC	–0.507*	–0.783**	–0.373	–0.686**	—				
DOMI	–0.385	–0.651**	–0.255	–0.606**	0.934**	—			
INTE	–0.624**	–0.835**	–0.511*	–0.814**	0.948**	0.878**	—		
AROU	–0.329	–0.622**	–0.195	–0.600**	0.878**	0.872**	0.895**	—	
FAMI	-0.201	–0.482*	–0.125	–0.430	0.715**	0.664**	0.659**	0.750**	—

ATTR, attractiveness; AROU, Arousal; DOMI, dominance; FAMI, familiarity; HEAL, health; PLEA, pleasantness; MASC, masculinity; INTE, intensity; SEXI, sexiness.

*$P < .05$; **$P < .01$.

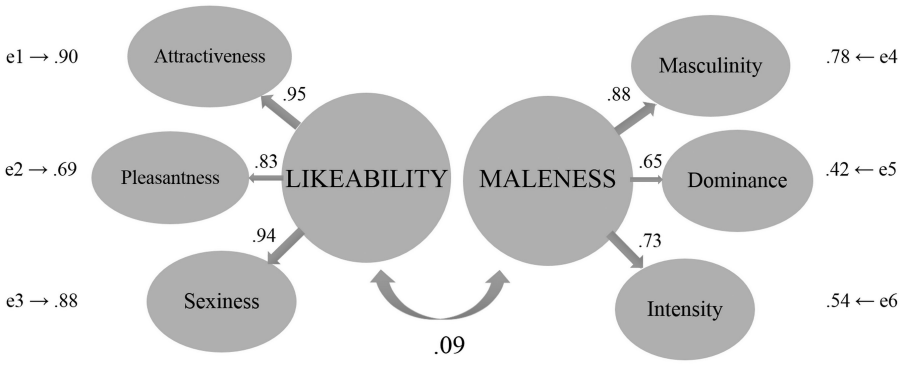

Figure 1. Confirmatory factor analysis of the factors, Likeability and Maleness. Proportions represent, from centre to periphery, the correlation between factors, factor weights, and individual reliabilities, respectively.

the factor weights of each variable (e.g. Likeability = Sexiness*0.94 + Pleasantness*0.83 + Attractiveness*0.95).

The influence of skin color masculinity on odor ratings

The following multilevel analyses took into consideration likeability, maleness, arousal, familiarity, and health as dependent variables (separate analysis were performed for each of the variables). The color masculinity score predicted positively both likeability (Unstandardized $\beta = 4.44 \pm 1.944$, Wald Chi-square = 5.228, $df = 1$, $P = 0.022$) and health (Unstandardized $\beta = 2.102 \pm 0.756$, Wald Chi-square = 7.731, $df = 1$, $P = 0.005$). Maleness was predicted negatively by the color masculinity score (Unstandardized $\beta = -8.403 \pm 1.464$, Wald Chi-square = 32.924, $df = 1$, $P < 0.001$). Finally, color masculinity score did not predict ratings of familiarity (Unstandardized $\beta = -0.643 \pm 0.849$, Wald Chi-square = 0.573, $df = 1$, $P = 0.449$) or arousal (Unstandardized $\beta = 1.756 \pm 0.955$, Wald Chi-square = 3.377, $df = 1$, $P = 0.066$).

Discussion

The main aim of this work was to explore if skin color masculinity had any association with odor judgments of the same participants. To do so, we measured skin color L*a*b* values of male donors and calculated their masculinity index according to a regression model of skin color sexual dimorphism. The body odors of each donor were rated by female participants. Results showed that the donors' skin color masculinity index predicted positively their likeability (attractiveness, pleasantness, and sexiness) and health ratings, but negatively their maleness (masculinity, dominance, and intensity) ratings.

Skin color has been reported as an important determinant of perceived health (Stephen et al. 2009a; Stephen et al. 2009b; Stephen et al. 2011; Re et al. 2011). Skin color is also related to reproductive life (Jones et al. 2015) and plays an important role in the perception of face attractiveness (Fink et al. 2006; Matts et al. 2007; Fink et al. 2012). It has been found that the way in which skin color influences attractiveness seems to be different for each sex (Russell 2003; Russell, 2009). Previous studies from Van den Berghe and Frost (1986) and Frost (1988, 1994) have suggested that skin color is sexually dimorphic and that a more typical color of the respective sex is attractive for the opposite sex. According to Carrito et al. (2016), a more masculine skin color tends to be attractive for both sexes yet more so for male faces. Using the same methodology of skin color measurement, we found that men with highly masculine color have a body odor perceived not only as more attractive, pleasant and sexy, but also as healthier.

Consistent findings have been reported that more dominant men have a sexier smell than less dominant men (Havlíček et al. 2005). Dominant and masculine men might constitute a beneficial choice as partners since they ensure access to resources and protection (Puts 2010). In fact, a recent explanation regarding the mate value of masculinity emphasizes its relation to competitive status-seeking behaviors, more than actual immunocompetence (Scott et al. 2010). Despite the controversy surrounding the exact function of masculinity (whether it relates to health and/or competitiveness), masculinity does seem to be attractive when considering preferences for body shape (Little et al. 2007), voice (Vukovic et al. 2008) and skin color (Carrito et al. 2016). It remains unclear why studies exploring face shape report inconsistent results but these might reflect methodological issues (Rhodes 2006).

How skin color is related to body odor production also remains to be known. A recent study by Zuniga and coworkers (2016) found skin yellowness to be positively correlated with body odor hedonic evaluations when female participants rated odors of male donors. The authors claimed that such result represented a preference for odors of possible healthy mates that had a rich diet in fruit and vegetables. However, self-reported fruit and vegetable consumption did not predict the participants' affective evaluation of the odors. Because skin yellowness is sexually dimorphic, as we observed in the Skin Color Measurements section (in the Materials), it is possible that Zuniga et al.'s (2016) findings represent a preference for odors of men with more masculine color, similarly to our study. Body odors are caused by the presence of bacteria in the secretions of the sebaceous and apocrine glands which, in turn, are very frequent in human armpits (Leyden et al. 1981). Because sebaceous and apocrine glands develop during puberty (Wyatt 2015), simultaneously with the development of secondary sexual characteristics, it is possible that body odor communicates sexual maturity of the individual. On the other hand, considering the possibility that masculinity is indeed related to health and fitness, the relationship between skin color and odor production may be indirect, with men with more masculine skin color being healthier and consequently having a different odor. The health of the individual is believed to influence body odor, as disease can significantly alter the smell of sweat (Olsson et al. 2014; Shirasu and Touhara 2011), so heterosexual women may feel attracted to odors of more masculine, healthier men.

Concerning the results related with the maleness factor, previous findings have demonstrated that the odor of more dominant men is less intense (Havlíček et al. 2005) and a similar result was found in the present study for skin color masculinity. An inverse relationship between odor pleasantness and intensity has been reported in other studies (Doty et al. 1978; Havlíček et al. 2006; Mutic et al. 2016). Here, skin color masculinity negatively predicted the maleness factor that included masculinity, dominance and intensity ratings. At first sight, this result might seem unexpected, but it is probably due to the influence of a stereotype from female raters. It is possible that attributions of masculinity to odors are based on an overgeneralization of the stereotypic assumption that men smell worse than women. By such stereotypical overgeneralization, more masculine men should, therefore, smell (even) worse than feminine men. Unable to find literature that supports the existence of the stereotype "Masculine men smell intensely and badly", we conducted an online survey where female participants, facing an imaginary odor presentation, had to say if the intense/unpleasant odors normally belong to more or less masculine/dominant men (see data in Supplementary Material). As predicted, women associated the intense and unpleasant odors to hypothetical more masculine and dominant males. By this, we conclude that these findings probably result from the influence of a stereotype. This conclusion is supported by Mutic et al.' findings (2016) that suggest that both women and men are unable to correctly attribute masculinity ratings to odors. They found a masculinity bias in human odor since body odors tended to be rated as masculine, regardless of the sex of the donor. Their results were also interpreted as resulting from masculine gender stereotypes, with intense body odor being judged as originating from dominant and physically strong men.

More studies exploring the association between preferences for facial masculinity and odor preferences are needed since, to our knowledge, there is little evidence of this relationship. Despite the number of studies linking (face and body) symmetry and odor attractiveness

(Rikowski and Grammer 1999; Thornhill and Gangestad 1999; Thornhill et al. 2013; Thornhill et al. 2003), facial masculinity has been neglected by recent studies of odors (except for Allen et al. 2016). As mentioned before, higher masculinity, when measured through the levels of testosterone, seems to enhance the attractiveness of odors (Thornhill et al. 2013). Other studies have investigated sexually dimorphic preferences in odor cues, through preferences for putative pheromones (Cornwell et al. 2004). The use of putative pheromones has been criticized by some authors who claim that there is insufficient evidence that the compounds identified so far are actual pheromones (Wyatt 2015). For this reason, studies that use body odors are more ecologically valid than studies of preferences for putative pheromones.

It would also be of interest to test preference for odors of same-sex individuals to evaluate whether the preferences reported here and in similar studies (e.g. Zuniga et al. 2016) do in fact represent mate choice mechanisms or if they simply account for a need of individuals to be surrounded by healthy others in order to avoid infectious diseases. Carrito et al. (2016), when evaluating preferences for skin color masculinity in faces, found that female participants masculinized both male and female faces, noticing, however, that male faces were consistently more masculinized than the other face group. This difference in face color preferences, showed skin color masculinity to be especially important when women judge male faces, which might be taken as a possible mate choice strategy. Regarding odor preferences, if such difference was evident between same and other-sex odors, similar conclusions could be reached and a mate choice relevance would be indicated. Future studies should also try to understand if the menstrual cycle phase of the raters influences their preferences for odors of men varying in skin color masculinity. Such analyses were not performed in this work given the unequal number of female participants present in each group (only 10 female raters were in the fertile phase while the other 31 where in the non-fertile phase of their menstrual cycle).

To our knowledge, this study was the first to explore the relationship between skin color masculinity and odor attractiveness. The results show that females prefer the odor of men with more masculine face skin color. Our findings support the idea that chemosensory communication is important in the context of reproductive success (Lübke and Pause 2015) and that humans, like other animals, use olfactory signals for the transmission of information that is biologically relevant (Grammer et al. 2005).

Supplementary material

Supplementary material are available at *Chemical Senses* online.

Funding

This work was supported by Fundação para a Ciência e a Tecnologia and Programa Operacional de Potencial Humano/Fundo Social Europeu (SFRH/BD/77592/2011 to M.L.C.). The funding agency had no role in the study design, data collection, and analysis, decision to publish or preparation of the manuscript.

Acknowledgements

We give special thanks to João Labrincha and the Department of Materials and Ceramic Engineering from the University of Aveiro, for kindly letting us use their Chroma Meter. We also thank Anne Perrett for proofreading the manuscript and Lesley Ferrier for helping with logistical support.

References

Alho L, Soares SC, Ferreira J, Rocha M, Silva CF, Olsson MJ. 2015. Nosewitness identification: effects of negative emotion. *PLoS One*. 10:e0116706.

Allen C, Cobey KD, Havlíček J, Roberts SC. 2016. The impact of artificial fragrances on the assessment of mate quality cues in body odor. *Evol Hum Behav*. 37:481–489.

Anderson JC, Gerbing DW. 1988. Structural equation modeling in practice: A review and recommended two-step approach. *Psychol Bull*. 103:411.

Bell RC, Zamudio KR. 2012. Sexual dichromatism in frogs: Natural selection, sexual selection and unexpected diversity. *Proc Roy Soc Lond B Biol Sci*. doi:10.1098/rspb.2012.1609

Bortolotti GR, Negro JJ, Tella JL, Marchant TA, Bird DM. 1996. Sexual dichromatism in birds independent of diet, parasites and androgens. *Proc Royal Soc Lond B Biol Sci*. 263:1171–1176.

Brand G, Millot J. 2001. Sex differences in human olfaction: Between evidence and enigma. *Q J Exp Psychol B*. 54:259–270.

Carrito ML, Santos IM, Lefevre CE, Whitehead RD, Silva CF, Perrett DI. 2016. The role of sexually dimorphic skin colour and shape in attractiveness of male faces. *Evol Human Behav*. 37:125–333.

Cobey KD, Little AC, Roberts SC. 2015. Hormonal effects on women's facial masculinity preferences: The influence of pregnancy, post-partum, and hormonal contraceptive use. *Biol Psychol*. 104:35–40.

Cornwell RE, Boothroyd L, Burt DM, Feinberg DR, Jones BC, Little AC, Pitman R, Whiten S, Perrett DI. 2004. Concordant preferences for opposite–sex signals? Human pheromones and facial characteristics. *Proc Royal Soc Lond B Biol Sci*. 271:635–640.

Dale J, Dey CJ, Delhey K, Kempenaers B, Valcu M. 2015. The effects of life history and sexual selection on male and female plumage colouration. *Nature*. 527:367–370.

DeBruine LM, Jones BC, Little AC, Boothroyd LG, Perrett DI, Penton-Voak IS, Cooper PA, Penke L, Feinberg DR, Tiddeman BP. 2006. Correlated preferences for facial masculinity and ideal or actual partner's masculinity. *Proc Royal Soc B Biol Sci*. 273:1355–1360.

DeBruine LM, Jones BC, Smith FG, Little AC. 2010. Are attractive men's faces masculine or feminine? The importance of controlling confounds in face stimuli. *J Exp Psychol Hum Percept Performan*. 36:751.

Doty RL, Orndorff MM, Leyden J, Kligman A. 1978. Communication of gender from human axillary odors: relationship to perceived intensity and hedonicity. *Behav Biol*. 23:373–380.

Fink B, Bunse L, Matts PJ, D'Emiliano D. 2012. Visible skin colouration predicts perception of male facial age, health and attractiveness. *Int J Cosmet Sci*. 34:307–310.

Fink B, Grammer K, Matts PJ. 2006. Visible skin color distribution plays a role in the perception of age, attractiveness, and health in female faces. *Evol Hum Behav* 27:433–442.

Fornell C, Larcker DF. 1981. Evaluating structural equation models with unobservable variables and measurement error. *J Market Res*. 18:39–50.

Frost P. 1988. Human skin color: A possible relationship between its sexual dimorphism and its social perception. *Perspect Biol Med*. 32:38–58.

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 Motor Skills*. 79:507–514.

Gildersleeve K, Haselton M, Larson C, Pillsworth E. 2012. Body odor attractiveness as a cue of impending ovulation in women: Evidence from a study using hormone-confirmed ovulation. *Horm Behav*. 61:157–166.

Grammer K. 1993. 5-α-androst-16en-3α-on: a male pheromone? A brief report. *Ethol Sociobiol*. 14:201–207.

Grammer K, Fink B, Neave N. 2005. Human pheromones and sexual attraction. *Eur J Obstet Gynecol Reprod Biol*. 118:135–142.

Havlíček J, Dvořáková R, Bartoš L, Flegr J. 2006. Non-advertized does not mean concealed: body odour changes across the human menstrual cycle. *Ethology*. 112:81–90.

Havlicek J, Lenochova P. 2006. The effect of meat consumption on body odor attractiveness. *Chem Senses*. 31:747–752.

Havlíček J, Roberts SC, Flegr J. 2005. Women's preference for dominant male odour: Effects of menstrual cycle and relationship status. *Biol Lett*. 1:256–259.

Havlíček J, Saxton TK, Roberts SC, Jozifkova E, Lhota S, Valentova J, Flegr J. 2008. He sees, she smells? Male and female reports of sensory reliance in mate choice and non-mate choice contexts. *Pers Individ Differ*. 45:565–570.

Herz RS, Cahill ED. 1997. Differential use of sensory information in sexual behavior as a function of gender. *Hum Nat*. 8:275–286.

Herz RS, Inzlicht M. 2002. Sex differences in response to physical and social factors involved in human mate selection: The importance of smell for women. *Evol Hum Behav*. 23:359–364.

Jones BC, Hahn AC, Fisher CI, Wincenciak J, Kandrik M, Roberts SC, Little AC, DeBruine LM. 2015. Facial coloration tracks changes in women's estradiol. *Psychoneuroendocrinology*. 56:29–34.

Jones BC, Vukovic J, Little AC, Roberts SC, DeBruine LM. 2011. Circummenopausal changes in women's preferences for sexually dimorphic shape cues in peer-aged faces. *Biol Psychol*. 87:453–455.

Kirkpatrick M, Ryan MJ. 1991. The evolution of mating preferences and the paradox of the lek. *Nature*. 350:33–38.

Kodric-Brown A. 1998. Sexual dichromatism and temporary color changes in the reproduction of fishes. *Am Zool*. 38:70–81.

Kohl JV, Atzmueller M, Fink B, Grammer K. 2001. Human pheromones: Integrating neuroendocrinology and ethology. *Neuro Endocrinol Lett*. 22:309–321.

Lenochova P, Roberts SC, Havlicek J. 2009. Methods of human body odor sampling: the effect of freezing. *Chem Senses*. 34:127–138.

Leyden JJ, McGinley KJ, Hölzle E, Labows JN, Kligman AM. 1981. The microbiology of the human axilla and its relationship to axillary odor. *J Invest Dermatol*. 77:413–416.

Little AC, Burriss RP, Petrie M, Jones BC, Roberts SC. 2013. Oral contraceptive use in women changes preferences for male facial masculinity and is associated with partner facial masculinity. *Psychoneuroendocrinology*. 38:1777–1785.

Little AC, Hancock PJB. 2002. The role of masculinity and distinctiveness in judgments of human male facial attractiveness. *Br J Psychol*. 93:451–464.

Little AC, Jones BC, Burriss RP. 2007. Preferences for masculinity in male bodies change across the menstrual cycle. *Horm Behav*. 51:633–639.

Little AC, Mannion H. 2006. Viewing attractive or unattractive same-sex individuals changes self-rated attractiveness and face preferences in women. *Anim Behav*. 72:981–987.

Lundström JN, McClintock MK, Olsson MJ. 2006. Effects of reproductive state on olfactory sensitivity suggest odor specificity. *Biol Psychol*. 71:244–247.

Lübke KT, Pause BM. 2015. Always follow your nose: The functional significance of social chemosignals in human reproduction and survival. *Horm Behav*. 68:134–144.

Martinkauppi B. 2002. *Face Colour Under Varying Illumination: Analysis and Applications*. University of Oulu Finland.

Matts PJ, Fink B, Grammer K, Burquest M. 2007. Color homogeneity and visual perception of age, health, and attractiveness of female facial skin. *J Am Acad Dermatol*. 57:977–984.

Mitro S, Gordon AR, Olsson MJ, Lundström JN. 2012. The smell of age: perception and discrimination of body odors of different ages. *PLoS One*. 7:e38110.

Mutic S, Moellers EM, Wiesmann M, Freiherr J. 2016. Chemosensory communication of gender information: Masculinity bias in body odor perception and femininity bias introduced by chemosignals during social perception. *Front Psychol*. 6.

Nunnally JC. 1975. Psychometric theory. 25 years ago and now. *Educ Res*. 4:7–21.

Olsson MJ, Lundström JN, Kimball BA, Gordon AR, Karshikoff B, Hosseini N, Sorjonen K, Olgart Höglund C, Solares C, Soop A, Axelsson J, Lekander M. 2014. The scent of disease: Human body odor contains an early chemosensory cue of sickness. *Psychol Sci*. 25:817–823.

Perrett DI, Lee KJ, Penton-Voak I, Rowland D, Yoshikawa S, Burt DM, Henzi SP, Castles DL, Akamatsu S. 1998. Effects of sexual dimorphism on facial attractiveness. *Nature*. 394:884–887.

Puts DA. 2010. Beauty and the beast: Mechanisms of sexual selection in humans. *Evol Hum Behav*. 31:157–175.

Rantala MJ, Eriksson CJP, Vainikka A, Kortet R. 2006. Male steroid hormones and female preference for male body odor. *Evol Hum Behav*. 27:259–269.

Re DE, Whitehead RD, Xiao D, Perrett DI. 2011. Oxygenated-blood colour change thresholds for perceived facial redness, health, and attractiveness. *PLoS One*. 6:e17859.

Renfro KJ, Hoffmann H. 2013. The relationship between oral contraceptive use and sensitivity to olfactory stimuli. *Horm Behav*. 63:491–496.

Rhodes G. 2006. The evolutionary psychology of facial beauty. *Annu Rev Psychol*. 57:199–226.

Rikowski A, Grammer K. 1999. Human body odour, symmetry and attractiveness. *Proc Royal Soc Lond B Biol Sci*. 266:869–874.

Roberts SC, Kralevich A, Ferdenzi C, Saxton TK, Jones BC, DeBruine LM, Little AC, Havlíček J. 2011. Body odor quality predicts behavioral attractiveness in humans. *Arch Sex Behav*. 40:1111–1117.

Roberts SC, Little AC, Burriss RP, Cobey KD, Klapilová K, Havlíček J, Jones BC, DeBruine L, Petrie M. 2014. Partner choice, relationship satisfaction, and oral contraception: The congruency hypothesis. *Psychol Sci*. 25:1497–1503.

Russell R. 2003. Sex, beauty, and the relative luminance of facial features. *Perception*. 32:1093–1107.

Russell R. 2009. A sex difference in facial contrast and its exaggeration by cosmetics. *Perception*. 38:1211–1219.

Savic I, Berglund H. 2010. Androstenol–a steroid derived odor activates the hypothalamus in women. *PLoS One*. 5:e8651.

Scott IM, Pound N, Stephen ID, Clark AP, Penton-Voak IS. 2010. Does masculinity matter? The contribution of masculine face shape to male attractiveness in humans. *PLoS One*. 5:e13585.

Shirasu M, Touhara K. 2011. The scent of disease: Volatile organic compounds of the human body related to disease and disorder. *J Biochem*. 150:257–266.

Stephen ID, Coetzee V, Law Smith M, Perrett DI. 2009a. Skin blood perfusion and oxygenation colour affect perceived human health. *PLoS One*. 4:e5083.

Stephen ID, Coetzee V, Perrett DI. 2011. Carotenoid and melanin pigment coloration affect perceived human health. *Evol Hum Behav*. 32:216–227.

Stephen ID, Law Smith MJ, Stirrat MR, Perrett DI. 2009b. Facial skin coloration affects perceived health of human faces. *Int J Primatol*. 30:845–857.

Stephen ID, Scott IML, Coetzee V, Pound N, Perrett DI, Penton-Voak IS. 2012. Cross-cultural effects of color, but not morphological masculinity, on perceived attractiveness of men's faces. *Evol Hum Behav*. 33:260–267.

Thornhill R, Chapman JF, Gangestad SW. 2013. Women's preferences for men's scents associated with testosterone and cortisol levels: Patterns across the ovulatory cycle. *Evol Hum Behav*. 34:216–221.

Thornhill R, Gangestad SW. 1999. The scent of symmetry: A human sex pheromone that signals fitness? *Evol Hum Behav*. 20:175–201.

Thornhill R, Gangestad SW, Miller R, Scheyd G, McCollough JK, Franklin M. 2003. Major histocompatibility complex genes, symmetry, and body scent attractiveness in men and women. *Behav Ecol*. 14:668–678.

Van den Berghe PL, Frost P. 1986. Skin color preference, sexual dimorphism and sexual selection: A case of gene culture co-evolution?*. *Ethnic Racial Stud*. 9:87–113.

Vukovic J, Feinberg DR, Jones BC, DeBruine LM, Welling LLM, Little AC, Smith FG. 2008. Self-rated attractiveness predicts individual differences in women's preferences for masculine men's voices. *Personal Individ Differ*. 45:451–456.

Whitehead RD, Ozakinci G, Perrett DI. 2012. Attractive skin coloration: Harnessing sexual selection to improve diet and health. *Evol Psychol*. 10:842.

Wyatt TD. 2015. The search for human pheromones: The lost decades and the necessity of returning to first principles. *Proc Roy Soc Lond B Biol Sci*. 282:20142994.

Zuniga A, Stevenson RJ, Mahmut MK, Stephen ID. 2017. Diet quality and the attractiveness of male body odor. *Evol Hum Behav.* 38:136–143.