Beneath the beard: Do facial morphometrics influence the strength of judgments of men's beardedness?

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Abstract

Converging evidence suggests men's beards, like many androgen-dependent masculine secondary sexual traits, communicate masculinity and dominance intra-sexually while effects of men's beardedness on attractiveness ratings are more equivocal. Beards may enhance perceived masculinity and dominance via amplifying aspects of underlying craniofacial masculinity, particularly the size of the lower face and jaw. Here we tested these predictions across two studies. In Study 1, we tested how three facial metrics - objectively measured craniofacial masculinity, facial-width-to-height ratio (fWHR), and jaw size - calculated while clean-shaven impacted on ratings of attractiveness, masculinity and dominance of 37 men photographed when clean-shaven and with full beards. Results showed that beards exerted significant and positive effects on masculinity, dominance and to a lesser extent attractiveness. However, fWHR did not significantly interact with beardedness to influence the directions of any of the ratings, and while some linear and nonlinear interactions were significant between objective craniofacial masculinity and beardedness as well as between jaw size and beardedness, they tended to be subtle and dwarfed by the large main effect of beardedness on perceptual ratings. In Study 2, we measured ratings of attractiveness, masculinity and dominance for composite clean-shaven and bearded stimuli experimentally manipulated in facial shape to represent ±50% the shape of a beard, essentially manipulating the size of the lower face and jaw of the stimuli. We found a strong main effect whereby bearded stimuli enhanced dominance and masculinity ratings over clean-shaven stimuli. Increasing the size of the lower face and jaw augmented ratings of masculinity and dominance in clean-shaven stimuli but did not exert strong effects within bearded stimuli. Attractiveness ratings were highest for bearded faces with smaller jaws followed by bearded and clean-shaven faces with larger jaws and lowest for clean-shaven faces with small jaws. Taken together, our findings suggest that beards exert main effects on masculinity and dominance possibly by amplifying male typical facial shape. Attractiveness ratings of facial hair may reflect a compromise between overly dominant looking faces with larger jaws and the additive effects beardedness has on these ratings.

Keywords

Sexual selection; human evolution; facial hair; masculinity; dominance; attractiveness

1. Introduction

Sexual selection occurs when individuals compete for mating opportunities (Kokko, Brooks, Jennions, & Morley, 2003; Kokko, Jennions, & Brooks, 2006), and can result in extravagant weaponry used in competition with members of the same sex or ornamentation that enhances attractiveness to the opposite sex (Andersson, 1994; Emlen, 2008). Of all the human secondary sexual traits, amongst the most sexually dimorphic and visually conspicuous is beardedness (Dixson et al., 2005; Grueter et al., 2015). Facial hair grows due to the combined actions of the androgens dihydrotestosterone (DHT) and testosterone (Randall, 2008). Testosterone is associated with the number of active facial hair follicles and DHT with their distribution and density (Farthing, Mattei, Edwards, & Dawson, 1982). Male facial hair first diverges from that of females at around age 10 years (Trotter, 1922), continues to develop throughout puberty, and is fully developed at young adulthood (Hamilton, 1958; Hamilton, Terada, & Mestlert, 1958). There is considerable variation in beard development in men within and between populations (Hamilton, 1958; Hamilton et al., 1958) and strong concordance in beard density and distribution in monozygotic twins, highlighting an important genetic component to androgenic hirsutism (Hamilton, 1964).

Facial hair does not appear to provide any advantage to survival or performance in subsistence hunting and horticulture, suggesting that sexual selection is likely to have shaped the evolution of beardedness (Darwin, 1871). Converging evidence suggests that men's beards function intra-sexually in communicating age and dominance (Puts, 2010), as beards are consistently reported to enhance ratings of dominance (Dixson & Vasey, 2012; Muscarella & Cunningham, 1996; Neave & Shields, 2008; Saxton, Mackey, McCarty, & Neave, 2016; Sherlock, Tegg, Sullikowski, & Dixson, 2016) and aggressiveness (Dixson & Vasey, 2012; Geniole & McCormick, 2015; Muscarella & Cunningham, 1996; Neave & Shields, 2008). Further, male aggressiveness ratings of threatening facial displays were higher for bearded than clean-shaven faces (Dixson & Vasey, 2012). Taken together, evidence suggests that facial hair enhances perceptions of men's facial dominance compared to clean-shaven conditions.

In contrast, evidence for a role of facial hair as an ornament that enhances men's attractiveness to women remains largely equivocal (for review see Dixson & Rantala, 2016). One possibility is that beards reduce male facial attractiveness because they are judged as overtly dominant, while a clean-shaven appearance is judged as more socially appeasing and trustworthy (Guthrie, 1970). Another possibility is that beardedness increases perceptions of masculinity where an intermediate level is most attractive. This is supported by evidence that preferences for less masculine facial shape features and light facial hair or 'stubble' were positively correlated (Cunningham, Barbee, & Pike, 1990) and experimental studies demonstrating that women's preferences converge on faces with stubble, which received intermediate ratings of masculinity and dominance between clean-shaven conditions and full beardedness (Dixson & Brooks, 2013; Neave & Shields, 2008).

Beards may enhance perceptions of men's dominance and masculinity because they emphasise sexually dimorphic aspects of underlying craniofacial shape (Goodhart, 1960; Guthrie, 1970). For example, among the Meldpa of Papua New Guinea, parting the beard and thrusting the jaw towards a rival occurs during agonistic encounters and may curtail the escalation of conflict (Eibl-Eibesfeldt, 2007). However, if beards enhance perceived dominance via increasing jaw size and facial length, they may also decrease perceptions of attractiveness owing to breaching a threshold of masculinity at which facial hair enhances male attractiveness (Dixson & Brooks, 2013; Neave & Shields, 2008). Pertinent to the suggestion that beards emphasise masculine craniofacial shape, Geniole and McCormick (2015) found that clean-shaven faces were more attractive than full beards when accounting for variation in the underlying facial-width-to-height ratio (fWHR), a potentially sexually dimorphic trait associated with male dominance and aggressiveness (Geniole, Denson, Dixson, Carré, & McCormick, 2015). However, it remains unclear whether natural variation in craniofacial masculinity beyond fWHR interacts with beardedness to determine any threshold at which beards operate to enhance male facial attractiveness.

To this end, across two studies we tested whether differences in men's underlying craniofacial shape influenced how beards drove perceptions of men's sociosexual attributes. In study 1, we collected attractiveness, masculinity and dominance ratings for 37 male faces when clean-shaven and fully bearded. We assessed how these ratings were influenced by natural variation in levels of three underlying facial attributes: objective craniofacial masculinity, fWHR, and jaw size. We predicted that facial hair would have positive effects on masculinity and dominance (Dixson & Vasey, 2012; Muscarella & Cunningham, 1996; Neave & Shields, 2008; Saxton et al., 2015). However, this effect should be more pronounced among men low in objective craniofacial masculinity, with low fWHRs, and smaller jaws, as the additive effects of beards on dominance ratings may be more evident on an otherwise less masculine looking male (Sherlock et al., 2016). For attractiveness ratings, we also predicted that facial hair would enhance attractiveness among men with low objective craniofacial masculinity, low fWHRs, and smaller jaws (Dixson & Brooks, 2013; Neave & Shields, 2008). To test these predictions, in addition to testing linear effects of facial morphology on ratings of facial hair, we also tested for quadratic relationships in our models in order to expose any nonlinear relationships among the variables on perceptual ratings.

In study 2, we experimentally manipulated men's facial shape in composite clean-shaven and bearded stimuli to represent ±50% the shape of a beard, essentially manipulating the size of the lower face and jaw to test how they determined ratings of attractiveness, masculinity, and dominance. We predicted that enhancing the size of the lower face and jaw would be associated with higher masculinity and dominance ratings in bearded and clean-shaven stimuli (Dixson & Brooks, 2013; Neave & Shields, 2008). However, if facial hair enhances perceptions of dominance and masculinity because beards appear to enhance the prominence of the lower face and jaw (Guthrie, 1970), the additive effects of facial hair on perceived dominance and masculinity should be more pronounced on an otherwise less masculine looking face with reduced lower face

and jaw prominence than among bearded faces with larger jaws. For attractiveness ratings, we predicted that there would be a threshold of masculinity and dominance at which beards operated as an attractive trait (Dixson & Brooks, 2013; Neave & Shields, 2008), so that reducing the lower face and jaw size within bearded stimuli would enhance attractiveness judgments of beards relative to faces with larger jaws.

2. Methods

2.1.1. Study 1: Facial hair, facial shape and judgments of men's masculinity, dominance and attractiveness in natural faces

2.1.2. Facial hair stimuli

Thirty-seven men (mean age ± SD = 27.86 ± 5.75 years) of European ethnicity were photographed posing neutral facial expressions in front and profile view using a Canon digital camera (8.0 megapixels resolution), 150 cm from the participant under controlled lighting. Males were photographed when clean-shaven and with 4-8 weeks of natural beard growth (Figure 1).

2.1.3. Objective craniofacial facial masculinity score

To compute a data-driven single measure of facial masculinity, we used a separate face dataset of 40 male and 40 female faces (*M* = 32.65 years, *SD* = 11.35 years). All males in this face set were clean-shaven. We used geometric morphometrics, the statistical analysis of shape, to develop a facial masculinity score for each clean-shaven image of each participant from landmark coordinates (Bookstein, 1991; Zelditch, Swiderski, & Sheets, 2012).

All faces from the supplementary face set plus the clean-shaven and bearded images from the target set were delineated on 164 landmarks using Webmorph, an online tool for manipulating and transforming facial stimuli (DeBruine & Tiddeman, 2016). These landmarks are shown in Figure 2. To extract shape information from raw facial landmarks, we conducted a generalised Procrustes analysis (GPA), which removes non-shape information such as translation, size, and rotational effects (Zelditch et al., 2012). The GPA included the 40 male and female images from the supplementary face set, and the 37 clean-shaven images from the current stimulus set. The GPA produces 'shape variables' via a principle components analysis, which are a decomposition of the landmark coordinates and have the advantage of being compatible with conventional statistical techniques. Shape variables that explained greater than 1% of total shape variation across landmark configurations were maintained in further analyses (17 shape variables). A discriminant-function analysis (DFA) with sex as the grouping variable (male = 0, female = 1) was conducted with only the supplementary faces. This produced a discriminant function that represents the sexual-dimorphism dimension (linear differences that best discriminated between male and female faces). We then applied this function to the shape variables of the clean-shaven faces in the current stimuli set, computing a facial masculinity score for each of these faces. Composites of the 5 highest and lowest scoring faces for facial masculinity in the original face set are shown in Figure S1, which appears to validate the facial masculinity score. Correlations between

mean rated facial masculinity and the objective measure were also significant (r = .36, p = .030), further validating the objective masculinity measure. This procedure has previously been used to create facial masculinity scores (Lee et al., 2014); for further information on geometric morphometrics see Zelditch et al., 2012).

2.1.4. Facial width-to-height ratio (fWHR)

A research assistant who was blind to the hypotheses of the study carried out measurements and calculated the facial width to height ratio (fWHR) for each face when clean-shaven and fully bearded. Following published protocol, facial width was taken from one zygion to the other and divided by facial height, which was measured as the distance from upper lip to the middle of the brow (Geniole et al., 2015). As in previous work in which fWHR was measured in bearded and clean-shaven faces (Geniole & McCormick, 2015), we found a strong correlation between fWHR in the 37 males measured in bearded (mean FWHR ± SD = 1.873 ± 0.113) and clean-shaven faces (mean FWHR ± SD = 1.874 ± 0.115; r = 0.861, p < 0.001). FWHR was not significantly different in bearded faces compared to clean-shaven faces (t_{36} = -0.142, p = 0.888). FWHR of the clean-shaven faces were included as a predictor variable in the analysis.

2.1.5. Jaw Size

To assess whether any effects of underlying facial attributes are due solely to variation in the jaw, we computed a separate measure of jaw size. A "jaw masculinity" measure could not be computed using similar methods as overall craniofacial masculinity as this method removes size information, which is pertinent to our investigation (this method remains valid for computing overall facial masculinity as jaw size can be assessed in relation to the non-jaw aspects of the face). To compute jaw size, we used the centroid size of the 16 landmarks of the jaw (red landmarks in Figure 2) for each of the clean-shaven faces. Centroid size is a measure of size used in geometric morphometrics and is defined as the square root of the sum of squared distances of a set of landmarks and their central location. Centroid size was standardised before being entered into the models as a predictor.

2.1.6. Experimental procedure

Participants were online volunteers recruited via MTurk. Upon entry to the website, participants provided their biological sex (male or female), their age (in years) and stated their sexual orientation using the Kinsey scale (Kinsey, Pomeroy, & Martin, 1948). After providing these demographic data, participants were randomly assigned to one of three rating conditions in which they rated 37 faces for either attractiveness, dominance or masculinity on a scale of 0-100 (0 = low in the trait; 100 = high in the trait). Stimuli were drawn at random from the 37 faces so that participants saw each male face once either when clean-shaven or bearded.

2.1.7. Participants

A total of 751 participants completed the study (mean age ± SD = 35.86 ± 11.31 years, range 18-86), of which 398 were men (mean age ± SD = 33.61 ± 10.51 years, range 18-73) and 353 were women (mean age ± SD = 38.38 ± 11.66

years, range 18-86). The sample was predominantly heterosexual (89.5% reported Kinsey scale #1 or 2), 3.3% were heterosexual but more than incidentally homosexual (Kinsey scale #3), 2.5% were equally attracted to men and women, 0.7% were homosexual but incidentally heterosexual, and 4.0% were exclusively homosexual. Participants were all from the U.S.A.

As sexual orientation influences face preferences (Petterson, Dixson, Little, & Vasey, 2015; 2016), we retained only the ratings from heterosexual women and men. For masculinity ratings, 222 (36.76 ± 11.42 years) participants completed the ratings, of which 129 were men (34.82 ± 11.35 years) and 113 were women (38.55 ± 11.06 years). For dominance ratings, 221 (36.31 ± 12.17 years) participants completed the ratings, of which 121 were men (33.74 ± 11.05 years) and 100 were women (39.42 ± 12.78 years). For attractiveness ratings, 230 (35.85 ± 10.63 years) participants completed the ratings, of which 117 were men (32.74 ± 9.13 years) and 113 were women (39.08 ± 11.14 years).

2.1.8. Statistical analyses

Data were analysed using Mixed Effects Modelling, which are appropriate for non-independent data. We analysed the data using the lmer package in the R software package (for a full explanation of this technique's advantages over other approaches, see Kenny, Kashy & Cook, 2002). Separate models were run for each sex, for each of the outcome variables (attractiveness, masculinity, and dominance rating), and for each facial attribute (either fWHR, facial masculinity score, or jaw size). These data are non-independent because ratings could be nested in both participants and the stimuli face identity (i.e., ratings made by a single participant, or by multiple participants of the same face, are more likely to be similar). To control for this, random effects of beardedness and facial attribute were included in the model, which accounts for possible variation in the effect of beardedness and facial attribute both between participants, and between stimuli identity. Facial attributes scores were grand-mean centred. Both linear and quadratic effects were estimated, given that previous research has indicated that facial attributes effects could be nonlinear (e.g., women may prefer an intermediate level of facial masculinity, Scott et al., 2014). Predictors included in the model were both linear and nonlinear effects of the facial attribute for clean-shaven versions of each face (either fWHR, facial masculinity score or jaw size), beardedness of the face (0 = clean-shaven, 1 = bearded), and the linear and nonlinear interactions between facial attribute and beardedness.

While we report the estimated fixed effects here, the estimated random effects are reported in the Electronic Supplementary Material (ESM; Table S1-S3). Further, an additional model was run investigating the effects of jaw size and beardedness while controlling for objective facial masculinity; these models are also reported in the Electronic Supplementary Material. The fixed effects are reported in Tables S4-S6 for attractiveness, masculinity, and dominance models respectively, while the random effects are reported in Tables S7-S9 of the ESM. These models did not reveal any new significant interactions between beardedness and either facial attribute that were not found in the separate models.

2.1.9. Results

2.1.9.1 Correlations between underlying facial attributes

As expected, there was a significant correlation between objective facial masculinity and jaw size (r = .36, p = .031). However, neither of these measures were significantly correlated with fWHR (r = -.08, p = .631 for objective facial masculinity, r = -.15, p = .384 for jaw size). These correlations are consistent with recent evidence suggesting that fWHR may not be sexually dimorphic (Bird et al. 2016; Hodges-Simeon, Sobraske, Samore, Gurven & Gaulin, 2016; Lefevre et al., 2012).

2.1.9.2 Attractiveness ratings

There was a significant main effect of beardedness on attractiveness ratings (Table 1) for both males and females, such that full beards increased judgments of male facial attractiveness (Figure 3A1; though this was not significant in the fWHR or jaw size models for male raters; Table 1). There was also a main effect of fWHR for both males and females, such that higher fWHRs were judged as less attractive than smaller fWHRs (Table 1). There were significant linear and nonlinear interactions between objective craniofacial masculinity and beardedness on attractiveness ratings in the model for female participants, such that attractiveness ratings for intermediate levels of objective masculinity were marginally higher in bearded faces, but also marginally lower in clean-shaven faces; however, these interactions, although significant, were slight (see Figure 3B1). There was also a significant nonlinear interaction between jaw size and beardedness in male attractiveness ratings, such that males rated intermediate levels of jaw size for clean shaven faces as more attractive (see Figure 4B). There was no main effect of facial masculinity, or any linear or nonlinear interactions for other models for attractiveness ratings (Table 1).

2.1.9.3 Masculinity ratings

Facial hair had a significant main effect on facial masculinity ratings in all models (Table 2), such that full beards were judged as more masculine than clean-shaven faces (Figure 3A2; though this was not significant in the jaw size model for male raters; Table 2). There were no significant linear or nonlinear main effects or interactions in both fWHR models, though there was a significant main effect of objective facial masculinity, such that higher scores of objective craniofacial masculinity received higher masculinity ratings. There was also a significant positive main effect of jaw size on masculinity ratings, consistent with expectations. There was also a significant interaction between objective craniofacial masculinity and beardedness for both male and female raters, such that objective craniofacial masculinity had a slightly larger effect in clean-shaven images compared to bearded-images (see Figure 3B2). No other significant interactions for masculinity ratings were found (Table 2).

2.1.9.4 Dominance ratings

Facial hair had a significant main effect on facial dominance ratings (Table 3), which reflects that full beards were judged as more dominant than clean-shaven faces (Figure 3A3). There were no significant main effects or interactions for both fWHR and jaw size models, though objective craniofacial masculinity had a

significant main effect for both males and females. For males, there was also a significant nonlinear interaction between beardedness and the facial attribute for both the objective facial masculinity and jaw size models. For objective craniofacial masculinity, intermediate levels were rated slightly lower for dominance for bearded images compared to low and high levels of objective craniofacial masculinity (Figure 3B3). However, the reverse was true for jaw size, where intermediate levels were rated higher for dominance in clean-shaven images (Figure 4B). No other interactions were significant for dominance ratings (Table 3).

2.2. Study 2: Facial hair, facial shape and judgments of masculinity, dominance and attractiveness in computer-generated composites

2.2.1. Manipulations of facial shape

The same 37 males who were photographed when clean-shaven and with full beards used in Study 1 were used to create the stimuli in the Study 2. Images were manipulated the Webmorph software (DeBruine & Tiddeman, 2016). First, composites were created by averaging 5 individuals selected at random from the stimulus set used in Study 1. This was done for both the clean-shaven versions of each individual and the corresponding 5 bearded versions of the same individuals. The linear shape difference for each composite between the clean-shaven and bearded versions was then calculated based on 129 landmarks. This difference, representing the shape difference between the clean-shaven and bearded face, was then applied to the composite faces themselves.

The facial composites were manipulated by either adding or subtracting 50% of the shape difference while maintaining color and textual information. This created four images per composite: one in which the clean-shaven face dimensions were amplified on a clean-shaven face, one in which a clean-shaven face possessed the dimensions of a bearded face, a third in which the bearded face had the dimensions of a clean-shaven face, and a fourth in which the bearded face had accentuated the dimensions of bearded faces (Figure 5). These stimuli are hereafter referred to as clean-shaven small jaw, clean-shaven large jaw, bearded small jaw, bearded large jaw. Note that this method of manipulating the images ensures that the clean-shaven large jaw, and the bearded small jaw images have identical shape information, with only color and textural information related to beardedness differing between these two stimuli. This entire process was repeated 10 times, each time randomly sampling 5 individuals from the stimulus set to create 10 base composite pairs that were used in this study. Similar methods have been previously used to manipulate other facial dimensions, such as facial sexual dimorphism (Benson & Perrett, 1993; Perrett et al., 1998).

Comparing the standardized centroid size of the jaw (as calculated using the method detailed for Study 1) for that of the clean-shaven large jaw faces (*M* = .84, *range* = .18 to 1.40) and clean-shaven small jaw faces (*M* = -.74, *range* = -1.50 to -.29) with the jaw sizes of clean-shaven the natural male stimuli from Study 1 (*M* = .00, range = -2.06 to 2.09) suggests that the manipulated jaw sizes were within the levels that could naturally occur.

2.2.2. Experimental procedure

Participants were online volunteers recruited via Mturk. Upon entry to the website, participants provided their biological sex (male or female), their age (in years) and stated their sexual orientation using the Kinsey scale (Kinsey et al., 1948). After providing these demographic data, participants were randomly assigned to one of three rating conditions in which they rated the 40 faces for either attractiveness, dominance or masculinity on a scale of 0-100 (0 = low in the trait; 100 = high in the trait). Stimuli were presented in a random order.

2.2.3. Participants

A total of 702 participants completed the study (mean age ± SD = 36.66 ± 12.01 years), of which 350 were men (34.33 ± 10.84 years) and 352 were women (38.97 ± 12.67 years). The sample was predominantly heterosexual (89.2% reported Kinsey scale #1 or 2), 2.4% were heterosexual but more than incidentally homosexual (i.e. Kinsey scale #3), 3.3% were equally attracted to men and women, 0.7% were homosexual but incidentally heterosexual, 1.1% were exclusively homosexual and 3.3% elected not to respond to this question.

As in Study 1, we retained only the ratings from heterosexual women and men, leaving a sample of 626 (37.26 ± 12.13 years), of which 315 were men (34.62 ± 10.98 years) and 311 were women (39.93 ± 12.66 years). For masculinity ratings, 207 (36.51 ± 12.23 years) participants completed the ratings, of which 102 were men (34.11 ± 11.03 years) and 105 were women (38.85 ± 12.92 years). For dominance ratings, 209 (37.71 ± 12.56 years) participants completed the ratings, of which 107 were men (35.04 ± 11.68 years) and 102 were women (40.52 ± 12.90 years). For attractiveness ratings, 210 (37.53 ± 11.61 years) participants completed the ratings, of which 106 were men (34.68 ± 10.26 years) and 104 were women (40.44 ± 12.21 years). All participants were from the U.S.A.

2.2.4. Statistical analyses

Ratings for the ten stimulus images for dominance, masculinity and attractiveness within each category of facial hair (clean-shaven, bearded) and jaw size (small, large) showed strong internal consistency (all Cronbach alphas ≥ 0.927; Table S10). Thus, we averaged ratings for dominance, masculinity and attractiveness across the 10 stimuli within each of the four facial categories (i.e. full beards with large jaws, full beards with small jaws, clean-shaven with large jaws and clean-shaven with small jaws). These were the dependent variables in ANOVAs in which facial hair (bearded, clean-shaven) and jaw size (large, small) were within-subject factors and the sex of raters (male, female) was a between-subjects factor. All effect sizes in Table 4 are partial eta square (η_p^2).

2.2.5. Results

2.2.5.1. Attractiveness ratings

There were significant main effects of facial hair and jaw size on attractiveness ratings (Table 4). Attractiveness ratings were significantly higher for full beards than clean-shaven faces ($t_{209} = 7.25$, $p < 0.001$) and faces with large jaws than those with small jaws ($t_{209} = 4.48$, $p < 0.001$). There was also a significant facial hair × jaw size interaction (Table 4). Faces with full beards and small jaws

received significantly higher attractiveness ratings than bearded faces with large jaws and clean-shaven faces with high large and small jaws (all $t_{209} \geq 4.64$, all $p \leq 0.001$). Faces with full beards and large jaws received significantly higher ratings than clean-shaven faces with large and small jaws (all $t_{209} \geq 2.32$, all $p \leq 0.05$) and clean-shaven faces with large jaws received significantly higher ratings than clean-shaven faces with small jaws ($t_{209} = 10.23$, $p < 0.001$; Figure 6A).

There was also a significant facial hair × jaw size × rater sex interaction (Table 4). Within sex comparisons revealed ratings were higher for faces with full beards and small jaws than bearded faces with large jaws and clean-shaven faces with large and small jaws (male raters: all $t_{105} \geq 2.85$, all $p \leq 0.01$; female raters: all $t_{103} \geq 3.59$, all $p \leq 0.001$) and clean-shaven faces with large jaws received significantly higher ratings than clean-shaven faces with small jaws (male raters: $t_{105} = 6.53$, $p < 0.001$; female raters: $t_{103} = 8.12$, $p < 0.001$). Males rated faces with full beards and large jaws significantly higher than clean-shaven faces with large and small jaws (all $t_{105} \geq 2.04$, all $p \leq 0.05$). Females rated faces with full beards and large jaws significantly higher than clean-shaven faces with small jaws ($t_{103} = 5.93$, $p < 0.001$) but not large jaws ($t_{103} = 1.32$, $p = 0.191$). Between sex comparisons revealed that male participants gave higher ratings for clean-shaven faces with small jaws than female participants ($t_{208} = 2.48$, $p = 0.014$), but none of the other comparisons differed significantly between the sexes (all $t_{208} \leq 1.38$, $p \geq 0.168$; see Figure S2).

2.2.5.2. Masculinity ratings

There were significant main effects of facial hair and jaw size on masculinity ratings (Table 4). This reflects that masculinity ratings were significantly higher for full beards than clean-shaven faces ($t_{206} = 20.73$, $p < 0.001$) and faces with large jaws than those with small jaws ($t_{206} = 12.44$, $p < 0.001$).

There was also a significant facial hair × jaw size interaction (Table 4). Faces with full beards and large jaws received significantly higher masculinity ratings than bearded faces with small jaws and clean-shaven faces with large and small jaws (all $t_{206} \geq 7.45$, all $p \leq 0.001$). Faces with full beards and small jaws received significantly higher ratings than clean-shaven faces with large and small jaws (all $t_{206} \geq 15.96$, all $p \leq 0.001$) and clean-shaven faces with large jaws received significantly higher ratings than clean-shaven faces with small jaws ($t_{206} = 12.38$, $p < 0.001$; Figure 6B).

There was also a significant facial hair × rater sex interaction (Table 4). Female participants gave slightly higher ratings for clean-shaven faces than men ($t_{205} = 2.07$, $p = 0.039$), while ratings for facial hair did not differ significantly between the sexes ($t_{205} = 0.18$, $p = 0.861$).

2.2.5.3. Dominance ratings

There were significant main effects of facial hair and jaw size on dominance ratings (Table 4). This reflects that dominance ratings were significantly higher for full beards than clean-shaven faces ($t_{208} = 15.90$, $p < 0.001$) and faces with large jaws than those with small jaws ($t_{208} = 5.12$, $p < 0.001$). There was also a significant facial hair × jaw size interaction (Table 4). There was no significant

difference in rated dominance between faces with full beards and large jaws and full beards with small jaws (t_{208} = 1.38, p = 0.169). However, bearded faces with large and small jaws were rated as significantly more dominant than clean-shaven faces with large and small jaws (all $t_{208} \geq 11.62$, all $p \leq 0.001$). Clean-shaven faces with large jaws received significantly higher ratings than clean-shaven faces with small jaws (t_{208} = 9.12, $p < 0.001$; Figure 6C). There were no main or interaction effects involving the sex of the raters (Table 4).

3. Discussion

Men's beardedness represents an evolved secondary sexual trait of marked dimorphism and visual conspicuousness. Converging evidence suggests beards, like many androgen-dependent masculine secondary sexual traits, play a role in male-male communication of age and social dominance (Dixson & Vasey, 2012; Muscarella & Cunningham, 1996; Neave & Shields, 2008; Saxton et al., 2016; Sherlock et al., 2016). These effects may be attributable to the potential for beards to act as amplifiers to the overall length of the face and the prominence of the lower face and jaw (Guthrie, 1970), two sexually dimorphic components of facial morphology that enhance judgments of men's age, masculinity and dominance (Geniole et al., 2015; Perrett et al., 1998). However, few studies have directly tested how underlying androgen-dependent craniofacial shape might interact with beardedness to determine the strength of these effects. In Study 1, we reported on whether naturally varying levels of underlying craniofacial shape influences how beards are judged on attractiveness, masculinity, and dominance. In Study 2, we repeated these measures using composite stimuli in which we experimentally manipulated the size of the lower face and jaw.

In study 1, using a sample of 37 men photographed when clean-shaven and fully bearded, we quantified how facial masculinity, facial width-to-height ratio, and jaw size in clean-shaven conditions influenced ratings of attractiveness, masculinity, and dominance in clean-shaven and bearded conditions. We found that beards exerted strong main effects on masculinity and dominance ratings, and smaller but positive effects on attractiveness. While there was a negative relationship between fWHR and attractiveness, consistent with previous research (Geniole et al., 2015), there were no linear or nonlinear interaction effects between fWHR and the facial hair condition (clean-shaven or full bearded) to influence perceptual ratings. There were, however, some significant linear or nonlinear interactions in models that included objective craniofacial facial masculinity and jaw size. For women's attractiveness ratings, intermediate levels of objective craniofacial masculinity decreased ratings in clean-shaven faces. For men's attractiveness ratings, intermediate jaw sizes increased ratings, but only in clean-shaven faces. Objective craniofacial masculinity had a larger linear influence on both men's and women's masculinity ratings for clean-shaven images compared to bearded images. For men's dominance ratings, intermediate levels of objective craniofacial masculinity were rated slightly less dominant compared to high and low levels of objective masculinity; however, intermediate levels of jaw size were rated slightly more dominant in clean-shaven faces compared to lower or higher levels of jaw size. While these interactions were statistically significant, they tended to be subtle,

and were often dwarfed by a large main effect of beardedness on ratings. Together, our findings suggest that facial hair increases perceptions of men's masculinity, dominance and to some extent attractiveness, but only has small effects on perceptions of underlying variation in craniofacial shape. However, our results should be treated as preliminary; while our sample size of 37 individuals represents the largest to date, replicating these effects using a larger sample with greater variation in craniofacial morphology will be important.

In study 2, we experimentally manipulated facial shape to reflect +50% and -50% of the shape of full bearded faces to composites of the same five individuals when clean-shaven and bearded. Ratings of dominance and masculinity were significantly higher for bearded compared to clean-shaven faces, replicating the findings of study 1 and of previous research (Dixson & Vasey, 2012; Muscarella & Cunningham, 1996; Neave & Shields, 2008; Saxton et al., 2015; Sherlock et al., 2016). We also found that experimentally manipulating the size of the lower face and jaw in clean-shaven faces resulted in significantly higher dominance and masculinity ratings, which is also in accordance with the patterns of past studies (Windhager, Schaefer, & Fink, 2011). This also suggests that the experimental manipulation was capturing sexually dimorphic aspects of craniofacial shape. Interestingly, while bearded faces with large jaws received higher masculinity ratings than bearded faces with smaller jaws, there was no effect of jaw size on dominance ratings within bearded faces. A bearded male with a less pronounced lower face and jaw structure was judged as looking significantly more masculine and dominant than the same stimuli when clean-shaven presented with a larger jaw. To our knowledge, these findings provide the first experimental evidence confirming that facial hair enhances ratings of men's masculinity and dominance over and above any effects of underlying lower face and jaw size (Guthrie, 1970).

Debate surrounds the efficacy of various techniques used to measure masculinity across studies. While some researchers suggest that rated masculinity captures differences in sexual dimorphism (e.g., Rhodes, 2006), others advocate using morphological measures (Komori, Kawamura, & Ishihara, 2011). Perceived masculinity is linked to perceived attractiveness in some studies (Koehler, Simmons, Rhodes, & Peters, 2004; Rhodes, Simmons, & Peters, 2005). However, other studies using morphological measurements of masculinity do not report a relationship between masculinity and attractiveness (Stephen et al., 2012; Thornhill & Gangestad, 2006; Waynforth, Delwadia, & Camm, 2005). While our findings show that morphological masculinity was positively associated with rated masculinity and facial hair enhanced ratings of masculinity over clean-shaven faces, ratings of attractiveness were more complex and non-linear. Female participants gave marginally higher attractiveness ratings for intermediate levels of objective craniofacial masculinity in bearded faces and marginally lower in clean-shaven faces. This provides some support for our prediction that attractiveness ratings of facial hair may reflect a compromise between overly dominant and masculine looking faces with larger jaws and the additive effects beardedness has on these ratings.

It is important to note that the evidence that beards enhance male facial attractiveness to women is largely equivocal (Dixson, Sullikowski, Gouda-Vossos, Rantala & Brooks, 2016). In some studies, beards render male faces as more attractive to women (Janif, Brooks, & Dixson, 2014; Pellegrini, 1973), in others they are rated as less attractive than clean-shaven face (Dixson & Vasey, 2012; Dixson, Tam, & Awasthy, 2013; Muscarella & Cunningham, 1996; Neave & Shields, 2008), while in some studies ratings between clean-shaven and bearded show little differences (Dixson & Brooks, 2013; Saxton et al., 2016). Other studies have reported that intermediate degrees of facial hair or stubble are judged as most attractive (Dixson & Brooks, 2013; Janif et al., 2014; Neave & Shields, 2008). Faces with stubble also received intermediate ratings of masculinity and dominance between clean-shaven and fully bearded faces, which received the lowest and highest ratings on these dimensions respectively (Dixson & Brooks, 2013; Neave & Shields, 2008), which may reflect a threshold of masculinity and dominance at which facial hair operates as an attractive trait (Dixson & Brooks, 2013; Neave & Shields, 2008). In the current study, we found that bearded faces in which the jaw size was manipulated to appear less prominent were judged as most attractive, followed by bearded faces and clean-shaven faces with larger jaws. Clean-shaven faces with smaller jaws were rated the least attractive. If beardedness and masculinity had a linear effect on attractiveness, then we would expect the large jawed bearded faces to be judged as the most attractive. Thus, our findings suggest that facial hair may have positive effects on attractiveness at a lower level of underlying craniofacial masculinity. However, given that the manipulation of jaw size on bearded faces also made the face look larger, it is possible that preferences for small jaw sizes reflect preferences for a reduced amount of facial hair that is comparable to preferences for stubble over full beardedness in other recent studies. We therefore acknowledge that our results may also reflect contemporary cultural trends in preferences for facial stubble.

There are some other important limitations to our studies that should be highlighted for other researchers seeking to test how facial hair impacts on judgments of male faces. Thus, bodies and faces represent complex multivariate phenotypes (Brooks et al., 2015). While we used natural variation in craniofacial morphometrics to assess the impact of beardedness on ratings of men's sociosexual attributes, we acknowledge that there was variation in the absolute length of beardedness between the males who served as stimuli. This may have contributed to how underlying facial morphometrics influenced judgments. In an attempt to resolve this issue, we constructed composite stimuli using random combinations of the same males when clean-shaven and fully bearded. This approach may be affective in reducing some of the idiosyncratic variation between the raw male stimuli. However, we again acknowledge the artificial nature of the stimuli. A solution for future research will be to employ larger stimulus sets with more stringent criteria for photographing beard length.

Further, previous research has shown that men's self-reported masculinity and confidence is augmented when wearing a beard compared to when wearing

a bandana or when clean-shaven (Wood, 1986). Thus, it is possible that when posing a neutral expression, the effect of wearing a beard may have enhanced our participants' feelings of dominance and confidence which may have subtly transferred into their neutral expressions compared to when clean-shaven. For instance, ratings of facial attractiveness were influenced by a target's t-shirt colour, even when the t-shirt was not visible to raters (Roberts, Owen, & Havlicek, 2010). We acknowledge that such an effect may have occurred in our study, so that the effects of self-perceived masculinity and confidence when bearded were subtly evident in the neutral expression and influenced ratings of masculinity and dominance. Unfortunately, we did not collect measures of men's self-perceived confidence when clean-shaven and bearded and therefore cannot control for these effects in our study.

Our finding that beardedness is a significant amplifier of perceived male dominance is consistent with several past studies. Theoretical reviews have suggested that beards function like other androgen-dependent traits in augmenting formidability within contest competition scenarios (Puts, 2010; 2016). Thus, in earlier phases of human evolution, when the strength of female choice may have been weaker than in contemporary societies, cues that enhance formidability and fighting ability intra-sexually may have led to greater mating and reproductive success (Puts, Bailey, & Reno, 2015). Blanchard (2010) suggested that beards provide an advantage in fights as a cushion to blows to the face in a manner analogous to the mane in male lions. Indeed, Carrier and Morgan (2015) analysed the evolution of facial musculature in humans and demonstrated that such musculature may protect the midface from strikes. Under such a scenario within ancestral conditions when grooming rates may have been lower, the human beard may have further functioned to protect the face during combat (Blanchard, 2010). Beards may also enhance social aspects of dominance that lead to status and mating opportunities. For instance, while fashions in facial hair fluctuate (Robinson, 1976), men were reported to be more bearded at times when the marriage market was more male-biased (Barber, 2001), possibly as males enhance their masculinity as part of male-male signalling. When frequencies of facial hair become too saturated, however, preferences shift to more novel or rarer facial hair types, suggesting the attractiveness of beardedness is to some degree frequency-dependent (Janif et al., 2014). Identifying the mechanisms by which beardedness leads to status acquisition and mating success remains an important challenge for future research.

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Captions to Figures

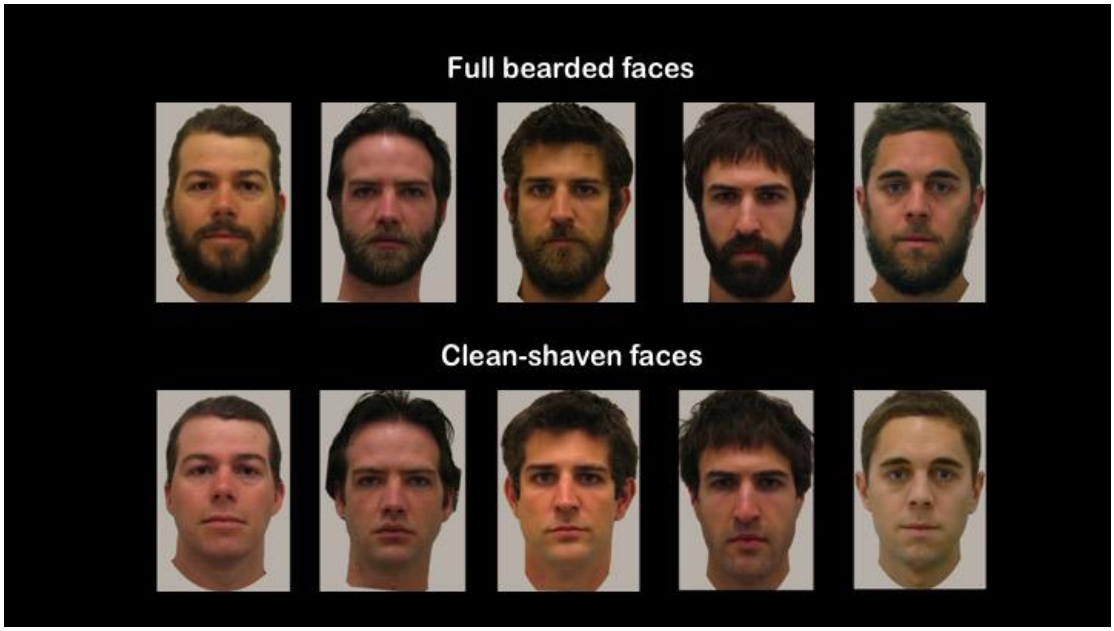

Figure 1.
Examples of the male stimuli used in Study 1. Images depict the same individuals with full beards (upper images) and when clean-shaven (lower images).

Figure 2.
This image shows where the landmarks were placed on faces to measure objective craniofacial masculinity in the current study. All faces from the supplementary face set plus the clean-shaven and bearded images from the target set were delineated on 164 landmarks using Webmorph (DeBruine & Tiddeman, 2016). While all the landmarks in red and green were used to compute the objective masculinity score, the 16 landmarks in red were also used to compute a measure of jaw size used in the analyses.

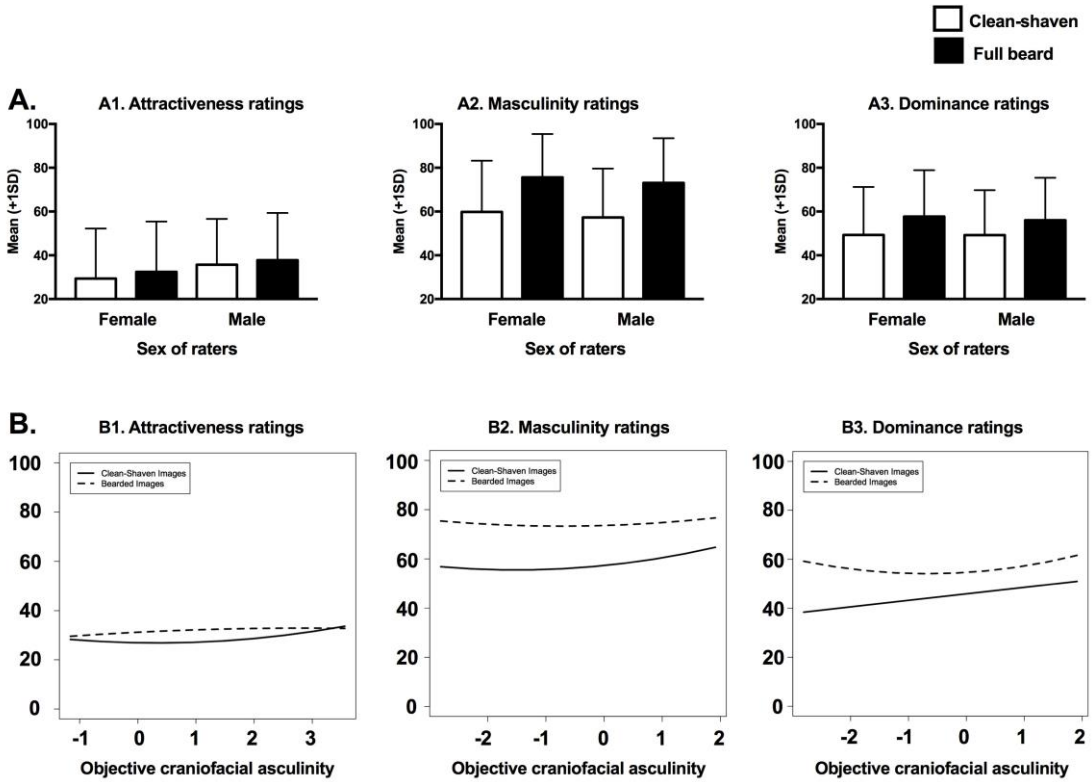

Figure 3.
Results from Study 1 showing: (**A.**) Mean attractiveness (**A1.**), masculinity (**A2.**) and dominance (**A3.**) ratings (± 1 SD) for clean-shaven (open bars) and bearded (filled bars) stimuli split by sex of raters; (**B.**) Quadratic effects of craniofacial masculinity on female attractiveness ratings (**B1.**), male and female masculinity ratings (**B2.**) and male dominance ratings (**B3.**) for clean-shaven (solid line) and bearded (dashed line).

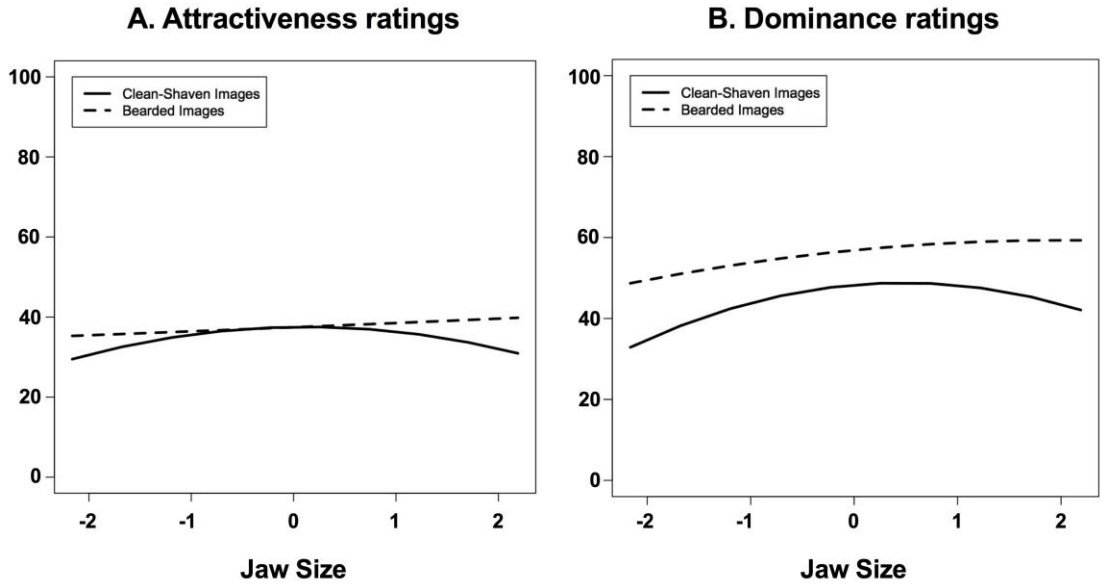

Figure 4.
Results from Study 1 showing: Quadratic effects of craniofacial masculinity on male attractiveness ratings (**A.**), and male dominance ratings (**B.**) for clean-shaven (solid line) and bearded (dashed line).

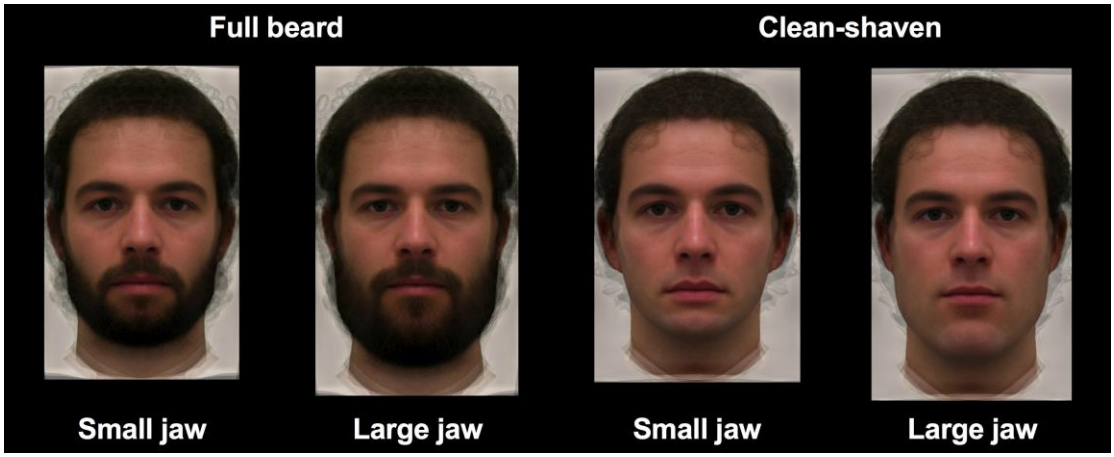

Figure 5.
An example of the stimuli used in Study 2. Images show composites of the same five individuals when clean-shaven and fully bearded manipulated to reduce (-50%) or enhance (+50%) lower facial shape, which is labelled as small jaw and large jaw respectively.

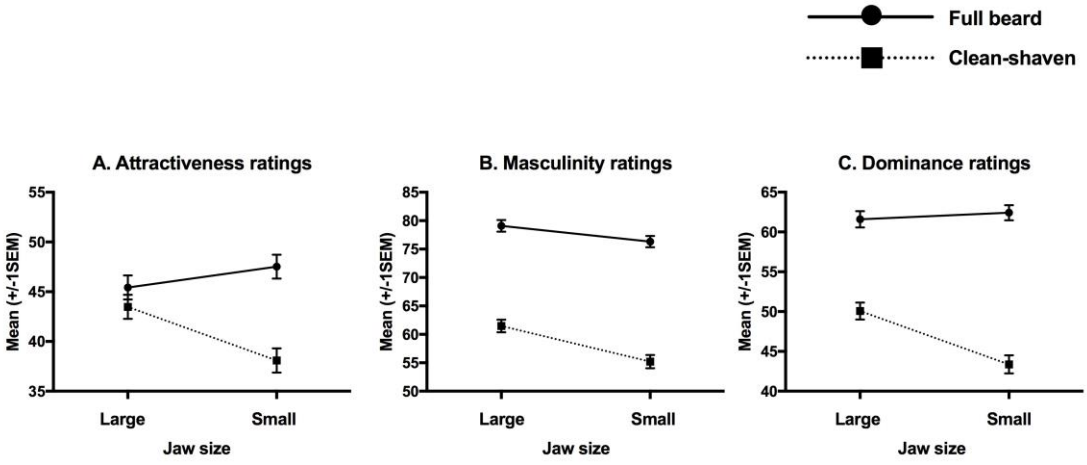

Figure 6.

Mean ratings (± 1 SEM) of clean-shaven (square symbol on the dashed line) and fully bearded faces (circular symbol on the solid line), split by jaw size (large, small) for judgments of attractiveness (**A.**), masculinity (**B.**) and dominance (**C.**).

Table 1. The γ coefficients (and standard errors) and associated 95% confidence intervals for the models predicting attractiveness ratings.

	fWHR				Objective Facial Masculinity				Jaw Size			
	Female		Male		Female		Male		Female		Male	
	γ (S.E.)	95% CI	γ (S.E.)	95% CI	γ (S.E.)	95% CI	γ (S.E.)	95% CI	γ (S.E.)	95% CI	γ (S.E.)	95% CI
Intercept	28.91 (2.41)	24.21, 33.58*	35.93 (2.13)	31.80, 40.05*	27.98 (2.36)	23.11, 32.59*	34.69 (2.03)	30.65, 38.68*	31.12 (2.34)	26.58, 35.69*	37.52 (2.12)	33.36, 41.69*
Beardedness	2.89 (1.20)	.57, 5.21*	.64 (1.17)	-1.62, 2.91	4.62 (1.09)	2.50, 6.75*	2.70 (1.09)	.57, 4.85*	2.31 (1.58)	.06, 4.55*	-.07 (1.06)	-2.14, 2.00
Facial Attribute	-35.23 (11.68)	-58.02, -12.41*	-31.50 (9.84)	-50.67, -12.33*	1.72 (1.35)	-.91, 4.56	.95 (1.14)	-1.27, 3.31	1.86 (1.38)	-.95, .11	.38 (1.28)	-2.29, 2.87
Facial Attribute^2	7.14 (99.86)	-189.98, 201.71	-.57 (85.62)	-172.32, 163.60	.65 (.93)	-1.35, 2.59	.81 (.73)	-.69, 2.31	-2.04 (1.04)	-4.08, .11	-1.54 (1.00)	-3.54, .68
Beardedness * Facial Attribute	-.63 (6.45)	-13.15, 11.89	8.99 (6.71)	-4.00, 21.98	-1.23 (.58)	-2.36, -.10*	-.40 (.65)	-1.68, .87	.01 (.70)	-1.35, 1.37	.66 (.70)	-.70, 2.03
Beardedness * Facial Attribute^2	30.95 (56.15)	-78.05, 140.35	76.69 (58.76)	-37.09, 190.51	-.86 (.38)	-1.62, -.11*	-.74 (.41)	-1.56, .08	.98 (.60)	-.20, 2.15	1.56 (.57)	.42, 2.68*

* = Confidence intervals do not contain zero, indicating a significant estimate.

Table 2. The γ coefficients (and standard errors) and associated 95% confidence intervals for the models predicting masculinity ratings.

	fWHR				Objective Facial Masculinity				Jaw Size			
	Female		Male		Female		Male		Female		Male	
	γ (S.E.)	95% CI	γ (S.E.)	95% CI	γ (S.E.)	95% CI	γ (S.E.)	95% CI	γ (S.E.)	95% CI	γ (S.E.)	95% CI
Intercept	57.62 (2.51)	52.60, 62.68*	55.49 (2.16)	54.43, 59.71*	59.01 (2.40)	54.32, 63.72*	55.96 (2.02)	51.99, 59.95*	61.78 (2.38)	57.13, 66.45*	58.51 (1.95)	54.67, 62.41
Beardedness	16.78 (1.86)	13.01, 20.50*	16.67 (1.61)	13.48, 19.82*	15.87 (1.74)	12.49, 19.26*	16.47 (1.49)	13.58, 19.38*	13.69 (1.78)	10.21, 17.15*	15.12 (1.51)	12.17, 18.08
Facial Attribute	-1.60 (12.23)	-25.23, 25.57	-4.30 (10.58)	-25.17, 16.76	2.52 (1.06)	.43, 4.59*	2.30 (.93)	.43, 4.10*	2.25 (1.24)	-.17, 4.69	2.44 (1.17)	.13, 4.84*
Facial Attribute^2	190.96 (99.33)	-81.01, 406.56	139.18 (91.88)	-48.25, 326.58	.69 (.76)	-.85, 2.23	.88 (.66)	-.48, 2.23	-1.63 (.99)	-3.57, .40	-1.15 (.67)	-2.69, .37
Beardedness * Facial Attribute	2.25 (9.35)	-15.99, 20.46	10.19 (7.67)	-4.72, 25.10	-1.81 (.85)	-3.48, -.15*	-1.58 (.71)	-2.98, -.20*	-.36 (.99)	-2.28, 1.56	-.47 (.84)	-2.10, 1.16
Beardedness * Facial Attribute^2	-117.52 (76.23)	-280.29, 54.90	-37.67 (67.09)	-174.56, 101.77	-.38 (.53)	-1.42, .67	-.21 (.43)	-1.07, .67	1.52 (.80)	-.08, 3.14	.97 (.62)	-.33, 2.21

* = Confidence intervals do not contain zero, indicating a significant estimate.

Table 3. The γ coefficients (and standard errors) and associated 95% confidence intervals for the models predicting dominance ratings.

	fWHR				Objective Facial Masculinity				Jaw Size			
	Female		Male		Female		Male		Female		Male	
	γ (S.E.)	95% CI	γ (S.E.)	95% CI	γ (S.E.)	95% CI	γ (S.E.)	95% CI	γ (S.E.)	95% CI	γ (S.E.)	95% CI
Intercept	47.69 (2.11)	43.57, 51.79*	44.96 (2.21)	40.64, 49.26*	49.10 (2.04)	45.13, 53.07*	45.87 (2.02)	41.97, 49.85*	51.39 (2.02)	47.34, 55.41*	48.30 (2.09)	44.33, 52.45*
Beardedness	18.82 (1.67)	5.56, 12.06*	10.48 (1.68)	7.19, 13.74*	7.24 (1.58)	4.17, 10.30*	8.70 (1.51)	5.78, 11.61*	6.94 (1.62)	3.80, 10.10*	8.57 (1.57)	5.56, 11.59*
Facial Attribute	1.17 (12.95)	-24.41, 26.68	-3.80 (13.74)	-30.46, 23.36	2.57 (1.14)	.27, 4.80*	2.65 (1.37)	.03, 5.31*	2.34 (1.27)	-.14, 4.83	2.18 (1.53)	-.72, 5.10
Facial Attribute^2	130.95 (108.74)	-93.25, 341.13	69.47 (118.10)	-170.28, 298.81	.17 (.77)	-1.35, 1.75	-.004 (.97)	-1.87, 1.89	-1.93 (1.08)	-4.32, .26	-2.29 (1.35)	-4.94, .28
Beardedness * Facial Attribute	-5.63 (8.64)	-22.47, 11.20	2.97 (9.46)	-15.41, 21.36	-.70 (.80)	-2.26, .86	-1.14 (.82)	-2.73, .45	.36 (.92)	-1.44, 2.15	.27 (.98)	-1.63, 2.18
Beardedness * Facial Attribute^2	-36.60 (71.29)	-177.20, 105.56	-6.10 (77.85)	-159.35, 148.11	.74 (.53)	-.28, 1.76	1.12 (.54)	.07, 2.17*	1.36 (.79)	-.22, 2.91	1.68 (.81)	.11, 3.22*

* = Confidence intervals do not contain zero, indicating a significant estimate.

Table 4. Repeated-measures ANOVAs testing effects of facial hair (clean-shaven, full beards), jaw size (small, large) and sex of raters (female, male) on ratings of masculinity, dominance, and attractiveness

	Attractiveness ratings				**Masculinity ratings**				**Dominance ratings**			
	DF	F	P	η_p^2	DF	F	P	η_p^2	DF	F	P	η_p^2
Facial hair	1,208	52.81	<0.001	0.202	1,205	443.87	<0.001	0.684	1,207	251.42	<0.001	0.548
Jaw size	1,208	20.13	<0.001	0.088	1,205	154.08	<0.001	0.429	1,207	26.07	<0.001	0.112
Rater sex	1,208	2.43	0.120	0.012	1,205	1.26	0.263	0.006	1,207	1.89	0.171	0.009
Facial hair x rater sex	1,208	1.46	0.228	0.007	1,205	7.11	0.008	0.034	1,207	0.03	0.871	<0.001
Jaw size x rater sex	1,208	0.81	0.371	0.004	1,205	0.44	0.506	0.002	1,207	0.02	0.899	<0.001
Facial hair x Jaw size	1,208	140.95	<0.001	0.404	1,205	46.92	<0.001	0.186	1,207	122.42	<0.001	0.372
Facial hair x Jaw size x rater sex	1,208	13.52	<0.001	0.061	1,205	1.53	0.217	0.007	1,207	1.72	0.192	0.008