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# Perceptions of facial trustworthiness and dominance modulate early neural responses to male facial sexual dimorphism

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ABSTRACT

Sexual selection may have shaped the evolution of cognitive mechanisms to assess dominance and trustworthiness among anonymous conspecifics. We tested the hypothesis that masculine facial morphology and beardedness modulate early P100, N170, P200 and N250 event related potentials (ERP) components using electroencephalography (EEG) during judgments of male facial dominance and trustworthiness. We found that facial hair drove early P100 neural effects while facial masculinity drove an N170 effect during perceptions of dominance. For perceptions of trustworthiness, there was a significant N170 peak for bearded over clean-shaven faces while no significant effects were observed when judging facial masculinity. Clean-shaven faces exerted significant effects over bearded faces for P200 amplitudes for dominance and trustworthiness perceptions. The only significant N250 amplitudes occurred for beardedness over clean-shaven faces when judging trustworthiness. There were no effects of facial masculinity on any ERPs when faces were bearded, supporting previous research demonstrating that facial hair may mask sexually dimorphic structural facial traits. Masculine faces augmented judgments of dominance and trustworthiness over less masculine faces. Likewise, bearded faces enhanced dominance and trustworthiness judgments over clean-shaven faces. Our findings suggest facial masculinity activates neural responses involved in face processing when judging assertiveness and status seeking involved in same-sex competition, but not socially affiliative attributes prioritised in more communal behaviours. In contrast, facial hair acts as a low-level visual feature that rapidly communicated dominance and latterly communicated trustworthiness, suggesting a role of competence for facial hair when assessing male sociosexual attributes.

## 1. Introduction

Humans are experts in rapidly gleaning social information from the superficial appearance of their conspecifics (Jack & Schyns, 2015). Personality judgments from faces, notably perceptions of trustworthiness and dominance, occur in just a tenth of a second (Willis & Todorov, 2006), and inform wide ranging social outcomes from political elections, choices of romantic partners, and even death sentences in criminal trials (Todorov, Olivola, Dotsch, & Mende-Siedlecki, 2015; Todorov, Said, Engell, & Oosterhof, 2008). Modern studies of face perceptions, which use Oosterhof and Todorov's (2008) *valence/dominance* model, have repeatedly shown judgments of personality from faces are informed by the social dimensions of trustworthiness and dominance (Todorov, 2017). These patterns replicate across 41 countries, highlighting the importance of first impressions from faces in disparate populations around the world (Jones et al., 2021) with the potential to shed light on the formation of interpersonal stereotypes.

Encouraged by evolutionary studies in nonhuman animals, research on human face perceptions has tested whether structural differences in facial morphology underpin perceptions of mates and same-sex rivals (Little, Jones, & DeBruine, 2011). On average, men have larger and squarer jaws, a more robust midface, a thicker brow ridge, deeper set

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eyes, and thinner lips than women (Caton & Dixson, 2022; Dixson, 2018; Whitehouse et al., 2015). These features, collectively termed facial masculinity, develop under the actions of androgens in utero (Whitehouse et al., 2015), come to prominence during adolescence (Marečková et al., 2011), and are fully developed at adulthood (Roosenboom et al., 2018). However, facial masculinity plays a contradictory role in perceptions of men's sociosexual attributes (Dixson, Sulikowski, Gouda-Vossos, Rantala, & Brooks, 2016). On one hand, men's facial masculinity enhances ratings of men's masculinity, dominance, and aggressiveness (Mefodeva et al., 2020; Caton & Dixson, 2022, Caton, Hannan, & Dixson, 2022; Caton, Brown, Zhao and Dixson, 2024; Caton, Zhao, Lewis and Dixson, 2022; Geniole, Denson, Dixson, Carré, & McCormick, 2015), with facial dominance being ascribed to masculine male faces in under 100 milliseconds (Albert, Wells, Arnocky, Liu, & Hodges-Simeon, 2021) and accurately reflects men's physical strength and behavioural dominance (Fink, Neave, & Seydel, 2007; Toscano, Schubert, & Sell, 2014; Windhager, Schaefer, & Fink, 2011; Caton et al., 2022). On the other hand, facial masculinity decreases ratings of male trustworthiness, warmth, and attractiveness in some cases (Chang, Doll, van't Wout, Frank, & Sanfey, 2010; Penton-Voak & Perrett, 2001; Perrett et al., 1998), but not in others (DeBruine, Jones, Crawford, Welling, & Little, 2010; Marcinkowska et al., 2019; Scott et al., 2014) suggesting masculine facial structure plays a more consistent role in communicating physical and social dominance than prosociality.

An important caveat to extant research on facial masculinity is that until recently it largely ignored how the co-occurrence of cutaneous facial features could influence social trait judgments (Dixson, 2019, 2022). Thus, facial hair is a prominent, heritable, male secondary sexual trait that develops under the effects of androgens (Randall, 2008). Compared to clean-shaven faces, bearded male faces are judged as looking older, more masculine, socially dominant (Dixson, Lee, Sherlock, & Talamas, 2017; Sherlock, Tegg, Sulikowski, & Dixson, 2017; Mefodeva et al., 2020), physically stronger (Gray et al., 2020; Nelson, Kennedy-Costantini, Lee, & Dixson, 2019), and more aggressive (Dixson & Vasey, 2012; Garza, Afhami, & Pazhoohi, 2024; Mefodeva et al., 2020) than clean-shaven faces. Beards may enhance perceived male formidability by exaggerating underlying masculine facial structure, especially jaw size (Dixson, Little, Dixson, & Brooks, 2017; Sherlock et al., 2017; Mefodeva et al., 2020), which could explain why beards facilitate recognition of male faces posing angry facial expressions (Craig, Nelson, & Dixson, 2019; Dixson, Barkhuizen, & Craig, 2021), but not happy faces (Dixson et al., 2022). Yet like facial masculinity, beardedness has variable effects on judgments of social traits related to trustworthiness, such that bearded faces are judged as more attractive than clean-shaven faces in some studies (Clarkson et al., 2020; Dixson, Rantala, Melo and Brooks, 2017; Dixson et al., 2018, Dixson, Lee, Blake, Jasienska, & Marcinkowska, 2018; Dixson & Rantala, 2016; Stower et al., 2020), but not others (Dixson & Brooks, 2013; Dixson, Tam, & Awasthy, 2013; Gray et al., 2020; Muscarella & Cunningham, 1996; Neave & Shields, 2008; Valentova, Varella, Bártová, Štěrbová, & Dixson, 2017), while facial hair increases perceptions of trustworthiness in several studies (Bakmazian, 2014; Guido, Peluso, & Moffa, 2011; Mittal & Silvera, 2021; but see Fetscherin, Tantleff-Dunn, & Klumb, 2020).

Despite convergent evidence that face perceptions are encoded rapidly and strongly influenced by facial sexual dimorphisms, how facial masculinity or beardedness contribute to fine grained neural responses while processing trustworthiness or dominance remains unknown. Electroencephalography (EEG) measures electrical potentials from the scalp and allows for the time course of brain activity during stimulus presentation to be tracked in milliseconds (Bentin, Allison, Puce, Perez, & McCarthy, 1996). EEG has uncovered distinct early event related potentials (ERPs) involved in face processing (Schindler & Bublatzky, 2020). The P100 component is detected via occipital electrodes beginning at 65-80 ms and peaking at 100-130 ms and is often attributed to processing low level stimulus features. However, higher order face processing during this early period of stimulus presentations also occurs (Itier & Taylor, 2004a, 2004b). The N170 is a selective response specific to faces wherein amplitudes typically peak around 140-230 ms from the onset of stimulus presentation (Bentin & Deouell, 2000; Herzmann, Schweinberger, Sommer, & Jentzsch, 2004; Itier & Taylor, 2004a, 2004b) and are linked to the structural encoding of face recognition and perceptions (Eimer & Holmes, 2002; McCarthy, Puce, Belger, & Allison, 1999). N170 ERPs also occur when evaluating traits associated with faces, including responses to facial dominance determined by competitive games (Feng, Tian, Feng, & Luo, 2015; Santamaría-García, Burgaleta, & Sebastián-Gallés, 2015). Likewise, perceptions of facial trustworthiness activate early ERPs in some studies and later ERPs in others (Dzhelyova et al., 2012; Marzi, Righi, Ottonello, Cincotta, & Viggiano, 2014; Yang, Qi, Ding, & Song, 2011), potentially due to participant familiarity with the faces (Pegna et al., 2019). When judging gender-ambiguous faces in profile view, masculine faces caused a right parieto-temporal N170 latency (Cellerino et al., 2007) and when explicitly judging facial gender, masculine male faces modulated a significantly higher N170 latency than feminised male faces (Welling, Bestelmeyer, Jones, DeBruine, & Allan, 2017). Finally, previous research reported that higher P200 and N250 amplitudes were associated with expertise in classifying facial ethnicity (Balas & Nelson, 2010; Scott et al., 2006, 2008) and sexual dimorphism (Welling et al., 2017).

If sexual selection has shaped the evolution of cognitive mechanisms to identify dominance and trustworthiness among anonymous conspecifics, then masculine facial morphology and beardedness should cause neural responses. The current study uses EEG to test whether masculine facial morphology modulates early P100 and N170 ERPs, and later P200 and N250 ERPs during judgments of male facial dominance and trustworthiness. Participants saw composite faces created from photographs of the same men when clean-shaven and with full beards. These faces were morphed to appear 60 % more or 60 % less masculine. We hypothesised that within clean-shaven faces, facial masculinity will cause higher ERP amplitudes for dominance, but not trustworthiness judgments (Hypothesis 1). In contrast, within bearded faces, facial masculinity may have smaller effects on ERPs as some sexually dimorphic traits, such as the jaw and bizygomatic arches (Caton & Dixson, 2022), are potentially masked by beardedness while others, such as the eyebrows and brow ridge (Mogilski & Welling, 2018) are not (Hypothesis 2). Finally, when comparing clean-shaven and bearded faces we hypothesised there will be higher ERP amplitudes for bearded than clean-shaven faces for dominance and trustworthiness judgments (Hypothesis 3).

## 2. Material and methods

(a) **Facial hair stimuli**. Thirty-seven men (mean age ± SD = 27.86 ± 5.75 years) of European ethnicity were photographed posing neutral facial expressions using a Canon digital camera (8.0 megapixels resolution), 150 cm from the participant under controlled lighting (Dixson, Lee, et al., 2017; Janif, Brooks, & Dixson, 2014). Males were photographed when clean-shaven and with 4–8 weeks of natural beard growth. To create composite bearded faces and composite clean-shaven faces, we randomly selected five males from the total pool of 37. For each of the five males, we used their bearded and clean-shaven versions to create a composite with a full beard and when clean-shaven. We repeated this process to create 10 composite identities, which were manipulated to appear more masculine or more feminine, as described below, resulting in 40 images. All composite facial images were created in Webmorph (DeBruine & Tiddeman, 2016).

(b) **Facial masculinity manipulation.** Facial masculinity was manipulated in Webmorph (DeBruine & Tiddeman, 2016). A composite male and female face were created from a separate face set of 40 male and 40 European females based on 189 landmarks. Landmarks were delineated manually in Webmorph using different templates for the bearded and clean-shaven faces. To manipulate facial masculinity, the linear shape differences between the average male and female faces were applied to the clean-shaven and bearded composites at 60 %, essentially manipulating faces along the sexual dimorphism dimension while keeping colour and textural information of the original face constant (Fig. 1). This procedure is a standard approach for manipulating sexual dimorphism in faces (Benson & Perrett, 1993; Perrett et al., 1998) and has been used in previous studies on perceptions of men's facial masculinity and beardedness (Clarkson et al., 2020; Dixson, Little, et al., 2017, Dixson, Blake, et al., 2018, Dixson, Lee, et al., 2018; Dixson, Kennedy-Costantini, Lee, & Nelson, 2019; Mefodeva et al., 2020; McIntosh et al., 2017). During the experiment, faces along with all other slides (instructions, response, and fixation) were presented against an off-white background (RGB: 218, 208, 199). Faces were 263 × 350 pixels and were presented centrally.

(c) **Dominance and Trustworthiness Ratings.** Participants completed surveys coded in Qualtrics to assess facial trustworthiness and dominance for each face. In one block, participants judged how dominant each face was using a 7-point scale ranging from 1 = not at all to 7 = extremely. Dominance was defined as "having power, command, and influence over others". Participants were presented with each face and asked to respond to the question "How dominant do you find this face?" In another block, participants rated the same faces for trustworthiness using a 7-point scale ranging from 1 = not at all to 7 = extremely. Trustworthiness was defined as "being reliably honest, truthful, or dependable". Each face was presented once per block, totalling 40 presentations per block and 80 presentations in the complete survey.

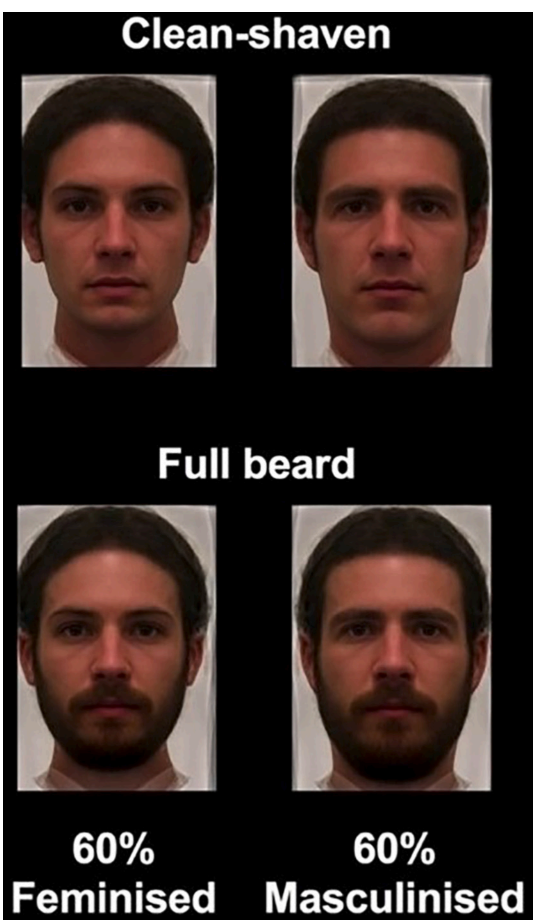


**Fig. 1.** An example of the stimuli used in the current study. Faces are composites of the same five men when bearded (bottom row) and clean-shaven (top row). The composites on the left were manipulated to appear 60 % feminised and those on the right were 60 % masculinised.

We also calculated the proportion of masculine (masculine compared to feminine) and bearded (bearded compared to clean-shaven) faces that were selected as looking dominant and trustworthy. Thus, for dominance judgments within each face category (e.g. masculine clean-shaven) we assigned a score of '1' when the face was selected as looking dominant and '0' when it was not selected as looking dominant. This process was undertaken for all four face categories (i.e. masculine clean-shaven feminine; clean-shaven; masculine bearded; feminine bearded) and an average proportion of selections was calculated for each face category within each participant. We employed the same approach trustworthiness judgments.

At the beginning of each block in the face perception task, participants were presented with an instruction screen that included the definition of dominance or trustworthiness. On each trial a fixation cross appeared for 105 to 300 ms, followed by a face presented for 1000 ms. Faces were presented in a random order. After this, a response screen appeared, which instructed participants to respond using their right hand and press the 'a' key if they deemed the face to be dominant (or trustworthy in the trustworthiness block) or 's' if they deemed the face not to be dominant (or trustworthy in the trustworthiness block). The response screen remained until a response was made. After a response was recorded, a fixation cross appeared for a 200 ms inter-trial interval. There were 80 trials (each of the 40 faces presented twice), with an approximate experiment run-time of 20 min. Afterwards, participants completed the trustworthiness and dominance ratings (Fig. 2).

(d) **Participants.** Twenty-six right-handed people, with normal or corrected-to-normal vision (12 female; Mean age = 20.92, SD = 4.30, ranging 18–34 years) completed the experiment for credit for a psychology course at the University of Queensland.

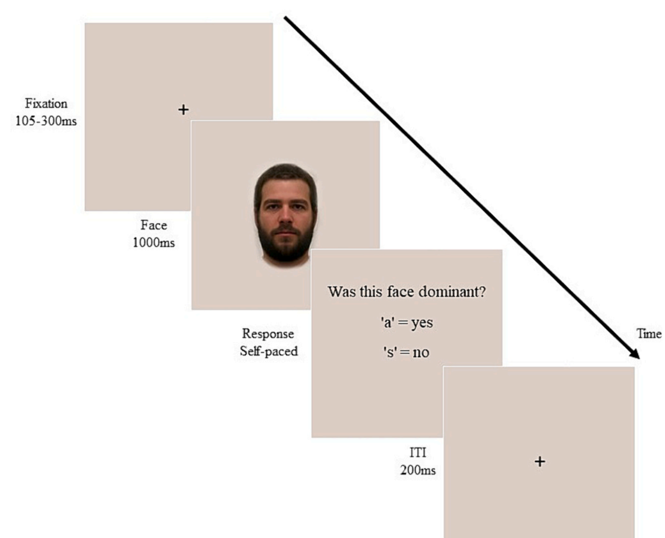


**Fig. 2.** The design employed in our study. Participants first saw a fixation cross for 100-300 ms, followed by a face varying in facial hair (clean-shaven or bearded) and facial masculinity (feminine or masculine) for 1000 ms. Participants then selected if the face looked dominant or trustworthy, depending on the experimental condition they were completing, that was followed by a fixation cross. This process was repeated for the full 40 images.

(e) **Experimental design.** The experiment was a 2 (Masculinity: Masculine, Feminine) x 2 (Facial Hair: Clean-Shaven, Bearded) x 2 (Condition: Dominance, Trustworthiness) within-subjects design. EEG recordings were taken while the face perception tasks were completed. There were 2 blocks, one to assess perceived dominance and one to assess perceived trustworthiness of the faces. The order in which the blocks were presented (i.e., dominance and trustworthiness) was randomized across participants.

(f) **EEG data recording and analysis.** Continuous EEG data was measured at a sampling rate of 1024 Hz with a BioSemi (Amsterdam, The Netherlands) amplifier using 64 electrodes placed according to the international 10–20 system. EEG data was re-referenced offline against the average of all 64 electrodes, and was down sampled from 1024 Hz to 512 Hz. All data was filtered with a low pass filter of 40 Hz, a high pass filter of 0.18 Hz, and with a notch filter centred at 50 Hz to account for electrical mains. Thus, data were filtered at 50 Hz, but not 51 or 49 Hz. Bad electrodes were interpolated using the 3D spline method, all participants had between 0 and 4 electrodes interpolated. A cut-off of +/− 80 μV was used to exclude EEG trials that contained eye-blinks and muscle movements; of 8320 total trials across all participants, 9.15 % were excluded leaving 7558. Data were segmented in epochs time-locked to the onset of the face appearing, from 100 ms prior to 400 ms post face onset, with a 100 ms pre-face baseline correction per trial.

ERPs were computed for clean-shaven masculine faces, clean-shaven feminine faces, bearded masculine faces, and bearded feminine faces for trustworthiness and dominance judgments. Mean amplitudes for the P1 were computed using the average of electrodes O1, O2, Oz, and Iz over the epoch of 95-110 ms. Mean amplitudes for the N170 were computed using the average of electrodes PO7, P7, P9 (left) and PO8, P8, and P10 over the epoch of 140-155 ms, and for the P200 the same electrodes were used over the epoch of 190-240 ms, for the N250 amplitudes were computed using the average of electrodes Pz, P1, P2, POz over the epoch 230-270 ms (see Welling et al., 2017). Epochs and electrodes for each component were based on previous conventions (Luck, 2014) and visual analysis of the ERPs for the grand average of all participants.

(g) **Statistical analyses.** Separate repeated-measures ANOVAs were conducted for the average ratings of dominance and trustworthiness, the average proportion of faces judged as dominant and trustworthy, and patterns of EEG activity for P100, N170, P200, and N250 ERPs. Facial masculinity (masculine, feminine) and beardedness (clean-shaven, bearded) were within-subject factors and we repeated all the ANOVAs including sex (female, male) as a between-subject factor. Effect sizes are eta squared ($\eta^2$) for the ANOVAs and Cohen's *d* for Post-hoc Bonferroni corrected paired sample *t*-tests. All analyses were undertaken in JASP (JASP Team, 2024).

## 3. Results

(a) **Dominance judgments.** For dominance ratings, the main effect of masculinity, F (1, 25) = 19.56, $p < .001$, $\eta^2 = 0.18$, reflects masculine faces were rated as more dominant than feminine faces (Mean difference = 0.80, SE = 0.18, $d = 0.91$). The main effect of facial hair, F (1, 25) = 15.78, $p < .001$, $\eta^2 = 0.21$, reflects bearded faces were rated as more dominant than clean-shaven faces (Mean difference = 0.87, SE = 0.22, $d = 0.99$). There was no significant interaction between facial masculinity and facial hair, F (1,25) = 0.10, $p = .760$, $\eta^2 < 0.01$. We ran this model again including sex, which revealed no main effects or interactions between sex, masculinity, and beardedness on ratings of facial dominance, all F ≤ 1.00, all $p \geq .326$. (Figs 3 and 4)

For the proportion of faces selected as dominant, there was a main effect of masculinity, F (1, 25) = 22.58, $p < .001$, $\eta^2 = 0.16$, such that masculine faces were more often selected as dominant than feminine faces (Mean difference = 0.20, SE = 0.04, $d = 0.87$). There was also a main effect of facial hair, F (1, 25) = 21.66, $p < .001$, $\eta^2 = 0.28$, where a higher proportion of bearded faces were selected as more dominant than clean-shaven faces (Mean difference = 0.26, SE = 0.06, $d = 1.17$). There was no significant interaction between facial masculinity and facial hair, F (1, 25) = 0.15, $p = .704$, $\eta^2 < 0.01$. We also ran this model including sex, which revealed no interactions between sex, masculinity, and beardedness on the proportion of faces selected as looking most dominant, all F ≤ 0.34, all $p \geq .566$.

(b) **Trustworthiness judgments.** For trustworthiness ratings, there was a main effect of masculinity, F (1, 25) = 7.70, $p = .010$, $\eta^2 = 0.09$, such that masculine faces were more often rated as trustworthy than feminine faces (Mean difference = 0.44, SE = 0.16, $d = 0.49$). There was also a main effect of facial hair, F (1, 25) = 5.70, $p = .025$, $\eta^2 = 0.10$, such that bearded faces were rated as more trustworthy than clean-shaven faces (Mean difference = 0.47, SE = 0.20, $d = 0.51$). There was no significant interaction between facial masculinity and beardedness, F (1, 25) = 0.07, $p = .791$, $\eta^2 < 0.01$. We also ran this model including sex, which revealed no significant interactions between sex, masculinity, and beardedness on trustworthiness ratings, all F ≤ 1.30, all $p \geq .266$.

For the proportion of faces selected as trustworthy, there was a main effect of masculinity, F (1, 25) = 10.45, $p = .003$, $\eta^2 = 0.11$, such that masculine faces were more often selected as trustworthy than feminine faces (Mean difference = 0.12, SE = 0.04, $d = 0.49$). There was also a main effect of facial hair, F (1, 25) = 10.95, $p = .003$, $\eta^2 = 0.18$, whereby a higher proportion of bearded faces were selected as trustworthy compared to clean-shaven faces (Mean difference = 0.16, SE = 0.05, $d = 0.64$). There was no significant interaction between facial masculinity and beardedness, F (1, 25) = 0.81, $p = .376$, $\eta^2 < 0.01$. We also ran this model including sex, which revealed no significant interactions between sex, masculinity, and beardedness on the proportion of faces selected as trustworthy, all F ≤ 2.21, all $p \geq .150$ (Figs 5 and 6).

(c) **Dominance ERPs.** There was a significant main effect of facial hair on P100 amplitudes for occipital electrodes, F (1, 24) = 10.88, $p = .003$, $\eta^2 = 0.11$, which reflects bearded faces drove larger peak amplitudes than clean-shaven faces (Mean difference = -0.55, SE = 0.17, $d = 0.18$; Fig. 7). There was no significant main effect of facial masculinity, F (1, 24) = 0.29, $p = .593$, $\eta^2 < 0.01$, or interaction between facial masculinity and beardedness, F (1, 24) = 0.03, $p = .872$, $\eta^2 < 0.01$. When we ran this model including sex, there were no significant interactions between sex, masculinity, and beardedness on P100 amplitudes, all F ≤ 0.31, all $p \geq .582$.

For N170 amplitudes over left parietal electrodes, there was no significant main effects of facial masculinity, F (1, 24) = 0.11, $p = .743$, $\eta^2 < 0.01$, or facial hair, F (1, 24) = 0.01, $p = .907$, $\eta^2 < 0.01$. However, there was a significant interaction between facial masculinity and beardedness, F (1, 24) = 4.98, $p = .035$, $\eta^2 = 0.05$. The largest effect size was reflected in clean-shaven masculine faces driving larger peak amplitudes than clean-shaven feminine faces (Mean difference = −0.61, SE = 0.35, $d = 0.18$; all other *d*s ≤ 0.16). We ran this model including sex, which revealed no significant interactions between sex, masculinity, and beardedness, all F ≤ 2.10, all $p \geq .160$. For N170 amplitudes over right parietal electrodes there were no significant main effects of facial masculinity, facial hair, or any interaction between facial masculinity and beardedness, F ≤ 1.17, all $p \geq .290$. The model including sex revealed no significant interactions between sex, masculinity, and beardedness, all F

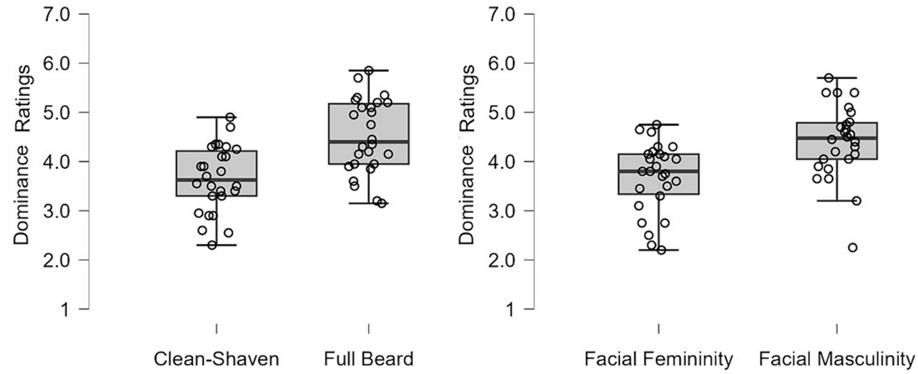


**Fig. 3.** Data are box plots with individual data points for participants dominance ratings when judging clean-shaven and bearded faces (left panel) and facial femininity and facial masculinity (right panel).

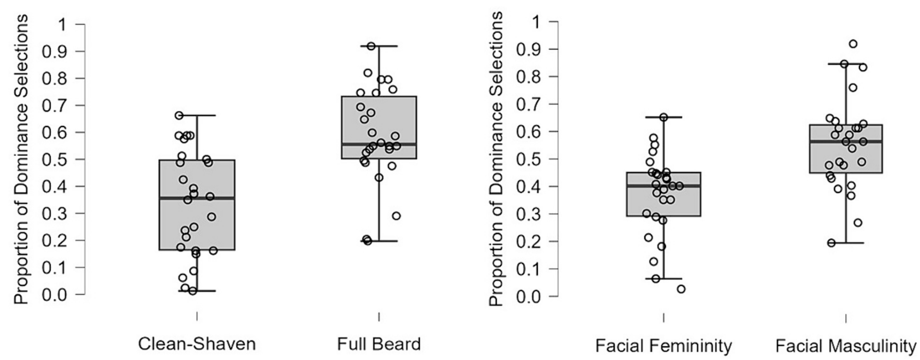


**Fig. 4.** Data are box plots with individual data points reflecting each participant for the proportion of faces selected as looking most dominant between clean-shaven and bearded faces (left panel) and feminine and masculine faces (right panel).

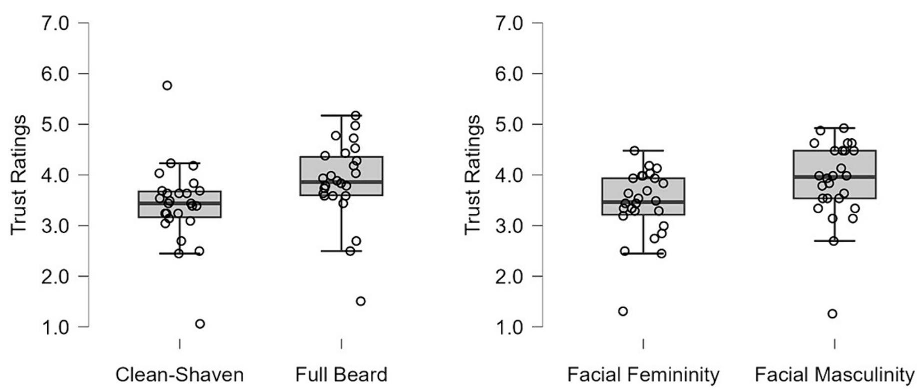


**Fig. 5.** Data are box plots with individual data points for participants trustworthiness ratings when judging clean-shaven and bearded faces (left panel) and feminine and masculine faces (right panel).

$\leq 0.88$, all $p \geq .359$.

Analyses of dominance on P200 amplitudes for left parietal electrodes revealed a significant main effect of facial hair, F (1, 24) = 7.25, $p = .013$, $\eta^2 = 0.096$, such that clean-shaven faces drove larger peak amplitudes than bearded faces (Mean difference = 0.67, SE = 0.25, $d = 0.17$). There was no significant main effect of facial masculinity, F (1, 24) = 2.22, $p = .149$, $\eta^2 = 0.021$, or a significant interaction between facial masculinity and beardedness, F (1, 24) = 0.00, $p = .948$, $\eta^2 < 0.01$. The model including sex revealed no significant main effects or interactions between sex, masculinity, and beardedness, all F $\leq 0.93$, all $p \geq .345$. Dominance perceptions also exerted a significant main effect of facial hair on P200 amplitudes for right parietal electrodes, F (1, 24) = 4.93, $p = .036$, $\eta^2 = 0.051$, where clean-shaven faces drove larger peak amplitudes than bearded faces (Mean difference = 0.55, SE = 0.25, $d = 0.15$). There was no significant main effect of facial masculinity, F (1, 24) = 3.99, $p = .057$, $\eta^2 = 0.05$, or any significant interaction between facial masculinity and beardedness, F (1, 24) = 1.88, $p = .183$, $\eta^2 = 0.027$. The model including sex also revealed no significant main effects or interactions between sex, masculinity, and beardedness, all F $\leq 1.03$, all $p \geq .321$. Finally, analyses of dominance on N250 amplitudes revealed no significant main effects of facial masculinity, facial hair, or any interaction between facial masculinity and beardedness, F $\leq 2.61$, all $p \geq .120$. The model including sex also revealed no significant interactions between sex, masculinity, and beardedness, all F $\leq 0.97$, all $p \geq .337$.

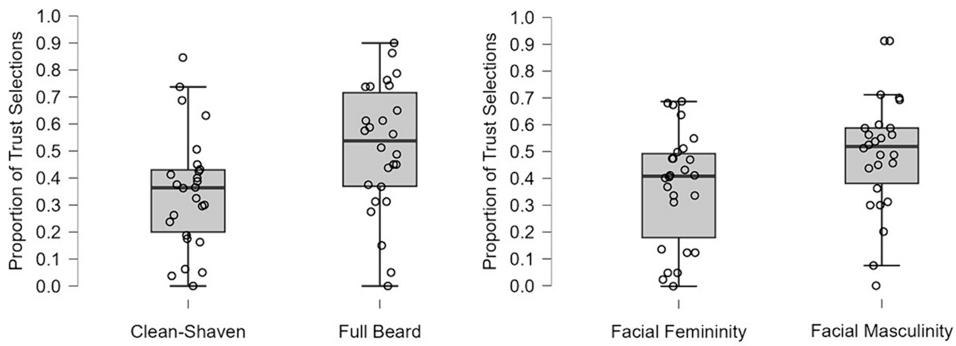


**Fig. 6.** Data are box plots with individual data points for each participant for the proportion of faces selected as looking most trustworthy when selecting between clean-shaven and bearded faces (left panel) and feminine and masculine faces (right panel).

(d) **Trustworthiness ERPs.** When judging facial trustworthiness, for P100 amplitudes over occipital electrodes there were no significant main effects of facial hair or masculinity, or any significant interaction between facial masculinity and beardedness, all F $\leq$ 1.24, all $p \geq .276$. Further, when we ran this model including sex, there were no significant interactions between sex, masculinity, and facial hair on P100 amplitudes, all F $\leq$ 0.77, all $p \geq .390$.

There was a significant effect of facial hair on N170 amplitudes over left parietal electrodes, F(1,24) = 7.82, $p = .010$, $\eta^2 = 0.116$, so that bearded faces drove larger peak amplitudes than clean-shaven faces (Mean difference = −0.72, SE = 0.26, $d = 0.22$; Fig. 8). While there was no significant main effect of facial masculinity, F(1,24) = 0.03, $p = .873$, $\eta^2 < 0.01$, there was a significant interaction between facial hair and facial masculinity, F(1,24) = 6.06, $p = .021$, $\eta^2 = 0.07$. This interaction was due to significantly higher amplitudes for feminine bearded faces compared to clean-shaven feminine faces (Mean difference = −1.26, SE = 0.34, $d = 0.39$), while other paired comparisons revealed smaller effect sizes (all *ds* $\leq$ 0.23). The model including sex revealed no significant interactions between sex, masculinity, and beardedness, all F $\leq$ 2.63, all $p \geq .118$. For N170 amplitudes over right parietal electrodes, there were no significant main effects facial masculinity, facial hair, or any interaction between facial masculinity and beardedness, F $\leq$ 2.99, all $p \geq$ .096. The model including sex revealed no significant main effects or interactions between sex and masculinity or sex and beardedness, all F $\leq$ 2.53, all $p \geq .126$.

Analyses of trust perceptions on P200 amplitudes for left parietal electrodes revealed no significant main effects facial masculinity, facial hair, or any interaction between facial masculinity and beardedness, F $\leq$ 4.18, all $p \geq .052$. The model including sex revealed no significant two-way interactions between sex, masculinity, and beardedness, all F $\leq$ 0.64, all $p \geq .432$. However, there was a significant three-way interaction between facial masculinity, facial hair and sex F(1,24) = 8.41 $p =$ .008, $\eta^2 < 0.01$. This interaction was driven by facial masculinity within clean-shaven faces driving higher peak amplitudes among male participants ($d = 0.14$), while peak amplitudes were higher for feminine clean-shaven faces compared to masculine clean-shaven faces among female participants ($d = 0.22$). Amplitudes for bearded faces varying in facial masculinity revealed small effects (all *ds* $\leq$ 0.08; Fig. S1; ESM).

Trustworthiness perceptions drove a significant main effect of facial hair on P200 amplitudes on right parietal electrodes, F(1, 24) = 5.32, $p = .030$, $\eta^2 = 0.084$, where clean-shaven faces drove larger peak amplitudes than bearded faces (Mean difference = 0.62, SE = 0.27, $d =$ 0.15; Fig. 8). There was no significant main effect of facial masculinity, F (1, 24) = 0.15, $p = .700$, $\eta^2 < 0.01$, or any significant interaction between facial masculinity and beardedness, F (1, 24) = 0.15, $p = .706$, $\eta^2 < 0.01$. Including sex revealed no main effect of sex or two-way interactions between sex, masculinity, and beardedness, all F $\leq$ 0.28, all $p \geq .601$. There was a significant three-way interaction between facial masculinity, facial hair, and sex F(1, 24) = 8.08, $p = .009$, $\eta^2 < 0.01$. Peak amplitudes among male participants were higher for clean-shaven masculine faces than masculine bearded faces ($d = 0.29$). Females had higher peak amplitudes for feminine clean-shaven faces compared to feminine bearded faces ($d = 0.31$; Fig. S2).

For N250 amplitudes there was a significant main effect of facial hair, F (1, 24) = 6.59, $p = .017$, $\eta^2 = 0.074$, where bearded faces drove larger peak amplitudes than clean-shaven faces (Mean difference = 0.23, SE = 0.09, $d = 0.20$). There were no significant main effect of facial masculinity or interaction between facial masculinity and beardedness, F $\leq$ 0.92, all $p \geq .348$. The model including sex revealed no significant interactions between sex, masculinity, and beardedness, all F $\leq$ 2.79, all $p \geq .108$.

## 4. Discussion

Human beings make rapid judgments regarding social attributes from faces that inform complex real-world decisions (Jones et al., 2021; Todorov et al., 2015). Studies employing the *valence/dominance* model have consistently shown judgments of personality from faces are informed by the social dimensions of trustworthiness and dominance (Jones et al., 2021; Todorov, 2017). The current study provides the first test of how facial masculinity and beardedness, two sexually dimorphic androgen-dependent characteristics putatively linked to intra-sexual social and physical dominance, influenced explicit judgments and implicit neural responses while assessing facial dominance and trustworthiness.

In support of Hypothesis 1, we found that clean-shaven masculine faces caused higher N170 ERP amplitudes for dominance judgments than feminine clean-shaven faces. Our findings are the first to demonstrate that facial masculinity (i.e., large jaw, robust midface, and pronounced brow ridge) causes face specific neural responses due to dominance perceptions. As facial masculinity is associated with upper body strength (Caton & Dixson, 2022; Fink et al., 2007; Windhager et al., 2011), striking force (Caton & Dixson, 2022,Caton, Hannan, & Dixson, 2022,Caton, Pearson, & Dixson, 2022), and victories in agonistic contest competition (Caton & Dixson, 2022,Caton, Hannan, & Dixson, 2022), our findings suggest neural responses are activated in response to male facial formidability. We also found that facial masculinity caused higher explicit ratings of dominance over less masculine male faces, corroborating prior results from a large body of research (e.g., Mefodeva et al., 2020). A recent study reported significant ERP responses at P200, but not N170 amplitudes, when viewing male faces varying in dominance (Miao et al., 2022). That study used as stimuli avatar models lacking hair that were manipulated along dimensions generated from perceived dominance rather than sexual dimorphism in facial morphology. Further, Miao et al. (2022) did not measure explicit ratings of dominance in their stimuli, which would have been beneficial to validate whether they caused higher dominance judgments. Thus,

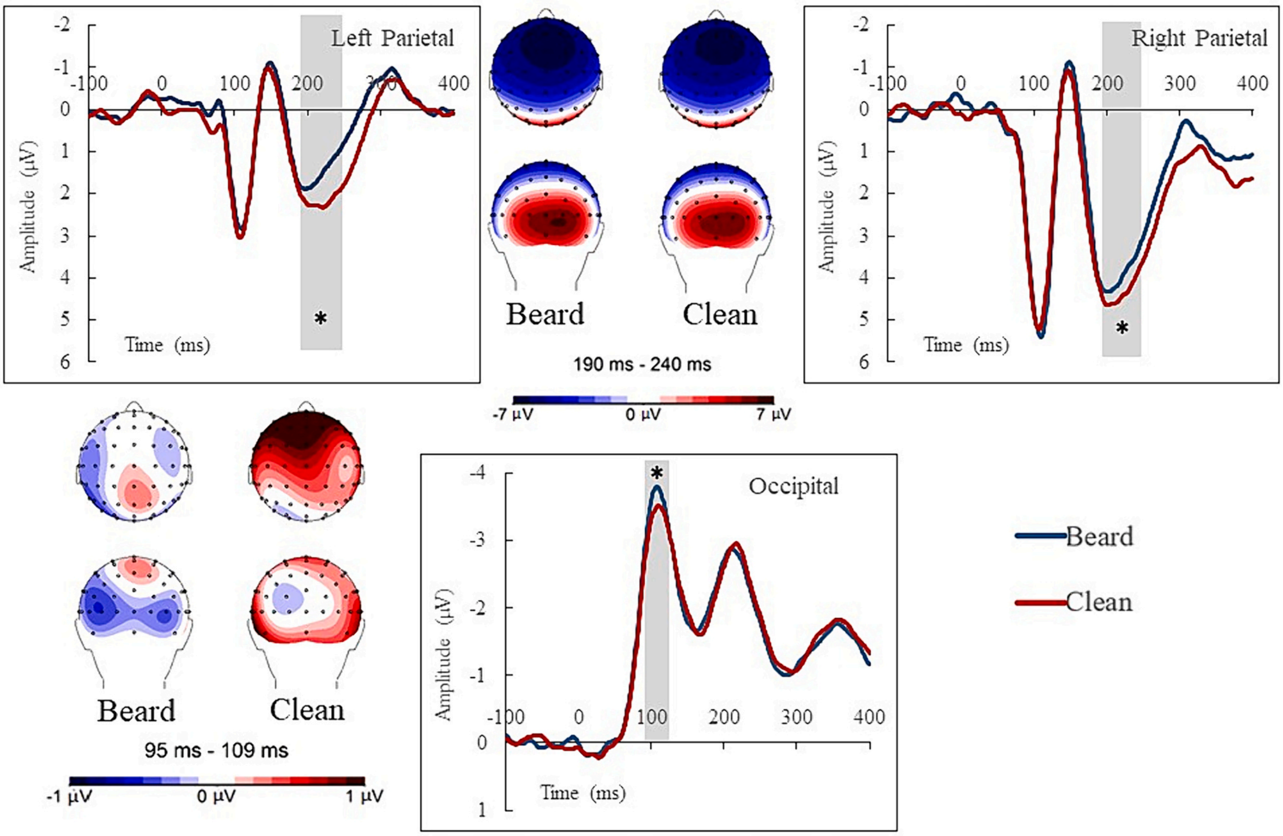


**Fig. 7.** ERPs for all bearded (dark blue), and all clean-shaven faces (dark red) presented in the dominance-judgement context. ERPs are averaged over the electrodes of interest, for the left parietal (PO7, P7, P9), right parietal (PO8, P9, P10), and occipital (O1, O2, Oz, Iz), and averaged over all facial masculinity conditions to assess beardedness alone. *The gray shaded regions and asterixis indicate where bearded faces are significantly different to clean-shaven faces over the occipital P1 (90-110ms) and left and right parietal P2 (190-240ms). The topographical scalp maps for the occipital P1 (bottom left) and parietal P2 (centre) show the significant epochs for the two conditions as viewed from above and behind. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

differences in the stimuli between this study and our own may explain variations in findings. While we also found higher P200 amplitudes for clean-shaven faces over bearded faces during dominance judgments, variation in facial masculinity did not determine the direction of these effects. Finally, we did not find significant corresponding peaks in N170 amplitudes when participants were judging trustworthiness, suggesting masculine secondary sexual craniofacial traits may principally communicate aspects of social and physical formidability (Puts, 2010, 2016).

A growing body of research implicates facial hair in augmenting perceptions of male social dominance (Dixson, 2022). Facial hairs grow on the regions of the face that show the most pronounced sexual dimorphism, including the chin, jaw, and around the zygomatic arches (Caton & Dixson, 2022; Whitehouse et al., 2015). In the current study, we hypothesised that within bearded faces, facial masculinity will not affect early ERPs during perceptions of dominance and trustworthiness as more fine-grained masculine morphological visual information is potentially masked by facial hair (Hypothesis 2). Our results supported this hypothesis, as there were no significant peaks in any ERPs within bearded faces varying in craniofacial masculinity for perceptions of dominance or trustworthiness. On one hand, beards may superficially mask the masculine craniofacial features people draw upon when making sociosexual judgments (Dixson et al., 2016). Indeed, when facial masculinity is experimentally manipulated on the same individuals photographed with and without facial hair, bearded feminine faces are judged as more masculine, socially dominant, and aggressive than clean-shaven masculine faces (Dixson, Lee, et al., 2017; Mefodeva et al., 2020; Sherlock et al., 2017). Alternatively, beards may augment intra-sexually relevant traits by enhancing the apparent size of the jaw and width of the cheekbones (Caton & Dixson, 2022; Geniole et al., 2015). One study found in both natural faces and composite faces that male jaw size augmented ratings of masculinity and dominance in clean-shaven faces. However, these effects were dwarfed by the main effect of facial hair, so that any influence of jaw size was subtle or not statistically significant within bearded faces (Dixson, Lee, et al., 2017). One way to resolve this debate could be to undertake data-driven conjoint analysis to uncover the most salient morphological features underpinning face perceptions. Using this approach, Mogilski and Welling (2018) demonstrated that eyebrow prominence, jaw thickness and greater facial height determined masculinity ratings in male and female faces. Future research employing this approach could help to resolve whether facial hair enhances perceptions of intra-sexually relevant traits by augmenting the salience of jaw and facial width, or via masking feminised versions of these traits relative to clean-shaven faces.

Given the strong effects of facial hair on perceptions of intra-sexually relevant social traits (Dixson, Lee, et al., 2017; Dixson, Little, et al., 2017; Gray et al., 2020; Neave & Shields, 2008; Saxton, Mackey, McCarty, & Neave, 2016), we hypothesised that bearded faces would cause higher ERP amplitudes than clean-shaven faces for dominance perceptions (Hypothesis 3). Indeed, during perceptions of dominance, beardedness caused a larger P1 amplitude over clean-shaven faces. P1 components are detected at 65-80 ms, peak at 100-130 ms post stimulus display, and are often attributed to processing low level stimulus features. The rapid assessment of beardedness during early perceptions of dominance could be driven by the contrast that dark facial hair creates relative to lighter facial skin complexion, a low-level feature in the

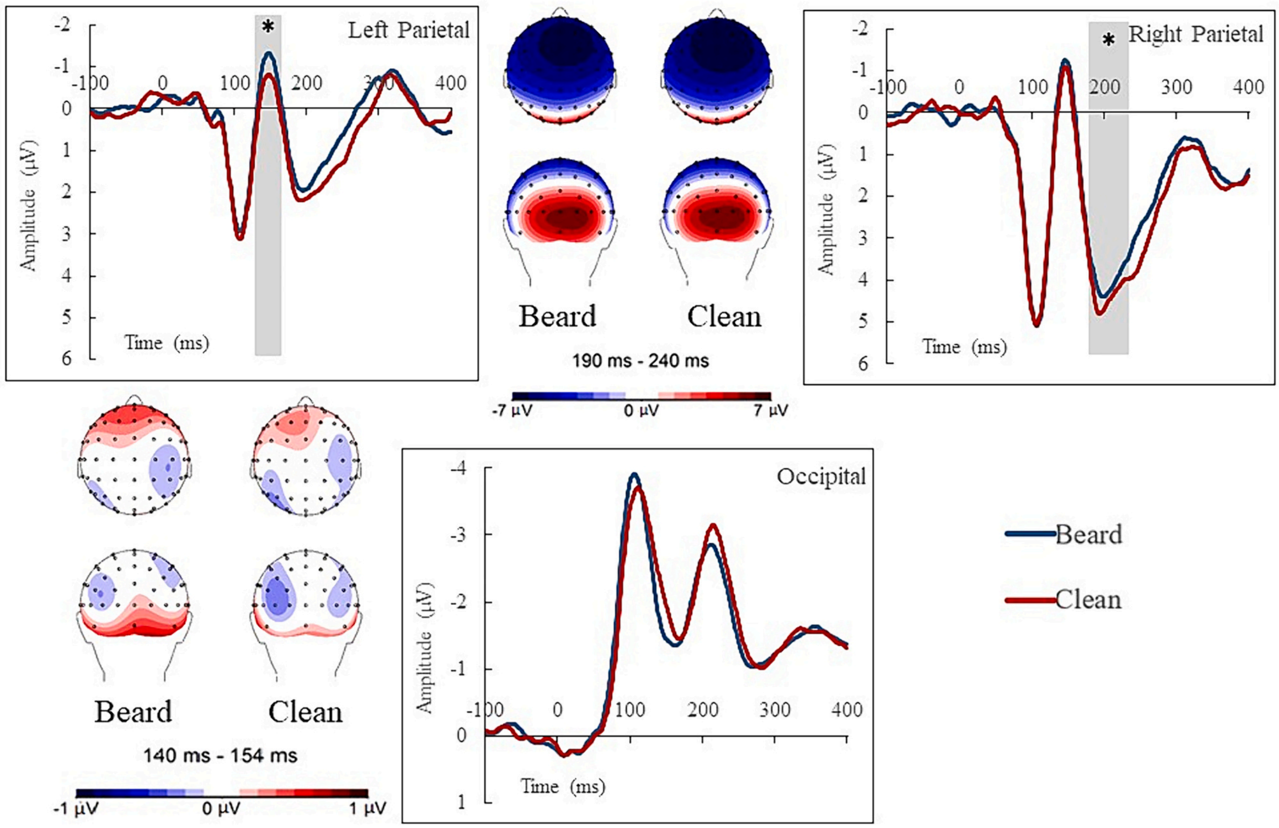


**Fig. 8.** ERPs for all bearded (dark red), and all clean-shaven faces (dark blue) presented in a trustworthiness-judgement context. ERPs are averaged over the electrodes of interest, for the left parietal (PO7, P7, P9), right parietal (PO8, P9, P10), and occipital (O1, O2, Oz, Iz), and averaged over all facial masculinity conditions to assess beardedness alone. *The gray shaded regions indicate where clean faces are significantly different to bearded faces over the left parietal N170 (140-155 ms), and right parietal P2 (190-240ms). The topographical scalp maps for the left parietal N170 (bottom left) and right parietal P2 (centre) show the significant epochs for the two conditions as viewed from above and behind. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

stimuli. However, higher order face processing also occurs at P1 amplitudes (Itier & Taylor, 2004a, 2004b; Herzmann et al., 2004) and people consistently attribute personality traits to faces (Willis & Todorov, 2006), including dominance to masculine faces (Albert et al., 2021), in under 100 milliseconds from the onset of stimulus presentation. Moreover, the P1 effect we report in response to beardedness over clean-shaven faces occurred in response to dominance perceptions, but not trustworthiness, providing support to prior evidence that beardedness determines rapid behavioural responses to aspects of male social dominance (Craig et al., 2019; Dixson et al., 2021).

While we did not find significantly different N170 responses between bearded and clean-shaven faces for dominance perceptions, bearded faces caused higher N170 and N250 responses than clean-shaven faces for trustworthiness judgments. Previous studies revealed facial hair increased explicit perceptions of trustworthiness (Bakmazian, 2014; Guido et al., 2011; Mittal & Silvera, 2021; Nelson, Munloch Kennedy-Costantini, Lee, & Dixson, 2023; but see Fetscherin et al., 2020), which may appear counter intuitive as beardedness enhances perceptions of age, masculinity, social dominance, and strength (Dixson & Vasey, 2012; Gray et al., 2020; Mefodeva et al., 2020; Muscarella & Cunningham, 1996). However, given that beardedness may be unrelated to physical aggression and formidability (Dixson, Sherlock, Cornwell, & Kasumovic, 2018), this pattern in judgments may reflect associations between facial hair, male competence, and social maturity (Dixson, Kennedy-Costantini, et al., 2019). Interestingly, we also found larger P200 amplitudes when judging trustworthiness among male participants when viewing clean-shaven masculine than feminine male faces. Whereas female participants had higher peak amplitudes for feminine clean-shaven faces compared to feminine bearded faces. These patterns support past research demonstrating P200 effects of sexual dimorphism in male facial morphology underpinning perceptions of masculinity (Welling et al., 2017) and suggest that trustworthiness perceptions for male facial masculinity may be sex specific. Taken together, our findings revealed that beardedness operates as a low-level feature that determines early dominance perceptions followed by later processing of trustworthiness, while facial masculinity activates face-specific neural responses during early processing and latter neural responses when evaluating trustworthiness.

Evolutionary perspectives highlight that status within human hierarchical social structures may be achieved via dominance, defined as the capacity to coerce others via strength and intimidation, or prestige, which refers to the capacity to persuade or influence via skills, abilities, and knowledge (Goode, 1978; Henrich & Gil-White, 2001). The social mechanisms governing how prestige and dominance are earned and maintained may be distinct (Chen Zeng, Cheng, & Henrich, 2022; Cheng, 2020). Thus, individuals who achieve status via dominance are vulnerable to attack from other individuals and to coordinated efforts to constrain their dominance. Some evidence suggests that the attribution of higher facial dominance and trustworthiness influences neural responses to anonymous conspecifics with the potential to influence subsequent behavioural outcomes. Thus, studies employing faces whose dominance was determined via competitive games or prior information, revealed early neural responses (Feng et al., 2015; Santamaría-García et al., 2015) and late effects arising after 400 ms from stimulus presentation (Breton et al., 2014; Breton et al., 2019). Comparative studies among anthropoid primates suggest men have similarly developed visually conspicuous secondary sexual facial traits and lower vocal pitch as those species with polygynous mating systems, multi-level social structures, and large social groups sizes (Aung et al., 2023; Dixson, Dixson, & Anderson, 2005; Grueter, Isler, & Dixson, 2015). Some evidence suggests that beardedness is more prevalent under prevailing social, economic, and environmental conditions favouring male-male competition (Dixson & Lee, 2020; Dixson et al., 2017; Dixson, Little, et al., 2017; Pazhoohi & Kingstone, 2020), which is in turn associated with women's preferences for facial hair in mates (Barber, 2001; Dixson, Little, et al., 2017; Dixson, Rantala, & Brooks, 2019) and men's sensitivity to beards as an intra-sexual cue (Jach & Moroń, 2020; Jach, Moroń, & Jonason, 2023; Moroń, Jach, & Jonason, 2024). Likewise, cross-cultural studies among diverse populations revealed men pay more attention to low vocal pitch when assessing dominance in societies where people interact more often with high numbers of anonymous conspecifics (Aung et al., 2024). Whether masculine facial morphology and beardedness determine neural responses in the context of competitive scenarios that influences subsequent attributions of positions within hierarchical social stratum would be valuable to determine in future research.

In any experimental study of face perceptions, the decisions researchers make regarding the choice of stimuli and experimental design impact the generalizability of their findings. In the current study, we employed composite images that reflected the same five men when bearded and when clean-shaven. We then manipulated these facial composites to reflect high and low facial masculinity via widely used morphing techniques (DeBruine & Tiddeman, 2016). This approach has the benefit of experimental clarity via tight control of the morphological factors of interest (Scott & Penton-Voak, 2011). However, it may reduce the ecological validity of the experiment, as in real world social interactions people view numerous faces of anonymous conspecifics that vary naturally in multiple facial dimensions. Indeed, studies employing data driven models of face and body perceptions may yield stronger support than theory driven models (Brooks, Shelly, Jordan, & Dixson, 2015; Holzleitner et al., 2019). We acknowledge that the approach we employed in our study has limitations and that future research employing combinations of data driven and theory driven models in concert with natural facial stimuli would be valuable. An additional limitation concerns our sample size of 26, which while in line with the 17–27 participants recruited in previous EEG studies quantifying perceptions of facial masculinity, (Feng et al., 2015; Miao et al., 2022; Pegna et al., 2023; Santamaría-García et al., 2015; Welling et al., 2017), was potentially not large enough to expose possible sex differences in perceptions in masculine facial morphology and beardedness. This is an important limitation as if male facial morphology is intra-sexually selected, we expect that males should judge masculine facial morphology as more dominant looking than female participants (e.g., Mefodeva et al., 2020). Thus, future research employing larger sample sizes to address this issue would be valuable. Finally, future research testing whether perceptions and neural responses when judging dominance for facial masculinity are intra-sexually selected in males should include a comparison with female faces experimentally altered to appear craniofacially masculine. For the present, our results demonstrate that beardedness and facial masculinity determine some neural responses during perceptions of dominance and trustworthiness, with implications for how sexual selection may have shaped face perceptions.

## Data accessibility

Open Science Framework: DOI 10.17605/OSF.IO/WZ2V4

## Ethical statement

Ethics clearance from the University of Queensland's Behavioural and Social Sciences Ethical Review Committee and the School of Psychology's Ethics Review Panel (Ethics Approval Number: 18-PSYCH-4G-13-JMC).

## Author contributions

BJWD, NLN, EM, AJL, and AP designed and conducted the study; EM and AP collected the data; EM and AP analyzed the data; BJWD, NLN, EM, AJL, and AP wrote the manuscript and commented and drafts. BJWD, NLN and AP provided funding for the research.

## CRediT authorship contribution statement

**Barnaby J.W. Dixson:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **Nicole L. Nelson:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Eleanor Moses:** Writing – review & editing, Writing – original draft, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Anthony J. Lee:** Writing – review & editing, Writing – original draft, Software, Resources, Methodology, Conceptualization. **Alan J. Pegna:** Writing – review & editing, Writing – original draft, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

## Declaration of competing interest

The authors have no competing interests.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.evolhumbehav.2024.106629.

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