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# How testosterone administration affects social rank perceptions: A double-blind, placebo-controlled study

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**Abstract**

**Background** Navigating social hierarchies is fundamental to human survival and reproductive success, relying heavily on the accurate perception of social rank. However, the neuroendocrine mechanisms underlying this perception remain largely uncharted. Given testosterone's established role in status-seeking motivation, we examined whether and how exogenous testosterone modulates the perceptions of dominance and prestige, two primary strategies for achieving social rank.

**Methods** We employed a double-blind, placebo-controlled, between-subjects design involving 110 healthy male participants. After receiving either testosterone or a placebo, participants evaluated various nonverbal displays representing four distinct social signals (prestige, dominance, neutral, and smiling). We assessed their ultimate perceptions of the targets' dominance and prestige, alongside their trait inferences of agency and communion, which were theorized to underpin social rank perceptions.

**Results** Results indicated that testosterone, rather than exerting a significant main effect on the overall magnitude of explicit dominance and prestige judgements, exerted a selective and subtle influence on the underlying cognitive pathways. Specifically, testosterone diminished the reliance on the indirect pathways involving perceptions of communion when evaluating non-dominant signals. Conversely, the cognitive processing of dominance displays, which relies predominantly on agency, remained highly resilient to testosterone administration.

**Conclusions** These findings indicate that testosterone's role in social rank perception is limited, subtly recalibrating the weighting of affiliative traits rather than biasing ultimate judgments. Crucially, the robustness of basic visual decoding in our study highlights that explicit verbal judgments of nonverbal displays may not be a sensitive signal carrier for observing testosterone's effects on social cognitive processes.

**Keywords** Testosterone · Social rank perception · Dominance · Prestige · Nonverbal cues

## Background

Social hierarchy is a fundamental organizing principle of social animals [1], shaping behaviors in both competitive and cooperative contexts [2, 3]. More than just a cultural construct, social hierarchy has deeply rooted biological foundations [4]. Accurately perceiving and responding to social hierarchy signals is a vital adaptive





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skill for group living, enabling individuals to minimize conflict and optimize social strategies [5]. Research from anthropology, evolutionary biology, and psychology has distinguished between two primary and independent strategies to achieve high social rank, namely dominance and prestige [6, 7]. Specifically, dominance relies on aggression and intimidation to elicit fear and forced deference, whereas prestige involves the display of knowledge and skill that garners respect and voluntary deference [8, 9]. While both strategies are viable pathways to high social rank, they differ profoundly in several aspects, ranging from ontogenetic mechanisms and behaviors to physiological correlates [6, 10]. Critically, this distinction can map onto the interpersonal circumplex, a fundamental framework in social behavior [11]. This model posits that interpersonal dispositions are organized along two orthogonal axes: agency and communion. Specifically, agency reflects the extent to which an individual seeks to assert themselves and pursue individual goals, while communion reflects the intention to foster warmth and maintain meaningful relationships. Consequently, when evaluating social targets, observers rapidly integrate trait inferences along these two dimensions to navigate social hierarchies. Within this framework, dominance is characterized by high agency but low communion, while prestige is characterized by high levels of both agency and communion [7, 12, 13].

Previous research on social rank has primarily focused on how individuals achieve and maintain status. However, navigating social hierarchies is a dyadic process that relies heavily on the accurate interpretation of others' social rank [14–17]. Recent studies have demonstrated that humans reliably communicate both forms of high social rank to their conspecifics through a range of cues [18]. Specifically, research using nonverbal displays of social rank has demonstrated that these cues are not only perceptually distinguishable but also spontaneously employed in ecologically valid settings, such as group interactions and real-world political debates [13]. This line of work also reveals a critical difference in their developmental and cultural trajectories: dominance is universally recognizable and emerges earlier in ontogeny, while the perception of prestige is more culturally variable [10].

The Biosocial Model of Status posits a reciprocal relationship between hormones and social behavior, providing a framework for research into the neuroendocrine mechanisms of social rank [19]. This model offers a key theoretical lens for understanding testosterone, a principal androgen regulated by the hypothalamic-pituitary-gonadal axis, and its link to status dynamics in humans. The model incorporates two primary lines of evidence. On the one hand, correlational studies have shown that endogenous testosterone levels respond dynamically to changes in social rank. Like other social mammals, humans calibrate their endogenous testosterone levels to success and defeat, as well as to changes in prestige [20–22]. Existing research indicates that testosterone functions as both a cause and a consequence of competitive interactions [23]. Experimental evidence suggests that exogenous testosterone propels a range of rank-seeking behaviors [24–27], although the relationship between testosterone and achieved social rank remains inconclusive [28–32]. Additionally, the dual-hormone hypothesis posits that the relationship between testosterone and status-relevant behavior is likely moderated by cortisol [33, 34].

Beyond its role in the pursuit of status, a critical yet largely understudied question is whether testosterone also shapes how we perceive the social rank of others. Considering that testosterone fluctuates with social challenges [35], it's likely that testosterone modulates not only status-seeking behaviors, but also the cognitive processes involved in interpreting status cues. Current neuroendocrine models suggest that hormones do not only trigger behaviors, but also reconfigure the information-processing architecture to meet the demands of the current motivational state [36]. Previous studies, often relying on small sample sizes, have identified the role of testosterone in social perception, including judgments of femininity and masculinity [37, 38], fear and anger [39–41], and trustworthiness [42]. Although the reliability of these early findings has been challenged by large-scale replication failures [32, 43, 44], the specific domain of social rank perception remains largely uncharted. Moreover, the limited research in this area has focused almost exclusively on the perception of dominance [42, 45], leaving the perception of prestige unexplored.

The present study seeks to address this gap by assessing the impact of testosterone on men's judgments of other men's social rank, specifically their judgments of dominance and prestige. We utilized distinct nonverbal displays as experimental stimuli, which effectively communicate dominance and prestige [10, 13, 46]. Dominance

and prestige are communicated through different head positions (tilted downward vs. upward), smiling behaviors (absence vs. presence), and postural expansiveness (space-taking vs. subtle chest expansion). Additionally, perceptions of agency and communion were collected, given their established associations with dominance and prestige [13]. Based on prior evidence that testosterone modulates social processing [47, 48], we hypothesize that testosterone administration will influence explicit judgments of dominance and prestige. Furthermore, we aimed to explore whether testosterone recalibrates the extent to which trait dimensions (i.e., agency and communion) are integrated into the perception of social rank. Given the complex nature of endocrine effects, examining both the explicit rank judgments and their underlying trait associations allows us to rigorously test testosterone's influence.

## Methods

### Participants

A total of 111 healthy men participated in this experiment. We recruited male participants as the dosing and pharmacokinetics of single dose Androgel administration are well established for men [49–52]. In a double-blind, placebo-controlled, between-subjects design, participants were randomly assigned to receive either a single dose of testosterone gel (Androgel) or a matched placebo gel. One participant from the placebo group was excluded from all analyses due to non-varying responses, yielding a final analytical sample of 110 men (testosterone group: $N = 55$, mean± age SD = 20.84 ± 2.85 years; placebo group: $N = 55$, mean± age SD = 20.60 ± 1.83 years). All participants reported to be Han Chinese, had normal or corrected-to-normal vision, and no history of psychiatric or neurological disorders.

Our sample size was determined by an a priori power analysis ($\alpha = 0.05$, Power = 80%) to detect medium effect sizes ($d \approx 0.55$). Because no previous studies have investigated testosterone's effects on social rank perception specifically using nonverbal displays, we determined this target effect size based on broader literature examining testosterone and general social perception [47, 48]. Furthermore, because our central hypotheses involve conditional process models, we verified the power of this sample size for the moderated mediation analyses. Following the joint significance approach [53], adequate power for a moderated mediation model can be demonstrated by ensuring sufficient power for its constituent moderated pathways [54]. A sensitivity analysis by G*Power 3.1 on these key components confirmed that the sample size of 110 provides > 85% power to detect a moderate ($f^2 = 0.15$) group × display interaction and > 95% power to detect a moderate ($f^2 = 0.15$) group × mediator interaction. Collectively, these analyses demonstrate that our sample size yields sufficient power for both the primary group comparisons and the moderated mediation analyses. This study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board at the Hong Kong Polytechnic University. All participants provided written informed consent prior to the study and were compensated 200 Chinese Yuan (~$30) for their time.

### Testosterone administration

All sessions started at 13:00 and lasted approximately 3.5 h. Participants in the testosterone group received a single dose of testosterone gel, containing 150 mg testosterone [Androgel®]. Participants in the placebo group received a colorless hydroalcoholic gel. In both treatment groups, the gel was applied to the shoulders and upper arms by a male research assistant, who was blind to both the purpose of the study and the experimental condition (i.e. the Androgel and placebo were packed identically). We began our experimental tasks 3 h post-dosing, following the previously established interval to ensure the hormone concentration in the testosterone group significantly exceeded that in the placebo group [49, 50, 52]. During the waiting period, participants rested in the testing rooms and were provided with newspapers and magazines that were not related to the study.

## Stimuli

The experimental stimuli were nonverbal displays representing four distinct social signals: prestige, dominance, neutral, and smiling. Specifically, the morphological features of each display were operationalized according to validated coding schemes (10, 13). The dominance display combined an expansive posture, no smile, and a downward head tilt. In contrast, the prestige display was defined by subtle chest expansion, a slight smile, and an upward head tilt. The neutral and smiling displays both lacked postural expansiveness and had a neutrally positioned head, differing only in the presence of a smile.

These stimuli were created using a standardized protocol. Five Han Chinese male actors (aged 18–25) were instructed to pose according to the specifications of each of the four display types. This procedure generated 20 images in total. Actors were instructed to remove jewelry and eyewear, wore plain grey t-shirts and jeans, and were photographed from just below the waist to above the head. All photographs were taken indoors by the same experimenter, with consistent lighting and a white background across actors and display categories (Fig. 1).

## Procedure

Upon arrival, participants were asked to provide their basic demographic information. After that, they were randomly assigned to the testosterone or placebo group in a double-blind, between-subjects design. Participants were then briefed on the tasks, which involved three sequential blocks: dominance perception, prestige perception, and agency/communion perception. The order of the first two blocks (dominance perception and prestige perception) was counterbalanced across participants. Each block began with two practice trials to familiarize participants with the procedure, followed by 20 experimental trials. Each trial began with a central fixation cross presented for 500 ms, followed by a blank screen for 500 ms. Subsequently, the target visual stimulus (a nonverbal display) was presented for 1,500 ms. After the stimulus offset, participants were prompted to rate the previously seen display on the corresponding dimension in a self-paced manner. Each specific display was presented once per block, with the order of the nonverbal displays randomized within each block. Each block lasted approximately 2 min, with a break of at least 1 min in between consecutive block to eliminate fatigue. The experiment was carried out in a controlled setting with the experimenter in a separate, adjacent room, observing the participants through a monitor. Upon completing these tasks, participants engaged in two additional behavioral tasks (a prosocial learning task and a bribery-related decision-making task) that pertained to separate research questions, data from these tasks were not discussed in the present report.

## Perception of dominance

Following the previous practice [12], dominance was measured with four items: “This person would enjoy having control over others,” “This person would be willing to use aggressive tactics to get their way,” “This person would often try to get his way regardless of what people may want,” and “This person would try to control others rather than permit them to control him”. Participants provided ratings of each display on a 7-point Likert scale,

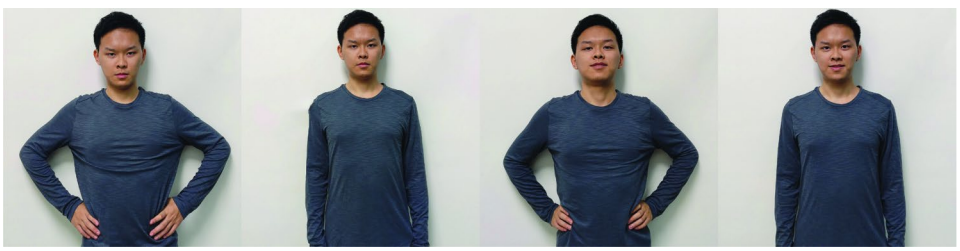

**Fig. 1** A representative subset of the displays used in the study. Displays of dominance, neutral, prestige, and smiling display stimuli (from left to right) are shown

where 7 marked very much and 1 marked not at all. Internal consistency for this scale was high across all four display conditions (mean Cronbach's α = 0.93, Table S1 for Cronbach's α across the four display conditions).

### Perception of prestige

Consistent with established methods [12], prestige was measured with four items: "This person would be considered an expert on some matters," "This person's unique talents and abilities would be recognized by others," "People would seek this person's advice on a variety of matters," and "Members of this person's group respect and admire him". Participants provided ratings of each display on a 7-point Likert scale, where 7 marked very much and 1 marked not at all. Internal consistency for this scale was high across all four display conditions (mean Cronbach's α = 0.90, Table S1 for Cronbach's α across the four display conditions).

### Perception of agency and communion

Based on prior approaches [13], agency was assessed using three items: "I would pay attention to this person," "This person is a leader," and "This person is influential". On the other hand, communion was assessed with a single item: "I would like this person". Participants rated each display on a 7-point Likert scale, where 7 marked very much and 1 marked not at all. Internal consistency for agency scale was acceptable across all four display conditions (mean Cronbach's α = 0.85, Table S1 for Cronbach's α across the four display conditions).

### Statistical analysis

Data were analyzed using Jamovi (Version 2.7.37.0) with the GAMLj module, and the brms package in R [55]. First, to test whether testosterone administration alters general social perception, a series of linear mixed-effects models were conducted on judgments of dominance, prestige, agency, and communion, respectively. We specified crossed random intercepts for both participants and individual actors, which accounts for the variance attributable to individual perceivers and the characteristics of specific target displays. Treatment group (between-subjects factor), display type (within-subjects factor), and their interaction were entered as fixed effects. Furthermore, to decompose differences among display types while strictly controlling for inflated false discovery rates, we conducted all possible pairwise comparisons across the four display conditions, with all p-values adjusted using the Bonferroni correction.

Second, to examine whether testosterone shifts the cognitive processing strategies underlying status conferral, we conducted moderated mediation analyses using Bayesian multivariate mixed-effects models. The models included all four display conditions (neutral, smiling, dominant, and prestigious) with the neutral display specified as the baseline reference category. This allowed us to explicitly determine how active status signals differ from a non-active baseline in triggering cognitive pathways, while simultaneously maximizing statistical power. In specific, display type served as the within-subject independent variable, with perceptions of agency and communion functioning as parallel mediators. The dependent variable was dominance judgments (in the first model) and prestige judgments (in the second model). Treatment group (placebo vs. testosterone) was entered as a moderator on all paths (i.e., modifying the direct effect and the indirect effects via both mediators). Crucially, to rigorously account for our repeated-measures design and stimulus-level variance, we included crossed random intercepts for both participants and target stimuli across all equations. Models were estimated using Hamiltonian Monte Carlo (HMC) sampling with four chains, each containing 3,000 iterations (including 1,000 warmup iterations). Convergence was excellent across all parameters (R-hat ≤ 1.01). The conditional indirect effects and indices of moderated mediation were computed directly from the posterior samples. Statistical significance was determined using 95% Bayesian credible intervals (CIs), an effect was considered significant if its 95% CI did not encompass zero. In addition, we performed leave-one-out cross-validation (LOO-CV) to assess global model fit. Specifically, we compared the full moderation models against constrained null models (excluding testosterone

moderation terms) and computed approximate Bayes factors based on the difference in expected log predictive density (ΔELPD) [56].

Data and analysis scripts for this study are available at https://osf.io/sqy48.

## Results

### Perceptual validation and general effects of testosterone on social rank perception

We first confirmed that our stimuli elicited the intended perceptions in a Han Chinese sample, replicating and extending findings beyond Western Caucasian populations. A linear mixed-effects models on perceptions of dominance revealed a significant main effect of display type on dominance ratings ($F_{3, 2080} = 110.40$, $p < 0.001$, Fig. 2a). Pairwise comparisons showed that dominance displays (display with an expansive posture, no smile, and a downward head tilt) were perceived as significantly more dominant than all other display types ($ps_{cor} < 0.001$, Fig. 2a, Table S2). No significant differences were found among the other three display types (all $ps > 0.46$, Fig. 2a, Table S2). Similar analyses on perceptions of prestige revealed that the prestige display (an upward head tilt, smile, and expansive posture) was perceived as significantly more prestigious than each of the other displays (main effect of display type: $F_{3, 2080} = 120.25$, $p < 0.001$; pairwise comparisons: $ps_{cor} < 0.005$, Fig. 2b, Table S2). Among the other three displays, smiling displays were perceived as significantly more prestigious than dominance and neutral displays ($ps_{cor} < 0.001$, Fig. 2b), between which there was no significant difference ($p_{cor} > 0.99$). However, as smiling displays were judged as significantly less prestigious than the full prestige display ($p_{cor} = 0.005$, Fig. 2b), suggesting that a smile alone conveys prestige, albeit to a lesser extent than the prestige display. Collectively, these analyses verified that nonverbal displays used in this study successfully communicate social rank.

On the other hand, there was no main effect of treatment group on social rank ratings ($Fs_{1, 108} = 0.013$ and 0.17, $ps = 0.91$ and 0.68, Fig. 2a, for perceptions of dominance and prestige, respectively), nor a significant interaction between treatment and display type ($Fs_{3, 2080} = 1.03$ and 0.26, $p = 0.38$ and 0.86, Fig. 2a, for perceptions of dominance and prestige, respectively). In parallel, similar analyses on perceptions of agency and communion revealed

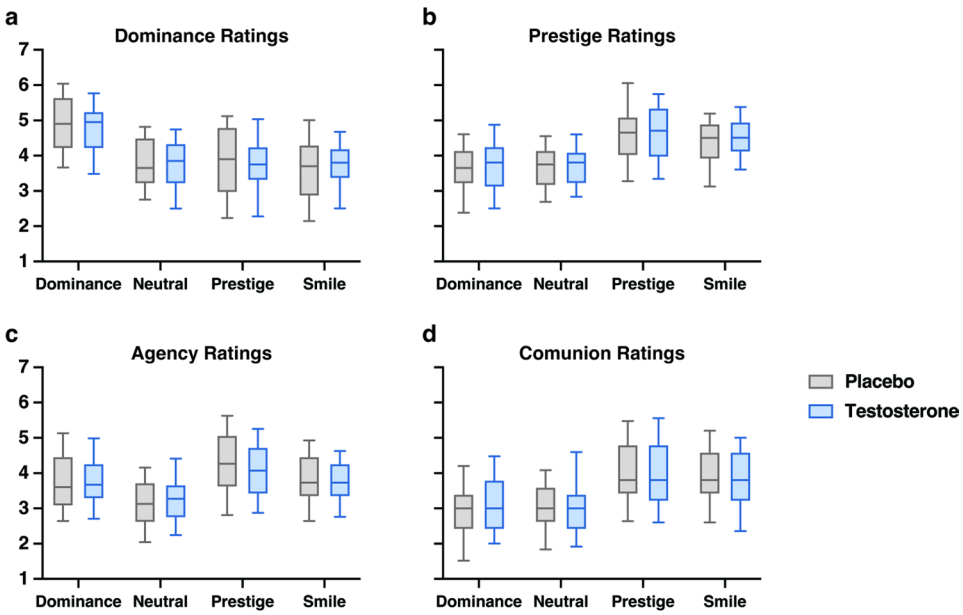


**Fig. 2** Judgments of dominance (**a**), prestige (**b**), agency (**c**) and communion (**d**) for nonverbal display by the placebo group (gray) and the testosterone group (blue). In each box-and-whisker plot, the central line, bottom edge and top edge of the box denote the mean, 25th percentile and 75th percentile, respectively. The ends of the whiskers represent the 10th and 90th percentiles

**Table 1** Moderated mediation of agency and communion on dominance perceptions by treatment group

| Display Type and Pathway | Placebo Estimate [95% CI] | Testosterone Estimate [95% CI] | Moderation index Estimate [95% CI] |
|---|---|---|---|
| Dominance vs. Neutral | | | |
| Direct effect | 0.94 [0.74, 1.14]* | 0.91 [0.71, 1.12]* | -0.024 [-0.31, 0.26] |
| Indirect effect via agency | 0.16 [0.095, 0.24]* | 0.081 [0.037, 0.14]* | -0.079 [-0.17, 0.007] |
| Indirect effect via communion | 0.028 [-0.041, 0.096] | 0.018 [-0.039, 0.080] | -0.031 [-0.11, 0.046] |
| **Prestige vs. Neutral** | | | |
| Direct effect | 0.087 [-0.12, 0.30] | 0.019 [-0.19, 0.23] | -0.068 [-0.36, 0.22] |
| Indirect effect via agency | 0.33 [0.23, 0.44]* | 0.15 [0.079, 0.22]* | -0.18 [-0.31, -0.057]* |
| Indirect effect via communion | -0.35 [-0.45, -0.25]* | -0.16 [-0.26, -0.077]* | 0.21 [0.082, 0.33]* |

Note. $N = 110$. Estimates represent posterior medians from Bayesian multivariate mixed-effects models. 95% CI = 95% credible interval. The moderation index represents the difference in the effect between the testosterone and placebo groups. * indicates that the 95% credible interval does not contain zero

**Table 2** Moderated mediation of agency and communion on prestige perceptions by treatment group

| Display Type and Pathway | Placebo Estimate [95% CI] | Testosterone Estimate [95% CI] | Moderation index Estimate [95% CI] |
|---|---|---|---|
| Dominance vs. Neutral | | | |
| Direct effect | -0.14 [-0.31, 0.032] | -0.12 [-0.29, 0.042] | 0.016 [-0.23, 0.25] |
| Indirect effect via agency | 0.083 [0.040, 0.14]* | 0.11 [0.055, 0.17]* | 0.023 [-0.051, 0.097] |
| Indirect effect via communion | -0.019 [-0.068, 0.027] | 0.003 [-0.021, 0.027] | 0.022 [-0.031, 0.077] |
| **Prestige vs. Neutral** | | | |
| Direct effect | 0.54 [0.37, 0.72]* | 0.62 [0.45, 0.79]* | 0.080 [-0.16, 0.33] |
| Indirect effect via agency | 0.17 [0.090, 0.25]* | 0.19 [0.12, 0.26]* | 0.019 [-0.086, 0.12] |
| Indirect effect via communion | 0.23 [0.16, 0.31]* | 0.095 [0.041, 0.15]* | -0.14 [-0.24, -0.040]* |

Note. $N = 110$. Estimates represent posterior medians from Bayesian multivariate mixed-effects models. 95% CI = 95% credible interval. The moderation index represents the difference in the effect between the testosterone and placebo groups. * indicates that the 95% credible interval does not contain zero

no significant difference between treatment groups ($Fs_{1,108} = 0.11$ and 0.044, $ps = 0.72$ and 0.83, for perceptions of agency and communion, respectively, Fig. 2c&d).

## Cognitive architecture underlying rank differentiation

Building upon the perceptual differences established in the linear mixed-effects models, we next investigated how testosterone alters the evaluative schemas underlying status perception using Bayesian multivariate mixed-effects models (see Table S4 for full path coefficients).

Accounting for participant and stimulus variances, the models confirmed expected baseline associations: compared to the neutral display, the dominance display was directly associated with higher dominance perception, while prestige and smile displays were directly associated with higher prestige perception. Crucially, testosterone did not significantly moderate any of these direct pathways (Tables 1 and 2), which indicates that testosterone administration does not alter the visual decoding of nonverbal status cues. While the direct decoding of status displays remained unaffected, testosterone significantly modulated how specific trait dimensions (agency and communion) were integrated into status judgments, specifically when evaluating non-dominant (smiling and prestigious) displays. Specifically, this modulation was highly specific to the prestige and smile displays, leaving the processing of the dominance display largely unchanged. (The smile display exhibited a similar pattern of moderated indirect effects to the prestige display. To maintain theoretical focus, detailed results for the smile display are reported in Table S3).

For dominance judgments, both the indirect and direct pathways associated with the dominance display were unaffected by testosterone. Specifically, the dominance display was positively associated with dominance

perception via perceived agency, and this link remained robust across both drug groups. In contrast, although the direct association between prestige display and dominance judgement was not modulated by testosterone, the indirect pathways for the prestige display were significantly altered. Under placebo, the prestige display was positively associated with dominance via perceived agency, but simultaneously demonstrated a negative indirect association via perceived communion (i.e., higher perceived communion was linked to lower dominance ratings). Although both indirect pathways remained statistically significant, testosterone significantly attenuated both of them by reducing the covariation between the prestige display and dominance via agency (moderation index = −0.18, [−0.31, −0.057], Table 1) and mitigating the negative indirect association via communion (moderation index = 0.21, [0.082, 0.33], Table 1).

For prestige judgments, a similar divergence between display types emerged. While testosterone did not moderate the direct effects of any display type, a divergence between display types emerged in the indirect pathways. The dominance display showed no moderated indirect effects (Table 2). For the prestige display, which under placebo was positively associated with prestige via both agency and communion, testosterone administration selectively weakened the communion link without eliminating it (moderation index = -0.14 [-0.24, -0.040], Table 2), leaving the agency link unaffected (moderation index = 0.019 [-0.086, 0.12], Table 2).

In sum, rather than altering the basic architecture of status perception, testosterone appears to exert a subtle and selective influence. Specifically, testosterone showed no evidence of affecting the cognitive pathways for the dominance display. However, when observers evaluated the prestige and smile displays, testosterone subtly modulated the indirect pathways, primarily by attenuating the degree to which affiliative cues (communion) were integrated into their status judgments. Complementing these localized influences, global model comparisons using LOO-CV indicated no substantial difference in overall predictive performance between the full moderation and null models (which excluded the moderation terms of testosterone) for both dominance (ΔELPD = -0.48, SE = 6.33, approximate Bayes factor = 1.61) and prestige judgments (ΔELPD = -0.45, SE = 5.62, approximate Bayes factor = 1.57). Together, these results suggest that testosterone induces subtle, specific shifts in the evaluative schemas underlying status perception, rather than a global restructuring.

## Discussion

The present study investigated how testosterone influences the perception of social rank from nonverbal displays. Our findings indicate that while the fundamental visual decoding of status cues remains robust, testosterone administration did not alter the direct associations between nonverbal displays and verbal judgments. Instead, testosterone exerted only a subtle and specific influence on the evaluative schemas underlying these judgments. Specifically, when observers evaluated non-dominant signals (i.e., prestige and smile displays), testosterone attenuated the degree to which inferences of communion were integrated into their status judgments, while leaving the processing of the dominance display unchanged.

With data collected from a Chinese Han sample, our results confirmed that nonverbal displays reliably communicate both dominance and prestige. Numerous studies have suggested that social rank can be decoded from a range of cues, including physical characteristics, behaviors, and possessions [46], but the evidence is predominantly based on Western Caucasian samples. Recently, cross-cultural research revealed that the cues of social rank can be culturally variable, particularly with regard to prestige cues [10], while dominance cues are perceived to be consistent across cultures [10, 45, 57]. In line with the cultural variability of prestige cues, our findings revealed a distinct pattern. Although prestige displays were reliably differentiated from all other displays, smiling displays were perceived as significantly more prestigious than both dominance and neutral displays. This pattern contrasts sharply with findings from Caucasian populations, where smiles are associated with lower prestige [58], but echoes findings from Mayangna, who perceive smiling as equally prestigious as the prestige display. This may reflect cultural norms prevalent in East Asian societies, where smiling individuals are perceived as more intelligent [59] and where humility and social harmony are emphasized [60]. We therefore speculate that smiling

displays signal an intelligent, non-threatening, harmonious confidence that aligns with values of modesty, making them an effective prestige cue.

While some earlier studies indicated that testosterone induces a social perceptual bias [48] or alters perceptual sensitivity [45], we did not observe a direct main effect of testosterone on explicit judgments of social rank. Importantly, this absence of a main effect aligns with recent large-scale replications demonstrating consistent null main effects of exogenous testosterone across various social and cognitive tasks [32, 43, 44]. This absence may also stem from the nature of the measurement. As an important hormonal factor in implicit motives [61], testosterone modulates nonverbal responses, such as emotion recognition, attentional orienting, and dominance behavior that largely bypass conscious introspection [62–64]. Consequently, explicit verbal self-reports may not fully capture its influence [65]. Moreover, although our results confirm that the 1,500 ms exposure was sufficient to reliably elicit perceptions of dominance and prestige, longer and more naturalistic exposures might engage deliberate cognitive processes that could alter these initial evaluations.

Nevertheless, our results point to a more nuanced role for testosterone in social rank perception than previously acknowledged. Although the direct perceptual pathways remained unaffected, exogenous testosterone selectively recalibrated the indirect cognitive pathways for specific social signals. Specifically, when observers evaluated non-dominant signals (i.e., prestige and smile displays), testosterone attenuated the extent to which perceived communion was linked to status judgments. This selective shift aligns with evidence showing that exogenous testosterone downregulates the social affiliation system. For instance, testosterone has been shown to reduce empathy and empathetic behavior [66, 67], decrease interpersonal trust [67]. If testosterone blunts the subjective value of affiliative signals, observers may naturally weigh communion less heavily when associating targets with higher social rank. However, we note that communion was operationalized in this study using a single-item measure of interpersonal liking. Although empirical research demonstrates that liking is driven by and highly correlated with perceived communion [68], the reliance on a single item warrants caution when interpreting the precise nature of this pathway. On the other hand, testosterone had limited impact on the agency pathway. From an evolutionary perspective, accurately assessing an individual's agency is critical for survival, navigating threats, and determining social standing [68]. Therefore, the cognitive pathway linking agency to status is evolutionarily preserved and resilient to endocrine modulation.

Furthermore, our findings revealed that the cognitive processing of the dominance display remained largely unperturbed by testosterone administration. As our models demonstrated, the evaluation of dominance displays is overwhelmingly associated with perceptions of agency, with minimal reliance on communion (Tables 1 and 2, Table S4). Because exogenous testosterone primarily recalibrated the communion pathway, the overall processing of dominance displays remained immune to this endocrine modulation. Additionally, the distinct nature of dominance signals may further explains this null effect. Unlike prestige, dominance displays actively communicate threat, coercion, and physical formidability [7]. Consequently, while exogenous testosterone dampens the affiliation system, it has limited effect on the threat-oriented schemas observers use to evaluate dominance displays. Notably, this is consistent with prior research demonstrating that exogenous testosterone yields null effects on the reactivity of dominance and threat cues, even if it alters implicit or neural responses [69, 70].

It is important to note several limitations of the present research. First, our findings are based solely on nonverbal displays. Social rank, however, can be communicated through a wide range of cues. An important direction for future research is to investigate whether testosterone's moderating effect generalizes to other cues of social rank. Second, our conclusions are limited by the exclusive focus on male participants. Although previous study has found no significant sex differences in social rank perceptions [13], others have reported sex differences in response to testosterone [71, 72]. Second, evidence indicates that social influence increases with dominance and prestige for men and women, respectively [73]. This difference suggests that the cognitive and neuroendocrine substrates of status seeking may not be identical. It thus remains a critical and open question for future research whether testosterone reshapes social rank perception in women similarly. Third, although we assessed dominance and prestige as the two fundamental theoretical dimensions of social rank, we did not directly ask participants to rate the targets' social status. Future research should include explicit measures of general social rank to fully

capture this broader construct. Finally, to minimize invasiveness, we did not collect blood samples to verify circulating testosterone levels, relying instead on a standardized administration protocol validated in our previous work [74]. While effective, the absence of a direct manipulation check limits our ability to examine how the specific magnitude of testosterone elevation directly correlates with changes in social rank perception.

When generalizing our findings to real-world settings, it is crucial to distinguish between the effects of endogenous testosterone and acute exogenous testosterone administration [23], as behaviors that strongly correlate with endogenous testosterone can yield null or highly context-dependent main effects under exogenous administration [43]. Moreover, to fully understand these context-dependent effects, our findings must be integrated with how testosterone modulates the appraisal of other concurrent social status cues, as individuals rarely evaluate nonverbal displays in isolation. Recent neuroendocrine research highlights that testosterone significantly alters perception of dominant facial signals and vocal cues [45, 75]. Furthermore, altering the appraisal of these social cues serves as the cognitive precursor to actual social action. While the present study specifically measured target appraisal, contemporary behavioral studies emphasize that testosterone subsequently drives actual behavior toward these targets. Once testosterone shifts the appraisal of the social environment, it facilitates context-appropriate status-seeking behaviors, ranging from reactive aggression to strategic prosociality [76]. Therefore, a vital direction for future research is to investigate how testosterone-induced shifts in the appraisal of social cues translate into actual behavioral responses.

## Conclusions

In summary, the present study provides evidence that testosterone plays a highly constrained and nuanced role in social rank perception. Importantly, because the verbal judgements of nonverbal status displays remained unaffected by testosterone administration, our findings suggest that explicit verbal judgments of nonverbal displays may not be a sensitive signal carrier for observing testosterone's effects on social cognitive processes. Rather than shifting individuals toward a fundamentally different processing route, testosterone selectively recalibrates affiliative traits (communion) are weighted when evaluating status signals.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1186/s40359-026-05508-z.

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**Author contributions** YY performed the formal analysis, created the visualizations, and wrote the original draft of the manuscript. XL reviewed and edited the manuscript. YN conducted the investigation and was responsible for data collection. YW conceptualized and designed the study, developed the methodology, and contributed to reviewing and editing the manuscript. All authors read and approved the final manuscript.

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**Data availability** The data that support the findings of this study are available at https://osf.io/sqy48.

## Declarations

**Ethics approval and consent to participate** This study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board at the Hong Kong Polytechnic University. All participants provided written informed consent prior to the study.

**Consent for publication** Not applicable.

**Competing interests** The authors declare no competing interests.



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