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Testosterone Affects Gaze Aversion From Angry Faces Outside of Conscious Awareness

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Abstract

Throughout vertebrate phylogeny, testosterone has motivated animals to obtain and maintain social dominance—a fact suggesting that unconscious primordial brain mechanisms are involved in social dominance. In humans, however, the prevailing view is that the neocortex is in control of primordial drives, and testosterone is thought to promote social dominance via conscious feelings of superiority, indefatigability, strength, and anger. Here we show that testosterone administration in humans prolongs dominant staring into the eyes of threatening faces that are viewed outside of awareness, without affecting consciously experienced feelings. These findings reveal that testosterone motivates social dominance in humans in much the same ways that it does in other vertebrates: involuntarily, automatically, and unconsciously.

Keywords

social interaction, neuroendocrinology, facial expressions, eye movements, aggressive behavior

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The notion that individual animals, including humans, pursue dominant social positions to ensure access to resources and reproductive advantage is of great scientific and societal interest (Archer, 2006; Bos, Panksepp, Bluthé, & van Honk, 2011; Eisenegger, Haushofer, & Fehr, 2011; Josephs, Newman, Brown, & Beer, 2003; Josephs, Sellers, Newman, & Mehta, 2006; Mazur & Booth, 1998). All the way through vertebrate phylogeny, from reptiles to mammals, the steroid hormone testosterone has been identified as a driving force for engaging and prevailing in confrontations for social dominance (Archer, 2006), which underlie the formation of social hierarchies (Mazur & Booth, 1998). For millions of years, testosterone evidently has acted on evolutionarily primordial brain mechanisms that motivate animals to increase and maintain social status and power.

In humans, though, the expanded neocortex is thought to be in control of primordial drives, and testosterone's effects on social behavior are said to have shifted to the promotion of feelings of superiority, strength, anger, and low anxiety. In turn, these consciously experienced motivational states are said to direct voluntary control of behavior dealing with social challenges and threats (Eisenegger et al., 2011; Josephs et al., 2003; Josephs et al., 2006; Mazur & Booth, 1998). This notion, however, is currently under debate because it is based on merely correlational evidence; consequently, one cannot exclude the possibility that testosterone regulates status-seeking behaviors in humans unconsciously and automatically without affecting conscious motivational states (Bos et al., 2011).

In earlier research, we showed that salivary testosterone levels were associated with attentional vigilance to angry faces (van Honk et al., 1999), and that testosterone administration increased cardiac reactivity to angry faces (van Honk et al., 2001). A third study demonstrated that testosterone administration increases amygdala reactivity to angry (relative to happy) faces (Hermans, Ramsey, & van Honk, 2008). These findings converge to suggest that testosterone enhances vigilance toward social signals of dominance (i.e., angry faces). In these studies, however, the facial expressions were perceived consciously, whereas our hypothesis has been that testosterone increases vigilance, or dominance, primarily through automatic, unconscious mechanisms (van Honk & Schutter, 2007; van Honk, Schutter, Hermans, & Putman, 2004). Although other researchers found correlational support for this hypothesis (Wirth & Schultheiss, 2007), it has not yet been confirmed with causal methodology. Here, we report a placebo-controlled study of the effects of testosterone administration in which we not only used infrared eye tracking to measure a social-dominance behavior

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that was much more ecologically valid than the measures in our earlier studies, but also used a backward-masking technique to ensure that the facial expressions did not reach consciousness.

We administered testosterone and placebo to 20 healthy volunteers and tested effects on performance on a social-dominance task, as well as self-reports on a widely used inventory that assesses conscious motivational states of anger, vigor, fatigue, anxiety, and depression. In the social-dominance task, faces were presented outside of conscious awareness, and eye movements were tracked to assess participants' inclination to either gaze away from (submission) or endure (dominance) face-to-face status threats in the form of angry stares (Terburg, Hooiveld, Aarts, Kenemans, & van Honk, 2011). Thus, we measured genuine gaze aversion from masked angry faces and tested the causal role of testosterone in promoting social dominance unconsciously.

Method

Participants and design

Twenty healthy volunteers (age range: 20–25 years) received sublingual testosterone and placebo in counterbalanced order, with the two tests separated by 1 week. We exclusively recruited women using single-phase contraceptives for several reasons. First, this minimized menstrual-cycle effects on basal hormone levels. Second, the magnitude and time course of the neurophysiological effects of testosterone have been established only in women (Tuiten et al., 2000). Third, basal testosterone levels in females have been shown to correlate with both aggressive behavior and implicit measures of dominance (Cashdan, 1995; Dabbs & Hargrove, 1997; Josephs et al., 2003; Josephs et al., 2006).

Drug samples

Sublingual drug samples consisted of 0.5 mg of testosterone, 5 mg of cyclodextrin (carrier), 5 mg of ethanol, and 0.5 ml of water. The placebo samples were the same except that testosterone was omitted. Sublingual administration of testosterone induces behavioral and physiological effects, as indexed by subjective and vaginal arousal to erotic stimuli, that peak after 4 hr (Tuiten et al., 2000). Accordingly, experimental testing was started 4 hr after drug (and placebo) administration. Note that this method has been used successfully in more than a dozen studies on social and emotional aspects of human behavior (Bos et al., 2011).

Conscious assessment of mood state

Before performing the social-dominance task, participants completed the Profile of Mood States (Shacham, 1983), a validated 30-item questionnaire that indexes consciously experienced anger, anxiety, depression, fatigue, and vigor, using visual analogue scales.

Social-dominance paradigm

The stimuli for the social-dominance task included angry, happy, and neutral faces of five men and five women. On each trial, a gray mask with a central fixation point was followed by a face that was presented in blue, green, or red for 33 ms before a mask stimulus of the same color; the masks and face had similar luminance properties. At the bottom of each face and mask display were three circles; participants were instructed that when the central stimulus turned from gray to a color, they should avert their gaze from the central fixation point to the circle with the corresponding color (see Fig. 1a). The difference in gaze-aversion latency between angry and happy expressions in this task is a reliable index of dominance motives (see Terburg et al., 2011). Facial expressions were presented in a fixed sequence that was repeated five times (NxxyNyyxNNyyxNxxyN; N = neutral; x and y = angry and happy, counterbalanced across the two sessions). This order ensured that all combinations of successive trial types occurred equally often, allowing us to analyze trials following a neutral baseline separately and eliminating trial-by-trial interference of emotionally conflicting information (Etkin, Egner, Peraza, Kandel, & Hirsch, 2006; Kunde & Mauer, 2008).

Gaze movements were recorded with a Tobii-1750 eye tracker (Tobii Technology, Danderyd, Sweden), and gaze-aversion latency was defined as the time between face onset and first gaze on the target circle. Latencies more than 3 standard deviations from an individual's mean were excluded (2.2%).

Emotion awareness check

At the end of the final session, participants were asked whether they had seen the emotional expressions during the task. Subsequently, all 30 face stimuli (10 faces × 3 emotions) were presented again, masked, and participants were instructed to identify each facial expression as happy, angry, or neutral, in a forced-choice design.

Results

Mean latencies on angry-face and happy-face trials were baseline-corrected by subtracting the mean latency on neutral-face trials and then entered in a 2 (emotion: angry vs. happy) × 2 (drug condition: testosterone vs. placebo) repeated measures analysis of variance. The Emotion × Drug Condition interaction was significant, $F(1, 19) = 8.84$, $p = .008$, $\eta_p^2 = .32$. Post hoc paired t tests confirmed that after testosterone administration, $t(19) = 3.06$, $p = .006$, but not after placebo, $t(19) = -1.33$, $p = .201$, gaze aversion from angry faces was slower than gaze aversion from happy faces (see Fig. 1b).

Next, we assessed angry- and happy-face trials that followed neutral-face trials separately. This analysis revealed a main effect of emotion, $F(1, 19) = 5.06$, $p = .037$, $\eta_p^2 = .21$, which was explained by the Emotion × Drug Condition

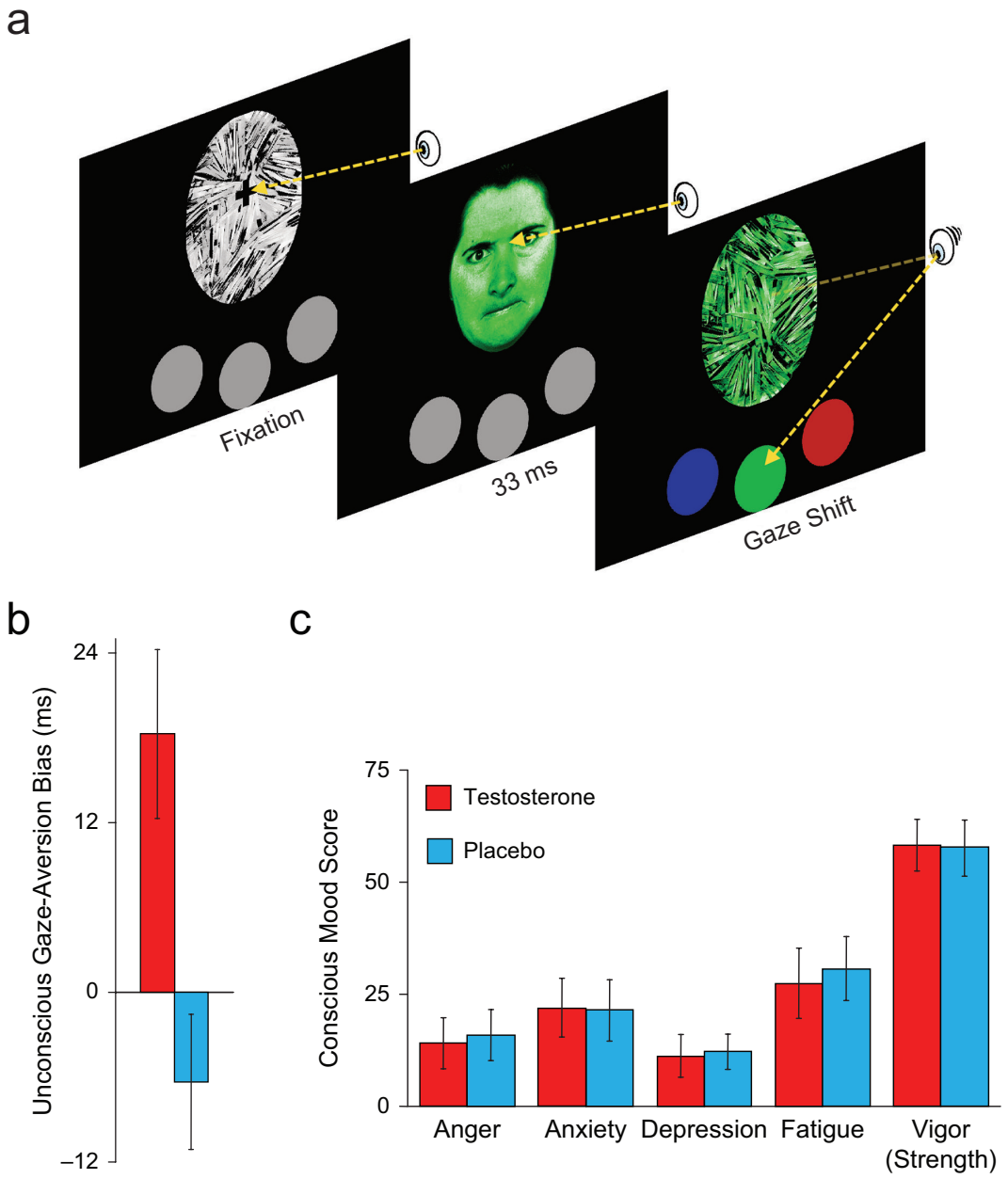

Fig. 1. Illustration of the experimental method and results. In each trial of the social-dominance task (a), participants watched a meaningless gray picture turn blue, green, or red, at which point they were to shift their gaze downward, as fast as possible, to the circle with the corresponding color. Crucially, during the color transition, a facial expression was presented too quickly to be consciously perceived; thus, the downward gaze shift was an implicit act of gaze aversion from a social signal of reassurance (happy expression), a neutral signal (neutral expression), or a face-to-face status threat (angry expression, which rendered the gaze shift an unconscious act of submission; figure adapted from Terburg, Hooiveld, Aarts, Kenemans, & van Honk, 2011). The graphs present (b) the mean difference in baseline-corrected gaze-aversion latency between angry and happy faces (angry – happy) and (c) the mean self-reported mood states in the two drug conditions (testosterone vs. placebo). Error bars represent standard errors of the mean.

interaction, $F(1, 19) = 5.74$, $p = .027$, $\eta_p^2 = .23$ (see Fig. S1 in the Supplemental Material available online). Post hoc paired t tests confirmed that testosterone administration slowed down gaze aversion from angry faces, $t(19) = 2.13$, $p = .046$, and not from happy faces, $t(19) = 0.10$, $p = .992$. In sum, although slower gaze aversion from angry faces compared with happy faces can be interpreted as reflecting either dominance or reduced reward sensitivity (Terburg et al., 2011), this anger-specific effect confirms that testosterone promotes dominance-related gaze behavior.

None of the participants reported awareness of the facial expressions, but 5 scored significantly above chance level on the awareness check (i.e., > 14 correct; chance level = 10 correct; binomial test with $n = 30$, one-tailed $\alpha = .05$). Crucially, the effect of testosterone on gaze aversion remained significant (tested with one-tailed Wilcoxon signed-ranks tests because of the small sample size and directed hypotheses) for both these participants ($Z = -2.02$, $p = .022$, $n = 5$) and those who were not aware of the facial expressions ($Z = -1.70$, $p = .044$, $n = 15$).

Finally, there were no effects of drug condition on self-reported mood states (all ps > .5; see Fig.1c).

Discussion

Our results show that after testosterone administration, participants reflexively maintain eye contact when unconsciously confronted with angry faces. Crucially, this unconscious display of dominance in face-to-face confrontations (Terburg et al., 2011) was accompanied by neither increased anger and vigor nor decreased anxiety, fatigue, or depression. This finding indicates that these consciously experienced motivational states do not underlie testosterone-induced social-dominance behavior.

Slower gaze aversion from angry than from happy faces has been shown to be independently related to dominance motives and reduced reward sensitivity (Terburg et al., 2011). On the basis of these findings taken by themselves, we cannot exclude the possibility that our results are due to testosterone speeding up gaze aversion from happy faces. However, testosterone administration has previously resulted in increased reward sensitivity and appetitive motivation (Hermans et al., 2010; van Honk, Schutter, Hermans, Putman, Tuiten, & Koppeschaar, 2004), which makes the latter explanation unlikely. Most important, the effect of testosterone in the baseline-corrected analysis was anger-specific, which confirms our hypothesis that testosterone specifically induces dominance-related gaze behavior. Although our drug-administration method generally yields effects similar to those of endogenous testosterone in females as well as males (Bos et al., 2011; van Honk & Schutter, 2007), future research should confirm that the results we obtained are also observed in males.

These results extend our previous findings on vigilance to consciously processed angry faces after testosterone administration (Hermans et al., 2008; van Honk et al., 2001; van Honk et al., 1999), by showing that testosterone promotes dominance behavior toward unconsciously perceived angry faces as well. Our results add to the ongoing debate on whether testosterone promotes dominance through complex psychological mechanisms (Mazur & Booth, 1998) or reflexive biological mechanisms (van Honk, Schutter, Hermans, & Putman, 2004). Moreover, we have shown not only that testosterone affects vigilance to anger, but also that the hormone genuinely promotes social-dominance behavior by restraining gaze aversion when individuals are confronted with angry eye contact (Terburg et al., 2011). Although conscious psychological mechanisms unmistakably play a role in the urge for social status (Eisenegger et al., 2011; Mazur & Booth, 1998), testosterone's promotion of human social-dominance behavior evidently precedes these higher-order mechanisms. The present study thus provides compelling evidence that testosterone acts directly—involuntarily, automatically, and unconsciously—on social dominance in humans through phylogenetically ancient pathways shared with other vertebrate species (Archer, 2006; Bos et al., 2011).

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Supplemental Material

Additional supporting information may be found at http://pss.sagepub.com/content/by/supplemental-data

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