



Exogenous testosterone in women enhances and inhibits competitive decision-making depending on victory–defeat experience and trait dominance



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ABSTRACT

The present experiment tested the causal impact of testosterone on human competitive decision-making. According to prevailing theories about testosterone's role in social behavior, testosterone should directly boost competitive decisions. But recent correlational evidence suggests that testosterone's behavioral effects may depend on specific aspects of the context and person relevant to social status (win–lose context and trait dominance). We tested the causal influence of testosterone on competitive decisions by combining hormone administration with measures of trait dominance and a newly developed social competition task in which the victory–defeat context was experimentally manipulated, in a sample of 54 female participants. Consistent with the hypothesis that testosterone has context- and person-dependent effects on competitive behavior, testosterone *increased* competitive decisions after victory only among high-dominant individuals but testosterone *decreased* competitive decisions after defeat across all participants. These results suggest that testosterone flexibly modulates competitive decision-making depending on prior social experience and dominance motivation in the service of enhancing social status.

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Testosterone is theorized to play a role in behaviors implicated in the pursuit of social status, such as competitive behavior (Mazur and Booth, 1998), but the precise role of this hormone in human social behavior remains controversial. One key limitation is that this body of research is comprised primarily of correlational studies. To date, it remains unknown whether testosterone has a causal influence on human competitive decision-making, and if so, the precise nature of that influence. To identify the causal impact of testosterone on human competitive behavior, the present study combined hormone administration, measures of trait dominance, and a newly developed social competition task in which the context was experimentally manipulated. This novel design allowed us to gain a mechanistic understanding about the nature of testosterone's influence on competitive decision-making.

Prevailing theories suggest that testosterone should directly boost competitive and dominant behaviors during periods of social competition or challenge (Wingfield et al., 1990; Mazur and Booth, 1998; Archer, 2006). Consistent with this *challenge hypothesis* is evidence that higher testosterone is positively related to aggressive and dominant behaviors across a variety of non-human animal species, especially during times of social instability (Wingfield et al., 1990; Muller and Wrangham, 2004; Archer, 2006; the biosocial model of status makes similar predictions, Mazur and Booth, 1998; see also Terburg and van Honk, 2013). Support for the challenge hypothesis has also emerged in human studies as well. Indeed, a compelling line of research demonstrates that testosterone administration enhances neural, attentional, and behavioral responses to social signals of dominance threat (e.g., angry faces, Hermans et al., 2008; Bos et al., 2012; Terburg et al., 2012; Terburg and van Honk, 2013; Goetz et al., 2014; Enter et al., 2014; Radke et al., 2015). Other studies suggest that testosterone administration influences psychological processes implicated in dominance motivation, such as reduced trust and empathy (Hermans et al., 2006; Van Honk

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et al., 2011; Bos et al., 2010; Boksem et al., 2013). However, inconsistencies have also begun to accumulate in other research on testosterone and human social behavior (Mazur and Booth, 1998; Archer, 2006; Eisenegger et al., 2011; Carré and Olmstead, 2015). For example, the few human studies that investigated exogenous testosterone's influence on status-relevant behaviors such as bargaining behaviors or aggression have revealed inconsistent results (e.g., Eisenegger et al., 2009; Zak et al., 2009; Zethraeus et al., 2009; for relevant review see Eisenegger et al., 2011). Although these studies of bargaining behavior used different methods to exogenously administer testosterone and different populations (Eisenegger et al., 2009: female participants with an average age of 25.16 years in Switzerland who were administered a single dose of testosterone sublingually; Zak et al., 2009: male participants with an average age of 20.8 years in the United States who were given AndroGel®; Zethraeus et al., 2009: postmenopausal women in Sweden between the ages of 50–65 who were administered testosterone undecanoate daily for four weeks), it remains unclear what factors account for the heterogeneous results across these studies. Collectively, prior research lends some support for the hypothesis that testosterone may enhance competitive and dominant behaviors, but there are many inconsistent findings.

These inconsistencies may arise because testosterone's role in status-relevant behavior could depend on key aspects of the *context* and the *person* relevant to social status. Consistent with this possibility, several correlational studies reveal that testosterone's role in status-relevant behavior depends on one specific contextual factor: whether a prior dominance contest resulted in victory or defeat (Newman et al., 2005; Schultheiss et al., 2005; Josephs et al., 2006; Mehta and Josephs, 2006; Mehta et al., 2008; Carré et al., 2009, 2013). In a study of undergraduate females for example, high basal testosterone was associated with increased competitive behavior after victory and decreased competitive behavior after defeat (Mehta et al., 2008). These results suggest that higher testosterone is related to a drive to attain high status and leads to heightened reactions to rises/drops in status (victory/defeat) within the dominance hierarchy. Higher testosterone predicts increased competitive behavior after victory presumably to reinforce one's higher status position in the hierarchy, whereas higher testosterone predicts reduced competitive behavior after defeat presumably to avoid further loss of status in the hierarchy (Mehta et al., 2008). Yet other correlational studies that also accounted for wins versus losses and measured testosterone showed different results (e.g., null direct associations between testosterone and behavior after victory, Mehta and Josephs, 2006; Carré et al., 2009). These inconsistencies suggest that there is unexplained variability in testosterone's behavioral effects that cannot be accounted for by the victory–defeat context alone.

A possible explanation for these heterogeneous findings is that testosterone's role in status-relevant behavior may not only be *context-dependent* (prior victory–defeat experience) but may also be *person-dependent*. Trait dominance assesses a person's self-reported motivation to attain high status positions but does not strongly correlate with endogenous testosterone (Jackson, 1967; Josephs et al., 2006). Researchers have theorized that testosterone is an unconscious marker of dominance motivation (Terburg et al., 2012) that interacts with consciously experienced, self-reported dominance motivation to influence status-relevant behaviors (Slatcher et al., 2011). Consistent with this theorizing, two correlational studies found that testosterone's associations with mating and aggressive behaviors were stronger among individuals high in self-reported trait dominance. In one study, men reported to the lab in pairs, completed a self-report trait dominance scale, provided saliva samples for testosterone measurement, and engaged in a seven-minute videotaped social interaction with the other male participant as well as an attractive female confeder-

ate (Slatcher et al., 2011). The men were led to believe that this woman was another participant and that she would choose which of the two men she “clicked” with better. Results revealed a null association between endogenous testosterone and self-reported trait dominance, which is consistent with theory and evidence that testosterone influences dominance motivation outside of conscious awareness (Josephs et al., 2006; Terburg et al., 2012). Instead, endogenous testosterone interacted with self-reported trait dominance to predict men's dominant mating behaviors (e.g., taking control of the interaction, talking about himself). There was a positive association between testosterone and dominant mating behaviors only among men high in trait dominance, but not among men low in trait dominance. In a second study, participants completed a trait dominance questionnaire, were randomly assigned to win or lose in a cognitive contest, provided saliva samples before and after the competition to assess changes in testosterone concentrations, and then completed a task that measures aggressive behavior (Carré et al., 2009). Results revealed that endogenous testosterone interacted with trait dominance in the victory condition only, a social experience indicative of a more dominant position in the hierarchy. A rise in testosterone after victory was related to increased aggressive behavior only among men high in trait dominance but not among men low in trait dominance¹. These two correlational studies suggest that testosterone is positively related to mating and aggressive behaviors among men high in trait dominance, especially after a victory experience. However, no studies to date have investigated whether testosterone interacts with trait dominance and prior victory–defeat experience to predict competitive decision-making.

Taken together, these recent studies lend some indirect support for the hypothesis that testosterone's influence on competitive behavior should depend on status-relevant aspects of both the context (prior win–lose experience) and the person (trait dominance). However, the indirect evidence for this hypothesis has been derived *exclusively* from correlational data, and results are inconsistent across studies. To date, it remains unknown to what extent testosterone has a causal impact on human competitive decision-making, and if so, whether this hormonal influence on behavior depends on specific context- and person-factors implicated in social status (win–lose context and trait dominance). Research that delineates the causal pathway between testosterone and competitive decisions is critical to elucidating the neuroendocrine mechanisms of status-relevant behavior, but pharmacological studies that test this causal pathway are lacking. We designed a study in which hormone concentrations and the social context were experimentally manipulated in order to address these open questions regarding testosterone's causal role in competitive behavior.

1. Present experiment

The present experiment integrated hormone administration, measures of trait dominance, and a novel social competition task involving context manipulations in order to gain a mechanistic understanding of testosterone's causal role in competitive behavior. Participants competed on ninety rounds of a cognitive task in which victory–defeat context was experimentally manipulated. After each round of competition, participants made a competi-

¹ Carré et al. (2009) reported null associations between endogenous testosterone and aggressive behavior in women (non-significant main effect and non-significant testosterone × trait dominance interactions), but these null effects may have emerged because of lower measurement validity for salivary testosterone in females (Granger et al., 2004), because women may be less likely to employ aggression as a means for status attainment (e.g., Archer, 2009), or because of low statistical power (data from 50 women used in the main analyses). We return to the issue of potential sex differences in testosterone's behavioral effects in the discussion.

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