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SHORT COMMUNICATION

Testosterone responses to competition predict decreased trust ratings of emotionally neutral faces

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Summary A wealth of evidence has linked individual differences in testosterone (T) to social, cognitive, and behavioral processes related to human dominance. Moreover, recent evidence indicates that a single administration of T reduces interpersonal trust in healthy young women. Here, in a sample of men and women ($n = 96$), we investigated the extent to which endogenous fluctuations in T during a competitive interaction would predict subsequent ratings of trust from emotionally neutral faces. Results indicated that a rise in T predicted a decrease in trust ratings in men, but not women. These findings provide further support for the idea that competition-induced fluctuations in T may serve to modulate ongoing and/or future social behavior.

1. Introduction

A wealth of research indicates that testosterone (T) has a powerful modulatory effect on social cognitive processes (McCaul and Singer, 2012). Notably, a single administration of T significantly decreases ratings of trustworthiness from facial stimuli (Bos et al., 2010) and trust behavior (Boksem et al., 2013). The relevance of this effect for understanding complex social behaviors, however, remains unclear because T administration has been conducted exclusively in women in these studies. Moreover, despite the importance of using T administration to establish causation, it is critical to understand how fluctuations in endogenous T map onto social cognitive processes. Here, we examined whether endogenous fluctuations in T during a competitive interaction would predict changes in trust ratings made of emotionally neutral faces. To the extent that emotionally neutral male faces are perceived as relatively threatening (Becker et al., 2007), and that exogenous T administration promotes vigilance toward social threat (Terburg et al., 2012), we predicted that a rise in T during competition would predict decreased ratings of trust from emotionally neutral faces.

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2. Method

2.1. Participants

Ninety-six participants (45 men and 51 women, M_{age} = 19.40, SD = 1.21) were recruited from the ongoing Duke Neurogenetics Study. All participants provided written informed consent in accord with the Duke University Medical Center Institutional Review Board. Participants were instructed to refrain from eating any large meals or brushing their teeth at least 2 h prior to the experimental session. All testing took place between 11h00 and 17h00.

2.2. Procedure

Participants were first asked to provide ratings of trustworthiness from 24 emotionally neutral Caucasian male faces derived from our prior work (Carré et al., 2009a). For this task, faces were presented for 1000 ms and participants were asked: ''How trustworthy is this person?'' Participants responded using a 7-point scale through a numerical keypad (1 = not at all; to 7 = very much). Stimulus faces were presented on a black background using E-Prime software. Faces were presented in random order and participants were given unlimited time to make their ratings of trustworthiness.

Immediately after completing the trust rating task, participants provided a 1—2 mL saliva sample (T1) via passive drool into a polystyrene culture tube.

Next, participants performed the Point Subtraction Aggression Paradigm (PSAP). Here, participants were told that they were paired with another same-sex participant on a 'decision-making' task. Participants were told that pressing button ''1'' from a standard keyboard fifty consecutive times would earn them a point with each point earned exchangeable for money at the conclusion of the study. Participants were told that depending on their game partner's strategy, their point counter could flash several times and decrease by 1-point, indicating that the other person stole a point from them. In addition, participants were told that all points stolen from them would be added to their game partner's point total. Participants were then told that in addition to earning points by using button ''1,'' they could press button ''2'' fifty consecutive times to steal a point from their game partner. However, participants were told that they had been randomly assigned to a condition whereby the points that they stole would not be added to their own point total. Given that participants do not gain any financial reward by stealing points and that stealing points actually comes at the expense of gaining points, it can be inferred that participants are stealing points to 'punish' their partner. Consistent with this inference, we consider stealing points in this paradigm as a measure of reactive aggression (see Carré et al., 2010). Finally, participants could press a third button ''3'' fifty consecutive times to protect their points from being stolen by their game partner.

The PSAP task was composed of three 10 min blocks during which participants would be provoked (by having a points stolen) every 12—45 s in the absence of button ''2'' or button ''3'' responses. If participants stole points or protected points, the computer program did not provoke them for a minimum of 45 s and a maximum of 90 s after which the random point subtractions would continue to occur every 12—45 s.

Additional saliva samples were collected after each of the 10-min blocks, resulting in a total of 4 samples collected (T1 = pre-PSAP; T2 = post-block 1 PSAP; T3 = post-block 2 PSAP; T4 = post-PSAP).

After providing the final saliva sample (T4), participants performed the same trust-rating task. Specifically, they were asked to rate the same 24 emotionally neutral Caucasian male faces rated prior to the PSAP. Again, faces were presented in random order for 1000 ms, after which participants made trust ratings.

2.3. T concentrations

Saliva samples were stored at —20 C until assayed. All samples were assayed in duplicate using commercially-available enzyme immunoassay kits (DRG International). Intra- and inter-assay coefficients of variation were 10.02% and 13.2%, respectively.

2.4. Statistical analyses

For each participant, we calculated a change in trust metric by subtracting trust ratings prior to the PSAP from those after the PSAP for each of the 24 face stimuli. We assessed T reactivity by calculating a percent change score [(post-PSAP T − pre-PSAP T)/pre-PSAP T × 100]). Due to a technical problem, trust ratings from 6 participants were not recorded. Also, 3 participants provided insufficient saliva for assaying T. In addition, 2 participants responded with a trustworthiness of ''4'' for every stimulus face, suggesting that they were responding at random. These participants were excluded from the main analyses. Finally, 2 participants had T reactivity scores more than 3.5 standard deviations from the mean and were removed from the primary analyses. Thus, our primary analyses examining the association between T reactivity and trust ratings were based on 83 participants (42 men, 41 women).

3. Results

3.1. Baseline and reactive testosterone in men and women

As expected, men had significantly higher T concentrations (M = 80.40 pg/mL, SE = 4.94) compared to women (M = 37.66 pg/mL, SE = 3.72; t_{93} = 7.02, p < 0.001). In contrast, there were no sex-differences in pre- to post-PSAP changes in T (men: M = 13.5%, SE = 6.77; women: M = 20.1%, SE = 12.3; t_{89} = —0.46, p = 0.65). A one sample t-test indicated a significant increase in T from pre-PSAP to post-PSAP (M = 16.99%, SE = 7.22; t_{90} = 2.35, p = 0.021). When the same analysis was performed separately for men and women, the increase in T was significant for men (t_{42} = 1.99, p = 0.05), but not women (t_{47} = 1.63, p = 0.11). Fig. 1).

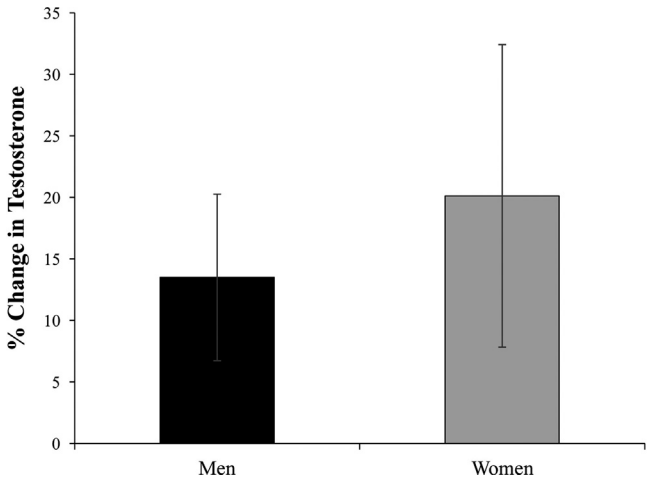

Figure 1 Testosterone reactivity (pre-PSAP to post-PSAP) to the Point Subtraction Aggression Paradigm for men and women.

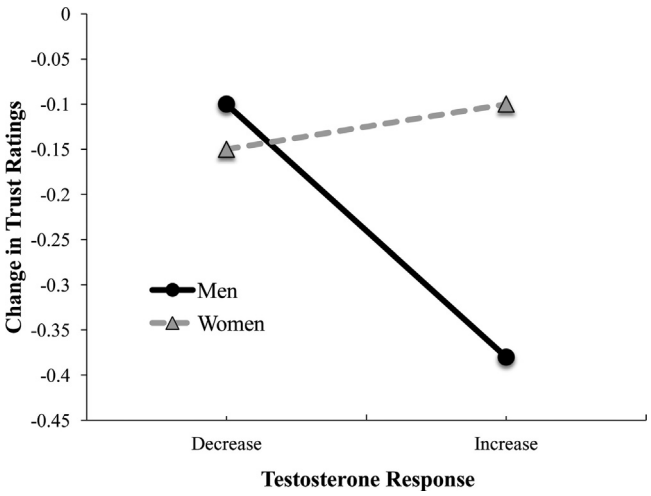

Figure 2 Participant sex moderates the relationship between testosterone reactivity and trust ratings. *Note*: For display purposes, testosterone decrease = 1 SD below the mean and testosterone increase = 1 SD above the mean.

3.2. Ratings of trust

Repeated measures ANOVA on trust ratings with sex as a between-subject factor and time (pre-PSAP trust ratings vs. post-PSAP trust ratings) as a within-subject factor revealed a significant effect of time ($F_{1,86} = 30.203$, $p < 0.001$) with mean trust ratings lower post-PSAP ($M = 3.61$, $SE = 0.07$) compared to pre-PSAP ($M = 3.79$, $SE = 0.06$), and no main effect of sex ($F_{1,86} = 0.046$, $p = 0.83$) or sex-by-time interaction ($F_{1,86} = 2.58$, $p = 0.11$).

3.3. Testosterone reactivity and changes in trust ratings

Regression analysis was performed to test our primary hypothesis that T responses to the PSAP would predict changes in trust ratings. For this analysis, changes in trust ratings were regressed onto participant sex and T reactivity (Step 1) and the participant sex-by-T reactivity interaction (Step 2). The predictor variables were mean centered prior to computing the interaction term. Results revealed no main effect of participant sex ($B = 0.12$, $SE = 0.07$, $p = 0.08$) or T reactivity ($B = -0.09$, $SE = 0.06$, $p = 0.15$). Critically, there was a significant participant sex-by-T reactivity interaction ($R^2_{change} = 5.3\%$, $B = 0.27$, $SE = 0.13$, $p = 0.035$). Simple slopes analyses indicated that a rise in T from pre- to post-PSAP was associated with a decrease in trust ratings in men ($B = -0.22$, $SE = 0.11$, $p = 0.04$), but not women ($B = 0.05$, $SE = 0.07$, $p = 0.49$; Fig. 2).

Because of their possible effect on T, we performed supplementary analyses to examine whether the use of oral contraceptives (OCs) would influence the pattern of findings in women. Specifically, we examined whether pre- or post-PSAP T concentrations (i.e., baseline T and T reactivity) would differ for women taking OCs ($n = 19$) versus those not taking OCs ($n = 32$). Women taking OCs had significantly lower baseline T concentrations ($M = 27.43$, $SE = 5.41$) compared to women not taking OCs ($M = 43.74$, $SE = 4.73$; $t_{49} = 2.20$, $p = 0.033$). However, there were no differences in T reactivity scores as a function of OC status ($p = 0.23$). A regression analysis was also performed to test whether OC use moderates the relationship between T reactivity and trust ratings in women. Here, change in trust ratings were regressed onto OC use and testosterone reactivity (Step 1) and the OC use-by-T reactivity interaction (Step 2). Results revealed no main effects or interaction (all $ps > 0.25$).

We also performed regression analyses examining the role of baseline T in modulating trust ratings. Here, pre-PSAP trust ratings were regressed onto participant sex and baseline T (Step 1) and participant sex-by-baseline T interaction (Step 2). T concentrations were standardized within sex prior to analyses. There were no main effects or interaction (all $ps > 0.28$). In addition, we investigated whether baseline T predicted *changes* in trust ratings from pre- to post-PSAP. Again, results revealed no main effects or interaction (all $ps > 0.11$).

3.4. Aggression, testosterone reactivity and trust ratings

Although our previous work indicated that the PSAP elicits aggressive behavior in the majority of participants, individuals in the current study engaged in very little aggression. Indeed, 35% of the sample did not exhibit a single aggressive response during the task compared to only 8% of participants in our previous study using the same PSAP parameters (Carré et al., 2010). Also, participants in the current study stole on average 2.80 points/block, whereas in our previous study, participants stole on average 7.36 points/block. Thus, it is perhaps not surprising that we found no significant relationship between T reactivity and aggression in men ($r = 0.06$, $p = 0.72$) or women ($r = 0.13$, $p = 0.39$). In addition, there was no relationship between aggressive behavior and changes in trust ratings for either men ($r = -0.01$, $p = 0.94$) or women ($r = 0.03$, $p = 0.83$).

4. Discussion

The current study reports the novel finding that acute changes in T in response to a competitive interaction

predict decreased ratings of trust in a sex-dependent manner. Specifically, a rise in T during competition predicted a decrease in ratings of trust from emotionally neutral faces in men, but not women. Notably, baseline levels of T did not predict ratings of trust for either men or women.

Previous studies conducted exclusively in women have reported that a single administration of T decreases ratings of trust from emotionally neutral faces (Bos et al., 2012) and decreases trust behavior during a financial investment task (Boksem et al., 2013). Although we also demonstrate decrements in interpersonal trust ratings among individuals showing a rise in endogenous T — our findings were in men only. For women, a rise in endogenous T during competition did not modulate subsequent trust ratings. Several unique features of our study may contribute to this sex-specific effect.

First, participants in our study only rated male faces, whereas the previous social perception study used a combination of male and female face stimuli (Bos et al., 2012). Thus, one intriguing area for future work will be to investigate whether acute fluctuations in T modulate trust ratings made of same-sex individuals. Second, we did not control for menstrual cycle variation. It is possible menstrual cycle variation may moderate the effect of T reactivity on trust ratings. Indeed, previous work indicates that menstrual cycle phase does influence interpersonal trust behavior (Ball et al., 2013) although it is unclear what role T plays in this instance.

Notably, we found no evidence for a relationship between baseline levels of T and ratings of trust in either men or women. In contrast, changes in T during the PSAP predicted subsequent trust ratings in men, but not women. The finding that aggressive behavior during the PSAP was unrelated to T reactivity or trust ratings in the current study suggests that it may be the competitive nature of the PSAP, and not aggressive behavior per se that was the stimulus for T reactivity and subsequent decrements in trust ratings. Our findings highlight the importance of considering T reactivity during social interactions as a key modulator of ongoing and/or future social behavior. Indeed, our findings are consistent with a growing body of evidence suggesting that acute changes in T, but not baseline levels of T, may play an important role in modulating ongoing and/or future dominance-related behaviors (e.g., Mehta & Josephs, 2006; Carré et al., 2009b; Carré et al., 2013; Carré et al., 2014 and Geniole et al., 2013).

We suggest that a rise in T during a competitive social interaction may decrease ratings of trust by increasing vigilance toward subtle cues of threat. Although we did not use faces depicting overt signals of threat (i.e., angry faces), previous work indicates that male neutral faces are perceived as relatively threatening and dominant (Becker et al., 2007; Hareli et al., 2009). Notably, the amygdala plays a key role in the neural processing of threat and the promotion of social vigilance (Davis and Whalen, 2001), and faces deemed untrustworthy elicit heightened amygdala reactivity (Winston et al., 2002). Moreover, a single administration of T increases amygdala reactivity to angry faces in men (Goetz et al., in press) and is associated with heightened amygdala reactivity to emotionally neutral faces rated as untrustworthy (Bos et al., 2012). The extent to which T's effects on interpersonal trust in young men are mediated via altered amygdala function will require further work.

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Conflict of interest

None declared.

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