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BRIEF REPORT

Anger and Testosterone: Evidence That Situationally-Induced Anger Relates to Situationally-Induced Testosterone

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Testosterone has been shown to relate to power, dominance, social status, and aggression. However, no research has related situationally induced changes in testosterone to subjective emotional experience. Based on the fact that anger relates to power, dominance, social status, and aggression, we predicted that testosterone would be uniquely related to the subjective experience of anger. In this study, salivary testosterone and cortisol were measured both prior to and following an anger-inducing event. In line with predictions, anger was associated with increased testosterone but not cortisol. These results provide the first evidence of a subjective emotional experience linked with changes in testosterone.

Keywords: anger, testosterone, approach motivation, ostracism

The link between aggression and testosterone has sparked the interest of many kinds of people, from a fan wondering whether anabolic steroids might be responsible for his favorite athlete's wild antics to the scientist hypothesizing about the biological processes involved in violence. And, as you might think, there is no shortage of evidence of such a relationship, both in the animal (Archer, 1988) and human (Archer, 2006; Brain, 1979; Dabbs, Frady, Carr, & Besch, 1987) literatures. However, research has also shown that, while they are related, the relationship is quite weak. In fact, testosterone is only responsible for a small portion of the variance in aggressive behavior, and some studies have shown no connection at all (Archer, Graham-Kevan, & Davies, 2005). Instead, researchers now believe that testosterone plays a role in a broader picture involving power and dominance (Archer, 2006; Eisenegger, Naef, Snozzi, Heinrichs, & Fehr, 2009; Mazur & Booth, 1998; Schultheiss, Campbell, & McClelland, 1999; van Honk et al., 1999) as opposed to aggression per se. That is, testosterone may facilitate behaviors aimed at obtaining and maintaining power and dominance. It is possible testosterone relates to aggression only because aggression can be one of many ways that people attempt to exert control over others (Tedeschi, 2001; Warburton, Williams, & Cairns, 2006).

While much research has focused on testosterone's relationships with various psychological variables, we were surprised to find no evidence linking testosterone to subjective emotional experience. One emotion that might relate to testosterone is anger, a negative affect with distinct approach-oriented tendencies that set it apart from other negative emotions. Indeed, rather than occurring in anticipation of something negative, such as the case of fear, anger often results from goal blockage or a disruption in action and tends to lead to the restoration of a desired state such as control over others (Carver & Harmon-Jones, 2009; Dollard, Miller, Doob, Mowrer, & Sears, 1939). With this in mind it comes as no surprise that anger also relates to variables such as power and status (Tiedens, 2001; Tiedens, Ellsworth, & Mesquita, 2000), dominance (Archer & Webb, 2006; Hareli, Shomrat, & Hess, 2009; Hess, Adams, & Kleck, 2005), and aggression (Anderson & Bushman, 2002; Berkowitz, 1993). Because these variables also relate to testosterone, we predicted that testosterone may also relate to the subjective experience of anger.

In the current study, we examined change in salivary testosterone and its relation to anger. Anger was evoked using Cyberball, a computer ball-toss game that can be used to evoke social rejection (Williams, Cheung, & Choi, 2000). This particular paradigm was chosen for inducing anger because of its known ability to evoke anger in an experimentally-controlled manner (Chow, Tiedens, & Govan, 2008; Harmon-Jones, Peterson, & Harris, 2009). The subjective anger that occurs in this paradigm has been found to be strongly related to approach motivation (Peterson, Gravens, & Harmon-Jones, in press). Because approach motivation relates to variables related to testosterone, such as power (Keltner, Gruenfeld, & Anderson, 2003; Galinsky, Gruenfeld, & Magee, 2003) and dominance (Putman, Hermans, & van Honk, 2004), we predicted that anger evoked in this paradigm would relate to testosterone. Furthermore, the ostracism evoked by Cyberball has been shown to threaten one's social control (or power/dominance; Williams, 2007), and a subsequent rise in anger and testosterone may be associated with an attempt to regain control. Cortisol, a hormone linked to stress and particularly fear (McCullough, Orsulak, Brandon, & Akers, 2007), was also measured but we

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expected it would not relate to anger because of dissimilarities between anger and fear (Carver & Harmon-Jones, 2009).

Method

Participants and Procedure

Forty-three (18 male) nonsmoking introductory psychology students 18–20 years old were run between 12:00 p.m. and 5:30 p.m. to reduce diurnal influence. The first saliva sample was taken after obtaining informed consent; participants then performed a neutral task for 5 min not relevant to the present research questions. Next, participants played Cyberball. All participants were told they were playing with two other students currently in the lab. They were instructed to practice their mental visualization skills during the game and to imagine that they were playing the game in real life. They were told that when they received the ball, they were to press the right button to throw to the player on their right, and the left button to throw to the player on their left. The game was programmed so that participants were included during the first part of the game (approximately 8 throws) and ostracized the remaining 16 throws. When the game was over (approximately 4 min later), participants completed questionnaires assessing their self-reported anger and other emotions (i.e., sadness, fear) on 9-point scales from 1 (*not at all*) to 9 (*very much so*). A second saliva sample was taken approximately 15 min after the game (Riad-Fahmy, Read, Walker, Walker, & Griffiths, 1987; Schultheiss et al., 2005).

Testosterone and Cortisol Measurement

Participants chewed sugarless gum and then passively drooled 2 mL of saliva into plastic scintillation vials. Saliva samples were stored in an −80° C research freezer until assayed, and enzyme immunoassays were conducted by Biomarkers Core Laboratory at the Yerkes National Primate Research Center (Atlanta, GA) using commercially prepared kits produced by Diagnostic Systems Laboratories (Beckman Coulter; Webster, TX). For testosterone, normal assay range was 2–500 pg/ml at a 200-μl sample 200-μl incubation buffer dilution. Interassay coefficients of variation (CVs) were as follows: kit control 1: 19.16% at 5.03 pg/ml; kit control 2: 15.08% at 170.81 pg/ml; ECL saliva control 16.40% at 25.31 pg/ml. The intraassay CV was 3.41% at 26.89 pg/ml (BCL saliva control). For cortisol, normal assay range was 0.10–10.00 μg/dl (extended assay range: .025–10.00 μg/dl). Interassay CVs were as follows: kit control 1: 2.91% at 0.26 μg/dl; kit control 2: 4.39% at 1.94 μg/dl. These methods of collecting and processing hormones have been used in much past research (Schultheiss & Stanton, 2009).

Raw testosterone and cortisol values were log transformed to normalize distributions. Change in testosterone and cortisol were calculated by subtracting baseline values from values after the manipulation. Because neither change in testosterone/cortisol nor post-Cyberball self-reports different significantly as a function of participant gender, we collapsed the data across gender for analyses.

Results and Discussion

As predicted, an increase in testosterone was associated with greater anger. This was revealed in a regression analysis in which time of the first saliva sample and change in testosterone from baseline to after ostracism were used to predict self-reported anger, $\beta = .31$, $r(40) = .31$, $t(40) = 2.03$, $p < .05$ (Figure 1).

As expected, none of the other emotions measured related to change in testosterone (rs $< .09$, ps $> .56$). That testosterone did not relate to other emotions is not surprising. Although fear and sadness are both negative in valence like anger, they are not approach motivated affects. Rather, fear and sadness often lead to avoidance behaviors, whereas anger tends to propel individuals

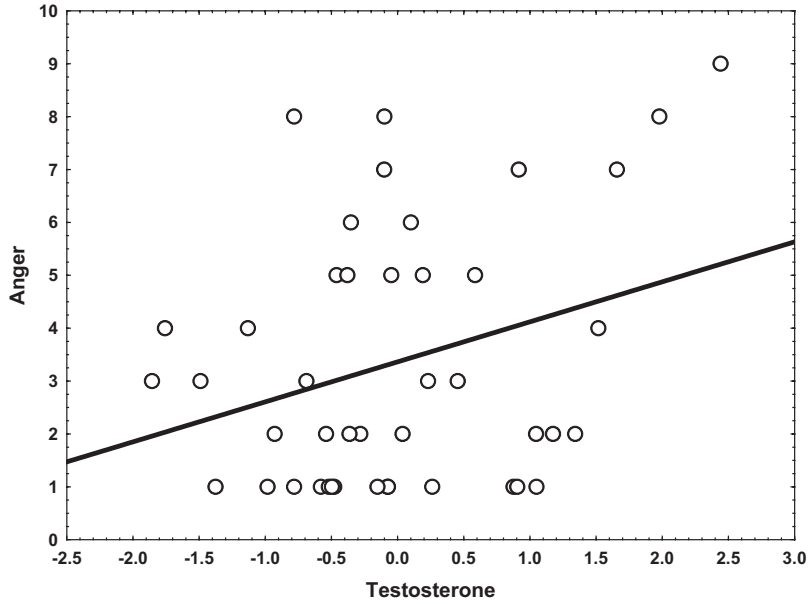

Figure 1. Relationship between self-reported anger and change in testosterone following ostracism.

toward the source of the anger, as in power, dominance, and control confrontations (Carver & Harmon-Jones, 2009).

Change in cortisol also did not relate to any emotions ($rs < .20$, $ps > .21$). This too is not surprising as emotions often associated with cortisol, such as fear, were not aroused by ostracism in the current study. In addition, past research has shown decreased cortisol levels associated with angry facial expressions (Lerner, Dahl, Hariri, & Taylor, 2007) or no relationship between cortisol and angry facial expressions (Lewis, Ramsay, & Sullivan, 2006). One previous study found increases in both cortisol and testosterone levels following an interpersonal insult. However, a threat of shock also preceded the measurement of the hormone levels, making it difficult to interpret the increases in these hormones as being due solely to the insult (Cohen, Nisbett, Bowdle, & Schwarz, 1996). Moreover, in this past study, the hormone changes were not associated with emotional experience. The aim of the current research was not to show the effect of the insult on hormones per se but rather to demonstrate how changes in levels might relate to emotional experience.

The present research provides the first evidence demonstrating that testosterone relates to the subjective experience of anger. These results concur with distinct theories that posit that anger and testosterone are associated with attempts to exert power, control, and dominance over others. In the case of ostracism, in which basic needs such as belonging and control are threatened (Williams, 2007), anger may fuel behaviors directed at regaining a sense of control over the social situation. Consistently, angry responses to ostracism have been shown to relate to approach-motivated patterns of relative left frontal cortical activity, which may also aid in attempts at regaining social control (Peterson, Gravens, & Harmon-Jones, in press). Although we believe that a motivation to regain control may assist in explaining the observed correlation between self-reported anger and testosterone, future research is necessary to elucidate the precise mechanisms underlying the link between anger and testosterone.

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