Psychoneuroendocrinology (2013) xxx, xxx—xxx

Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: www.elsevier.com/locate/psyneuen

Changes in testosterone mediate the effect of winning on subsequent aggressive behaviour

Justin M. Carré*, Jocelyn A. Campbell, Elianna Lozoya, Stefan M.M. Goetz, Keith M. Welker

Wayne State University, United States

Received 5 November 2012; received in revised form 27 February 2013; accepted 18 March 2013

KEYWORDS
Testosterone reactivity;
Social status;
Sex differences;
Aggressive behaviour

Summary Testosterone concentrations rise rapidly in the context of competitive interactions and remain elevated in winners relative to losers. Theoretical models suggest that this divergent neuroendocrine response serves to mediate future dominance behaviours. Although research in animal models provides compelling support for this model, evidence for its applicability to human social behaviour is limited. In the current study, men and women were randomly assigned to experience a series of victories or defeats, after which aggressive behaviour was assessed using a well-validated behavioural measure. Winning produced elevated testosterone concentrations relative to losing in men, but not women. More importantly, testosterone reactivity to competition mediated the effect of winning on subsequent aggressive behaviour in men, but not women. We discuss limitations of the current study (e.g., the status manipulation may have affected other variables not measured in the study including competitiveness and physical activity expended), as well as discuss a potential neural mechanism underlying the effect of testosterone reactivity on aggressive behaviour.

1. Introduction

Testosterone plays a critical role in modulating aggressive behaviour in numerous animal species, yet its relationship to human aggression remains controversial (Eisenegger et al., 2011). Most human studies examining the association between testosterone and aggression have correlated testosterone concentrations obtained at a single point in time with aggressive behaviour measured using self-report, laboratory-based tasks, or court records. Meta-analyses of this work have revealed a small, yet significant association between baseline testosterone concentrations and various measures of human aggressive behaviour (see Archer et al., 2005; Archer, 2006 for meta analyses). A limitation of this work is that testosterone concentrations are not static, but rather fluctuate rapidly in the context of competitive interactions (see Archer, 2006 for review). Indeed, rapid fluctuations in androgens during competition are found across animal species including birds (Wingfield et al., 1990), fish (Oliveira, 2009), insects (Scott, 2006), non-human primates (Cavigelli and Pereira, 2000) and humans (Archer, 2006). It has been suggested that context dependent changes in

* Corresponding author at: Department of Psychology, Wayne State University, 5057 Woodward Avenue, Detroit, Michigan 48202, United States. Tel.: +1 519 995 6205.
E-mail address: jcarre14@gmail.com (J.M. Carré).

0306-4530/$ — see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.psyneuen.2013.03.008

testosterone may be a biological mechanism for rapidly adjusting dominance behaviour in the face of social challenges (Wingfield et al., 1990). Thus, it may be that acute fluctuations in testosterone, rather than baseline levels of testosterone, are more relevant to our understanding of individual differences in human aggressive behaviour (Carré et al., 2011).

A growing body of evidence also indicates that changes in testosterone concentrations during competition depend critically on the outcome, with testosterone concentrations typically rising in winners relative to losers (Archer, 2006). In humans, this pattern of testosterone reactivity has been observed in competitive athletes (Elias, 1981), laboratory-based competition tasks (Gladue et al., 1989), voters of political elections (Stanton et al., 2009), stock traders (Coates and Hebert, 2008) and sport spectators (Bernhardt et al., 1998). What evolutionary function does this divergent testosterone response pattern serve? Mazur's (1985) biosocial model of status suggests that rising testosterone in winners serves to increase subsequent dominance behaviours aimed at defending and/or gaining further social status, whereas decreasing testosterone in losers serves to increase submissive behaviours aimed at avoiding further threats to status. Given the fitness benefits of elevated status and the costs of failed attempts to gain status, a highly flexible neuroendocrine system capable of integrating status related contextual cues (e.g., victory or defeat) with behavioural output (e.g., dominant or submissive behaviour) might be adaptive in an ever-changing social environment.

Evidence in animal models indicate that winning an aggressive interaction increases one's probability of winning subsequent interactions, while losing has the opposing effect (Dugaktin, 1997; Hsu and Wolf, 1999). Experimental work in animal models provides compelling support for the idea that testosterone reactivity mediates the effect of winning on subsequent competitive and aggressive behaviour. Specifically, an increase in testosterone after a victory is necessary to increase both future aggressive behaviour (Trainor et al., 2004; Gleason et al., 2009) and the animal's probability of winning a future competitive encounter against a novel opponent (Fuxjager et al., 2010; Gleason et al., 2009; Oliveira et al., 2009a). There is some evidence in studies of people demonstrating that testosterone reactivity to competition predicts subsequent willingness to compete again (Mehta and Josephs, 2006) and aggressive behaviour in men (Carré et al., 2009).

In the current experiment, we used a novel competition paradigm (Xbox Kinect video game) in which participants were able to fully immerse themselves in sport competition (see Supplementary Video S1 and S2). Unknown to participants, the game was rigged such that half of the participants were assigned to a win condition and half to a loss condition. Specifically, prior to participants' arrival to the laboratory, we programmed the Xbox video game such that participants played against a very difficulty or very easy computer opponent. After playing the video game, participants were taken to a separate room where they were paired with another same-sex opponent and played the point subtraction aggression paradigm (PSAP). Based on the animal literature (Fuxjager et al., 2010; Gleason et al., 2009; Oliveira et al., 2009b; Trainor et al., 2004) and predictions derived from the biosocial model of status (Mazur, 1985), we hypothesized that winners would demonstrate an increase in testosterone and would be more aggressive in a subsequent interaction relative to losers. Further, we predicted that testosterone responses to the video game would mediate the association between competition outcome (win vs. loss) and subsequent aggressive behaviour. That is, winning would produce a significant increase in testosterone, and this endocrine response would in turn be associated with increased aggressive behaviour. We also predicted that although mean levels of testosterone would decrease after a defeat, individual differences in testosterone reactivity among losers would be positively correlated with aggressive behaviour (e.g., Carré et al., 2009). In other words, individuals who did show a rise in testosterone after a defeat would be more aggressive than the majority of losers who decreased in testosterone. Finally, given the scarcity of research examining sex-dependent associations between testosterone and aggressive behaviour, we examined whether associations between testosterone reactivity, competition outcome, and aggressive behaviour would be found in men and women.

2. Methods

2.1. Participants

Undergraduate students ($N = 237$, 52% women, mean age = 21.73, $SD = 4.66$) were recruited from the Wayne State University (WSU) Research Participation Pool. Participants received partial research credit and a $10 honorarium for their participation. The WSU Institutional Review Board approved all procedures.

2.2. Procedure

Saliva samples were obtained from participants before and after they played an Xbox Kinect video game (between 11 am and 5 pm). Participants were randomly assigned to one of four experimental conditions that differed in the type of game played (boxing vs. volleyball) and the outcome of the game (win vs. loss). We included a competitive game with aggressive content (boxing) and one without aggressive content (volleyball) with the hypothesis that competitive games with aggressive content would elicit a more robust testosterone response and have a larger effect on subsequent aggressive behaviour. However, preliminary analyses indicated that type of video game (boxing vs. volleyball) did not influence testosterone reactivity or aggressive behaviour ($ps \geq 0.364$), nor did it interact with sex and/or game outcome to predict testosterone reactivity or aggression ($ps \geq 0.127$). Thus, all analyses were collapsed across type of video game. After the video game, participants completed a questionnaire assessing whether they found the game exciting, frustrating, difficult, enjoyable, and fast paced. Next, participants were paired with another same-sex participant (actually a computer program) and performed the point subtraction aggression paradigm (PSAP; Cherek et al., 2006; see Fig. 1 for experimental timeline). The PSAP is a well-validated behavioural measure of reactive aggression (see Cherek et al., 2006 for review) in which participants were told they were