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Exogenous testosterone in a non-social provocation paradigm potentiates anger but not behavioral aggression

Despina Panagiotidis[a,*], Benjamin Clemens[a], Ute Habel[a,b,d], Frank Schneider[a,b,d], Isabella Schneider[c], Lisa Wagels[a,b,d,1], Mikhail Votinov[a,b,d,1]

[a]*Department of Psychiatry, Psychotherapy and Psychosomatics, Medical Faculty, Uniklinik RWTH Aachen, Pauwelsstrasse 30, 52074 Aachen, Germany*
[b]*JARA-Institute Brain Structure-Function Relationship, Research Center Jülich and RWTH Aachen University, 52074 Aachen, Germany*
[c]*Department of General Psychiatry, Center of Psychosocial Medicine, University of Heidelberg, Germany*
[d]*Institute of Neuroscience and Medicine 10, Research Center Jülich, Jülich, Germany*

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Abstract
Animal studies suggest a causal link between testosterone and aggression. However, in human research the exact role of this hormone is still unclear, having been linked to dominance and approach behavior rather than to aggression per se. In a social context, the induction of aggression might be confounded with dominance or status changes, which potentially influence the association between aggression and testosterone. The objective of the current study was to investigate the influence of testosterone on non-social aggression in a double-blind, placebo-controlled experiment including 90 healthy male participants. To this end, we developed an innovative paradigm in which participants were provoked by a malfunctioning joystick restraining them from a promised reward. As measures for aggression throughout the task the joystick amplitude was recorded and anger was assessed via emotional self-ratings. Participants reacted to the provocation with a significant shift to more negative emotions and increased implicit aggressive behavior, reflected in the force exerted to pull the joystick following provocation. Importantly, the study demonstrated first evidence for a modulating influence of testosterone on non-social aggression in males: Self-rated anger was significantly elevated in the testosterone group compared to the placebo group as a function of provocation. Testosterone administration did not significantly influence the implicit aggressive response. These findings demonstrate a potentiating effect of testosterone on provocation-related anger

*Corresponding author. Fax: +0049 241 80 82401.
E-mail address: despina.panagiotidis@rwth-aachen.de (D. Panagiotidis).
[1]Equally contributed.

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in a non-social context. Furthermore, the results highlight the importance of disentangling different components of aggression and characterizing different influencing factors when inferring on hormonal effects.

1. Introduction

Aggressive behavior, especially in humans, can metaphorically be looked upon as a chameleon. It is displayed in varying shades and forms, often context-dependent and influenced by many situational and environmental factors. Previous studies identified and addressed several triggers and influencing factors of aggressive behavior. Provocation, for example, frequently leads to an aggressive reaction, even if a social interaction partner is not present in person, such as observed in the virtual context of validated experimental aggression paradigms (Carré and McCormick, 2008; Giancola and Parrott, 2008). From a neuroendocrine perspective, hormones such as testosterone have been discovered to impact aggressive behavior introducing promising research options (for review see Carré et al. (2011)). Particularly animal research supports a causal testosterone-aggression link (Breuer et al., 2001; Harrison et al., 2000; Wood et al., 2013).

In humans, various studies indicate a correlation between testosterone and aggression (Chichinadze et al., 2010; Derntl et al., 2009; Hermans et al., 2008; Mazur, 1995; Wirth and Schultheiss, 2007). However, testosterone studies often differ in their findings as well as in their methods (for reviews and meta-analysis see Archer et al. (2005), Batrinos (2012), Carré et al. (2011)). Some solely focus on questionnaires as self-report measures for aggression (Mazur, 1995) or only include participants with offender status into the study sample (Chichinadze et al., 2010), whereas others expose healthy men to laboratory paradigms (Pope et al., 2000). These differences might account for inconsistent findings with respect to the relationship between testosterone and aggression.

From a theoretic perspective, a widely accepted model for reactive aggression assumes that aversive stimulation is strongly connected to aggressive inclinations (Berkowitz, 1989). Aversive stimulation results in frustration and thus has been suggested to trigger reactive aggression in humans (Dollard et al., 1939). This theoretical aggression model, the frustration-aggression hypothesis (FAH), describes a person working towards an aspired goal or reward, who is externally restrained from reaching this specified aim. This restriction consequently evokes an aggressive response (Berkowitz, 1989).

Several laboratory paradigms use a provocation or frustration approach in a competitive context. These paradigms implement a task with a specified rewarding aim and simultaneously include factors, such as an unfair factitious opponent, which hinder participants from actually attaining this goal, i.e. the competitive reaction time task (CRTT) or Taylor Aggression Paradigm (TAP) (Krämer et al., 2007; Schneider et al., 2015; Taylor, 1967). An important commonality is that such tasks use a social context directly involving another human being or its (virtual) representation to investigate aggression in humans (for review see Ritter and Eslea (2005)).

Particularly investigations on neuroendocrine influences on aggressive behavior have focused on social aspects of aggression (for reviews see Archer (2006), Carré et al. (2011)). However, social provocation procedures may be confounded with an altered perception of status (Geniole et al., 2015). Some forms of provocation might even encourage social cooperation (Kopsida et al., 2016; Reimers and Diekhof, 2015).

In the present study, we aimed to clarify whether the described reactive aggression model also applies to situations, which do not involve social interactions, neither as a trigger nor as a target for an aggressive response. Methodologically, we designed a novel paradigm, which we termed "Technical Provocation Paradigm" (TPP). For this experimental task, participants are instructed to navigate a moving ball into a stationary barrel by pulling a joystick to receive a monetary reward. To trigger aggression, the program includes manipulations during which joystick movement does not lead to any effect on the ball. Thereby, participants are restrained from hitting the barrel and thus collecting money (anticipated goal), which supposedly elicits frustration and aggressive responses (Berkowitz, 1989; Dollard et al., 1939). With this paradigm, we aimed to investigate two forms of aggressive reactions: 1) Explicit emotional reactions assessed through self-report measurements (short rating questions) throughout the task, and 2) implicit (expressive) motor reactions continuously measured for each trial. The latter were operationalized by the joystick deflection amplitude representing the force applied when pulling the joystick. According to the FAH (Berkowitz, 1989), we predicted higher anger levels, and larger joystick amplitudes reflecting an increased impulsive-aggressive response, as a reaction to the provocation.

To examine the influence of testosterone administration on non-social aggression we used the TPP to provoke aggression in a placebo-controlled double-blind study design. The participants were randomly assigned to either a testosterone group ($n=44$) or a placebo group ($n=46$). Thereby, we aimed to find out whether testosterone exerts a modulating influence on aggression in healthy adult men. So far, the majority of evidence on the testosterone-aggression link in humans has been collected alongside a social framework. However, under the assumption of a general potentiating effect of testosterone on aggression we expected a similarly effective

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