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Testosterone facilitates the sense of agency

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ABSTRACT

Sense of agency (SoA) refers to feelings of being in control of one's actions. Evidence suggests that SoA might contribute towards higher-order feelings of personal control – a key attribute of powerful individuals. Whether testosterone, a steroid hormone linked to power in dominance hierarchies, also influences the SoA is not yet established. In a repeated-measures design, 26 females participated in a double-blind, placebo-controlled trial to test the effects of 0.5 mg testosterone on SoA, using an implicit measure based upon perceived shifts in time between a voluntary action and its outcome. Illusions of control, as operationalized by optimism in affective forecasting, were also assessed. Testosterone increased action binding but there was no significant effect on tone binding. Affective forecasting was found to be significantly more positive on testosterone. SoA and optimistic expectations are basic manifestations of power which may contribute to feelings of infallibility often associated with dominance and testosterone.

1. Introduction

Sense of agency (SoA) refers to the feeling that arises when effected changes are attributed to one's own actions and not to other factors or persons (Haggard & Tsakiris, 2009). In healthy adults, voluntary actions are accompanied by strong feelings of being able to control how these actions influence the environment. The brain mechanisms underpinning the SoA are multifaceted, involving both low-level sensory-motor and top-down inferential processes and are recruited differently depending on the context and availability of information in causal chains of events (Blakemore, Wolpert, & Frith, 1998; Farrer & Frith, 2002; Haggard & Clark, 2003; Moore & Haggard, 2008; Sato & Yasuda, 2005; Wegner, 2002). Though the feeling of agency is mostly taken for granted in one's everyday activities, aberrations in agency are seen in many self-limiting psychiatric disorders (Gentsch, Schütz-Bosbach, Endrass, & Kathmann, 2012; Haggard & Clark, 2003; Obhi, Swiderski, & Farquhar, 2013; Voss et al., 2010).

The feeling of personal control over events in the environment is thought to be foundational for sustaining motivated behavior and the basic sense of free will (Gentsch, Weiss, Spengler, Synofzik, & Schütz-Bosbach, 2015; Moore, 2016). It is therefore closely linked to the experience of power (Fast, Gruenfeld, Sivanathan, & Galinsky, 2009; Inesi, Botti, Dubois, Rucker, & Galinsky, 2011). Many authors agree that the influence that power has on behavior and perception (selective attention, processing flexibility and optimism, for example (Anderson & Galinsky, 2006; Guinote, 2007, 2010) can be explained in large part by the effects power has on an individual's sense of control (Galinsky, Gruenfeld, & Magee, 2003; Guinote, 2010; Keltner, Gruenfeld, & Anderson, 2003). In fact, Obhi, Swiderski, and Brubacher (2012) have shown that although power priming did not increase agency, individuals made to feel powerless experienced less agency over their actions. Such findings align closely with theories of embodied cognition, which assert that many complex mental states are grounded in more basic sensory-motor processes (Barsalou, 2008; Lackoff, 2012; Wilson, 2002).

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In other words, psychological meaning may derive from re-enactment of motor and perceptual states of the body. Perhaps, then, feeling powerful derives some of its phenomenology from sensory-motor mechanisms of control. Indeed, recent evidence indicates that social power affords individuals better access to their internal physiological signals (Moeini-Jazani, Knoeferle, de Moliére, Gatti, & Warlop, 2017), a form of bodily perception referred to as interoceptive awareness (Craig, 2002) and which is associated with elevated experiences of agency (Ainley, 2015). In this regard, the steroid hormone, testosterone, may be a potential modulator of the SoA because of its established role in the psychology of power (Ronay & Von Hippel, 2010; van der Westhuizen & Solms, 2015a).

1.1. Testosterone and control

Throughout mammalian species of both sexes, testosterone has been linked to control over the social environment, pro-active or "approach" social motivation and power in group hierarchies (see Eisenegger, Haushofer, & Fehr, 2011; van der Westhuizen & Solms, 2015b). In affective neuroscience, the term "social approach" refers to the active pursuit of something desirable, particularly in threatening social contexts where the tendency to avoid is resisted (Terburg & van Honk, 2013). Testosterone tends to surge in social situations when one's status is threatened and its role in social approach motivation is evidenced by its link to social threat monitoring (Goetz et al., 2014; Hermans, Ramsey, & van Honk, 2008; van Honk et al., 1999, 2001), preference for high status (Josephs, Sellers, Newman, & Mehta, 2006; van der Westhuizen & Solms, 2015b) and confidence (Baucom, Besch, & Callahan, 1985), outgoingness (Dabbs & Ruback, 1988), assertiveness (Cashdan, 1995) or aggression (Cashdan, 2003). From an embodied cognition perspective, this kind of social agency may depend in part on the same brain mechanisms that support sensory-motor agency. In corroboration, Pfister, Obhi, Rieger, and Wenke (2014) have shown that the SoA can emerge from actions that have social consequences. Thus, in social contexts, increased sense of agency over the behavior of another agent may give rise to feelings of authority and power. Given that testosterone is known to promote affective states related to social empowerment, this suggests that fluctuations in testosterone may in turn modulate sensory-motor agency.

Several lines of evidence point to a potential role of testosterone in SoA. Firstly, in both male and female adults, grey matter volume in the insula, a brain structure which has been identified as a major substrate of the SoA (Farrer & Frith, 2002; Karnath & Baier, 2010), positively correlates with testosterone levels (Bos, Hermans, Montoya, Ramsey, & van Honk, 2010; Lentini, Kasahara, Arver, & Savic, 2012). Secondly, the neurotransmitter dopamine not only maintains a great proportion of motivated behavior but has been linked to social dominance in several behavioral paradigms (Morgan et al., 2002; Winberg & Nilsson, 1992) and of significance, has also been shown to facilitate implicit feelings of volitional sensory-motor control (Moore, Ruge, Wenke, Rothwell, & Haggard, 2010; Moore et al., 2010). Testosterone is typically expressed in contexts where there is an opportunity to improve social status (Archer, 2006) and several studies have shown that it regulates the expression of dopamine in the brain (de Souza Silva, Mattern, Topic, Buddenberg, & Huston, 2009; Schroeder & Packard, 2000). Therefore, in such contexts, testosterone-mediated increases in dopamine may serve an adaptive role in social competition by facilitating feelings of personal control to encourage approach-related behavior.

Finally, there is in fact some evidence, albeit indirect, to suggest that testosterone may encourage approach-related behavior by acting on signals that prospectively contribute toward agency at the time of action selection, i.e., before the actual effects emerge, which is a potentially *illusory* manifestation of agency (Chambon & Haggard, 2012). Prospective mechanisms may be related in some instances to incentive processing, based on findings that reward priming increases the sense of agency (Aarts et al., 2012). Of relevance here, is that testosterone is known to facilitate incentive processing (Hermans et al., 2010), decrease fearfulness (Hermans, Putman, Baas, Koppeschaar, & van Honk, 2006; van Honk, Peper, & Schutter, 2005) and increase the excitability of motor neurons (Bonifazi, Ginanneschi, della Volpe, & Rossi, 2004). From an embodied cognition perspective, the basic experience of agentive control may not only contribute to the feelings of infallibility often associated with testosterone, but they may also constitute an important self-fulfilling mechanism by which power and dominance is initially achieved.

1.2. Overview of aims

Here we used the perceived attraction in time between a voluntary action and its outcome as an implicit marker of SoA (Haggard, Clark, & Kalogeras, 2002). When one intentionally causes an event through one's own actions, the action and its consequence are experienced as being closer together in time. On the other hand, when we unintentionally cause an event (for example, if someone else causes us to move) we experience this unintentional movement and its consequence as further apart in time. This effect is known as 'intentional binding'. It is a widely used measure of SoA (see also Moore & Fletcher, 2012, for a review).

In a placebo-controlled double-blind, repeated-measures study using 26 young women, we investigated if 0.5 mgs of testosterone modulated intentional binding. We hypothesized that testosterone would increase intentional binding, in line with the idea that feelings of social control are founded upon more rudimentary experiences of sensory-motor control. While in real-world settings, testosterone tends only to surge in social contexts where status is at stake, in this experiment we artificially elevated testosterone levels to mimic the expression of testosterone in social settings. Thus, although our experiment was not social in nature, the administration of testosterone in one condition functioned to simulate a physiological reaction that would normally occur in a socially competitive situation (Bateup, Booth, Shirtcliff, & Granger, 2002; Carré & Olmstead, 2015).

In a subset of the participant sample, we also investigated whether testosterone affected affective forecasting (Baron, 1992; Loewenstein & Schkade, 1999; Wilson & Gilbert, 2003), given that more optimistic perceptions of one's emotional state in the future has been linked to illusions of control (Taylor & Brown, 1988). Since the future is largely beyond one's control, and predictions are based on reconstructed memories (Schacter, 2012), optimistic perceptions about the future can be measured by comparing current