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Does risk-taking mediate the relationship between testosterone and decision-making on the Iowa Gambling Task?

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ABSTRACT

We hypothesized that men with high testosterone (T) would perform more poorly than men with low T on the Iowa Gambling Task (IGT), a task widely used in the laboratory and clinic to assess decision-making, and that an effect of T on risk-taking propensity would mediate the effect. Sixty-one healthy adult males completed the IGT. Current T was measured in saliva and T levels during early development were estimated using the 2D:4D digit ratio. Men with high T levels chose fewer cards from the advantageous decks on the IGT. Financial risk-taking, measured by the Jackson Personality Inventory, was negatively correlated with the number of good card selections. Mediation analysis showed that risk-taking was a significant mediator of the association between IGT and 2D:4D ratio (but not current T levels). An organizational effect of androgens during early development may affect adult IGT performance indirectly through an influence on willingness to take risks.

1. Introduction

A recent trend in the study of risk-taking is to examine the role of testosterone in self-reported willingness to take risks, overt risky behaviors, and risky financial decision-making. For example, in university students, testosterone levels have been found to correlate positively with risk-taking during a laboratory investment game with real monetary payoffs (Apicella et al., 2008) and both low and high levels of testosterone were associated with less risk aversion on a task involving certain outcomes and risky gambles (Stanton et al., 2011b). Apicella et al. (2008) have proposed an evolutionary explanation for the link between testosterone and risk propensity suggesting that increased risk-taking by males (specifically in the financial domain) leads to the gain of resources and in turn, to increased mating opportunities.

In addition to circulating hormones, the effect of prenatal exposure has begun to be examined, utilizing the 2D:4D ratio (the ratio of the second to fourth digit lengths) as a proxy measure of testosterone. A smaller 2D:4D ratio is said to reflect higher androgen levels during prenatal development, due to androgen's actions on digit growth (Manning, Scutt, Wilson, & Lewis-Jones, 1998). Though it is a crude indicator (Hampson & Sankar, 2012), recent evidence in mice does suggest that higher prenatal androgen levels cause elongation of the fourth digit relative to the second digit resulting in a smaller 2D:4D ratio (Zheng & Cohn, 2011) and in humans large alterations in testosterone availability during the prenatal period do affect the ratio (Brown, Hines, Fane, & Breedlove, 2002). With respect to financial decision-making, past studies found no association between 2D:4D ratio and risky financial decision-making (Apicella et al., 2008; Sapienza, Zingales, & Maestripieri, 2009), but recent work by Stenstrom, Saad, Nepomuceno, and Mendenhall (2011) found that self-reported financial risk-taking was negatively correlated with digit ratios in males, and two studies found that smaller ratios were correlated with riskier financial choices during laboratory decision-making tasks (Brañas-Garza & Rustichini, 2011; Garbarino, Slonim, & Sydnor, 2011). In general, whether testosterone does reliably influence financial decision-making, and the functional mechanisms responsible, are poorly understood.

The Iowa Gambling Task (IGT, Bechara, Damasio, Damasio, & Anderson (1994)) is widely used in both laboratory and clinical settings and predicts real-world financial decision-making (Shivapour, Nguyen, Cole, & Denburg, 2012), but to date, few studies have examined whether testosterone levels influence IGT performance. The IGT is a complex task that involves learning payoffs associated with different decks of cards over time. Two decks are advantageous because over time they lead to a net gain (despite yielding smaller immediate rewards), whereas two other decks are disadvantageous because they lead to a net loss (even

Abbreviations: CWT, California Weather Task; IGT, Iowa Gambling Task; JPI-R, Jackson Personality Inventory Revised; PFC, prefrontal cortex; T, testosterone; 2D:4D, ratio of the second to fourth digit lengths.

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though both yield larger immediate rewards). In young men, serum testosterone was inversely correlated with the number of good cards selected on the IGT in a seminal study by Reavis and Overman (2001; see also Stanton, Liening, & Schultheiss, 2011a). In contrast, Goudriaan et al. (2010) failed to find any association between testosterone levels and IGT performance. Thus, although there is preliminary evidence to suggest that testosterone might play a role in IGT performance, present findings do not uniformly suggest an association is present. No study has examined performance on the IGT vis-a-vis the 2D:4D digit ratio.

It has been speculated that any link between current testosterone and IGT performance could reflect a link between risk-taking and testosterone (Stanton et al., 2011a) as risk-taking does play a role in the IGT (Upton, Bishara, Ahn, & Stout, 2011). However, the IGT is not a pure measure of risk-taking and in addition to risk-taking, involves inhibitory control and learning from valenced, probabilistic feedback. Thus, testosterone need not be associated with IGT performance via risk propensity, given that other processes are involved. To date, no study has examined whether risk-taking mediates the relationship between current testosterone levels and IGT performance. Such an association would broaden the empirical evidence that testosterone levels are relevant to risky financial decision-making and would supplement our current understanding of the clinical use of the IGT.

The primary objective of the current study was to investigate whether current levels of testosterone and/or prenatal levels (as reflected in the 2D:4D digit ratio) predict decision-making in males, as measured by the IGT, and to determine if the observed relationships are mediated by risk-taking propensity. Physiologically, adult testosterone influences neural activity in brain regions where its receptors are expressed. However, testosterone can also exert lasting effects on brain organization during defined periods in prenatal development, when the testes become temporarily active (Breedlove & Hampson, 2002). Currently, it is unknown which time frame is the source of any effect of testosterone on the IGT or whether the influence of developmental versus current testosterone involves different functional mechanisms. Based on findings of past research (Reavis & Overman, 2001; Stanton et al., 2011a), it was hypothesized that men with lower levels of circulating testosterone would perform better on the IGT than men with higher levels.

2. Method

2.1. Participants and procedure

Sixty-seven male undergraduates ages 18–22 years (M = 18.85, SD = 0.98) with no history of central nervous system pathology were recruited. Two participants were excluded who either exhibited prior knowledge of the task or showed an aberrant pattern of responses (seen in only 0.6% of males who have completed the IGT in our lab, N = 179). Four participants met criteria for problem gambling on the South Oaks Gambling Screen and were excluded because problem gamblers are an identifiably distinct group known to show altered IGT performance (Kertzman, Lidogoster, Aizer, Kotler, & Dannon, 2011). The ethnic composition of the sample was White (84%), Asian (15%), Black (<2%). Some studies report ethnic differences in the 2D:4D ratio (Manning, Churchill, & Peters, 2007), but the whole dataset was used in the present analyses because our results, with one exception, were unchanged if limited to the White group only. To control for circadian and seasonal variation in testosterone production (Dabbs, 1990a,b), all testing took place between 1200–1800 h and during February, March, or April.

2.2. Materials

2.2.1. Iowa Gambling Task (IGT)

The version of the IGT used here was from the Psychology Experiment Building Language Battery (Mueller, 2009), which is identical to the original task by Bechara et al. (1994) except that the top card moves to the bottom of the deck on each draw. Four decks that differ in the magnitude of penalties and rewards and in loss frequency (see Table 1) are presented on a computer screen. Participants are not aware of the endpoint (100 trials) or the payoff structure of the task. To start, each participant is given a $2000 virtual loan and is instructed to try to win as much money as possible by choosing cards from the different decks. To ensure the physical ordering of the decks did not influence performance, the decks were presented on the screen in one of four arrangements, counterbalanced across participants. As in previous reports (e.g., Bechara, Tranel, & Damasio, 2000), the 100 trials of the IGT were broken down into 5 blocks (20 trials/block) for scoring and analysis. Only Block 1 and 5 of the IGT were examined statistically because most participants do not develop a full understanding of the deck differences until approximately the 80th trial (Bechara, Damasio, Tranel, & Damasio, 1997) and consequently the final trials best represent individual differences in decision-making under risk (Brand, Recknor, Grabenhorst, & Bechara, 2007). The primary dependent variable, following Bechara et al. (1994), was number of cards selected from the 'good' decks (i.e., Deck 3+4) that yield a positive net payoff.

2.2.2. California Weather Task (CWT)

The CWT was chosen as a control task. It shares some elements with the IGT (e.g., the probabilistic element; implicit learning), but does not have a monetary reward/punishment component. A correlation with testosterone was not predicted. The CWT is a probabilistic classification learning task in which participants are asked to decide if a set of cards shown on the computer screen predicts "sun" or "rain" (see Fig. 1 and Knowlton, Squire, and Gluck (1994) for details). The version of the CWT created for the current study differed from Knowlton's original in that it involved fewer trials (70 versus 200) and by default used slightly higher cue probabilities (77% and 63% here versus 76% and 58% in the original). The dependent variable was the percentage of correct predictions.

2.2.3. Jackson Personality Inventory-Revised (JPI-R)

The Risk-Taking Scale from the Jackson Personality Inventory-Revised (JPI-R; Jackson (1994)) was used to assess individual differences in risk-taking propensity. Participants selected *True* or *False* for each of 20 statements (e.g., "The thought of investing in stocks excites me."). Only the 11 items measuring propensity for financial risk were included when computing the score as financial risk-taking may be a form of male-male competition activated by testosterone that leads to resource maximization (Apicella et al., 2008).

2.2.4. Digit ratios

Digital images of both hands were obtained with fingers spread apart and palms facing down. Landmarks used to measure the lengths of the second and fourth digits were the most basal crease where the finger meets the palm and the most distal point at the finger tip. The distance between the landmarks was measured using digital callipers with a resolution of 0.005 mm (Digital Measurement Metrology, Inc., Model ABS). Digit lengths were independently measured by a second rater (inter-rater reliability: ICr = .92 for the left ratio and ICr = .98 for the right). For two participants, digit ratios could not be computed due to indistinct creases. In the analyses below, the left and right digit ratios from the primary rater were averaged to control Type I error as the hands were well