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Testosterone is positively associated with risk taking in the Iowa Gambling Task

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ABSTRACT

The association between testosterone and economic risk is not well-understood and is understudied. The present study aimed to further characterize what if any relationship testosterone has with risky economic decisions. To do so, 154 participants (78 men) completed the Iowa Gambling Task (IGT) (Bechara et al., 1994) and also provided saliva samples, which were assayed for endogenous testosterone levels using radioimmunoassay. High-levels of endogenous testosterone were associated with choosing less frequently from advantageous IGT decks of cards, indicating greater risk taking. The data showed that the effects of testosterone on IGT performance were similar for men and women. High-testosterone women and high-testosterone men made riskier choices than their low-testosterone counterparts of the same sex, and this effect was pronounced in women. Thus, high levels of testosterone are associated with willingness to incur greater risk in both sexes.

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Introduction

There is a growing interest in the biological correlates of risk taking, and in particular, testosterone has had both a folk and empirical history of being associated with risk taking (Price, 2005). Generally, testosterone has been positively associated with risk taking in a number of domains and across species. In humans, for example, taking anabolic steroids has been associated with a number of high risk health behaviors including drug use, aggressive violence, and high risk sexual behavior (Middleman and DuRant, 1996). Social dominance and aggression, which can jeopardize interpersonal relationships and physical well-being, are also generally associated with testosterone in men (Mazur and Booth, 1998; Stanton and Schultheiss, 2009). Some have also argued that testosterone partially mediates increased risk taking associated with adolescent development (Steinberg, 2008). Notably, while there is a large body of research on testosterone and risk taking, the focus of the bulk of past research has been on risk taking in social domains. Few studies have closely examined the influence of testosterone in other behavioral domains involving risk.

In humans, economic risk is another domain of risk most individuals frequently confront that has large social and personal impact. There are a few existing studies that have examined the relationship between economic risk and testosterone, yet their findings have not been coherent. For example, Sapienza et al. (2009) reported that aversion to risk was negatively associated with testosterone levels in women, but not in men. Conversely, Apicella et al. (2008) recently found that testosterone was positively associated with willingness to assume risk in a financial investment task in men. Via a different experimental approach, testosterone administration did not yield reduced risk aversion in women according to Zethraeus et al. (2009). These studies present a muddled picture of the relationship between testosterone and risk taking, likely because they have used different risk tasks, subject populations (e.g., men or women only), and methods to study the effect of hormones on risk taking (e.g., hormone administration vs. assessment of endogenous levels). However, one of the few tasks that has been used in more than one study to examine relationships between testosterone and risk is the Iowa Gambling Task (IGT) (Bechara et al., 1994, 2005).

The IGT is oft-employed to examine individuals' propensity for risk taking in the face of monetary rewards and punishments (Bechara and Damasio, 2005). Risk often involves exposure to both reward and punishment, such as monetary gains and losses in the case of economic risk. In the IGT, participants choose from 4 decks of cards, each of which has a more or less advantageous schedule of monetary

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rewards and monetary punishments. Relationships between testosterone and IGT performance have been studied, but with significantly different experimental paradigms. Perhaps as a function of these differences, these studies have also produced incongruent results. One method used to study the relationship between testosterone and IGT performance has been the pharmacological elevation of testosterone levels. van Honk et al. (2004) used testosterone administration to boost women's testosterone levels to supraphysiological levels and found that under testosterone administration women chose significantly more often from the disadvantageous, riskier decks in the IGT. In contrast, a recent study by Goudriaan et al. (2010) found that pharmacologically-elevated testosterone levels in men failed to produce significant differences in IGT performance. An alternative to pharmacological manipulation is to examine the relationship between endogenous testosterone levels and IGT performance. Using an early version of the IGT, one previous study employed this strategy and found that testosterone was negatively associated with choosing from optimal decks in young men but not in older men or women (Reavis and Overman, 2001). Yet, after a decade, these results have not been replicated and the independent studies have little overlap with each other. Moreover, little other research in the domain of economic risk taking that used tasks other than the IGT has consistently demonstrated a specific relationship between testosterone and risk taking.

In an effort to further elucidate relationships between testosterone and risk taking, we recruited both men and women with the goal of characterizing relationships between endogenous testosterone and IGT performance. We hypothesized that high-testosterone individuals would pick less often from advantageous decks in the IGT. We also tested the hypothesis that the genders would not significantly differ in their associations between testosterone and IGT performance.

Methods

Participants

154 students enrolled at the University of Michigan, Ann Arbor, participated in the study in exchange for monetary compensation or course credit. 78 were male and 76 were female, with a mean age of 19.81 years (±0.13), and 94.2% self-identified as Caucasian and 5.8% as African-American. Participants were recruited via flyers posted in campus buildings and contacted experimenters through an email address provided on the flyer. The study received approval from the Institutional Review Board at the University of Michigan prior to data collection, and all participants provided informed consent at the time of participation.

Procedure

After arriving at the lab and providing consent, participants were seated in front of a computer. An experimenter was on hand to direct the participant to the computer, start the program, and answer any questions the participant may have had, but the entire study was administered via computer programs and on-screen directions. Participants completed a number of personality questionnaires, a demographic questionnaire, a health questionnaire, and one of two cognitive tasks (either a measure of referential competency or a differential implicit learning task), provided a saliva sample for hormone assessment, and completed the Iowa Gambling Task (Bechara et al., 1994, 2000). The two cognitive tasks were paired with different questionnaires; no results from the questionnaires or cognitive tasks are reported here, but will be reported elsewhere (Schultheiss et al., in press).

Iowa Gambling Task (IGT)

The IGT is used to measure decision-making sensitivity to punishment and reward, and was administered via the computer (Bechara et al., 2000). Participants begin the task with a "loan" of $2000 and are instructed to "make" as much money as possible over a series of 100 trials. On each trial, the participant chooses from one of four decks of cards. Each selection yields two outcomes: an initial reward of monetary gain followed by a punishment of a reduction in money. Participants make decisions under uncertainty, since no information regarding the probability of outcomes is provided, but can be learned over the course of the 100 trials. Two decks are disadvantageous, initially offering higher rewards, but ultimately resulting in much more substantial losses via larger punishing losses. The two other decks are advantageous, initially offering more modest rewards, but ultimately resulting in more modest punishments. Sensitivity to punishment and reward is measured by examining the degree to which participants learn to choose the advantageous decks at a higher rate than the disadvantageous decks as the task progresses.

Salivary testosterone

Participants used a stick of sugar-free chewing gum to facilitate collecting up to 7.5 mL of saliva in a sterile polypropylene vial and discarded the gum (Schultheiss and Stanton, 2009). Vials were sealed immediately and placed in frozen storage after the study session. Samples were freed from mucopolysaccarides and other residuals by three freeze thaw cycles followed by centrifugation.

Salivary testosterone levels were assessed with solid-phase Coat-A-Count ^{125}I radioimmunoassay for testosterone (Diagnostic Products Corporation, catalogue number: TKTT). To determine salivary testosterone concentrations, we prepared water-based dilutions of all standards (with a resulting range of 5 to 400 pg/mL) and controls. 400 μL of the saliva samples, standards, and controls were pipetted into antibody-coated tubes and allowed to incubate overnight. Next, 1 ml radio-labeled testosterone tracer was added to each tube and was allowed to incubate overnight. Finally, the tubes were aspirated and counted for 3 min (Schultheiss and Stanton, 2009). Assay reliability was evaluated by including control samples with known hormone concentrations in each assay (Bio-Rad Lyphochecks from Bio-Rad Laboratories, Hercules, CA). For samples of known concentration (25 pg/mL, 90 pg/mL and 152 pg/mL) analytical recovery was 100.28%, 113.53%, and 106.20% respectively and inter-assay CV was 25.29%, 5.34%, and 3.89% respectively. Participants' saliva samples were counted in duplicate and had a mean intra-assay CV of 13.19%. Analytical sensitivity (B_0 −3 SD) was at 6 pg/mL. Two testosterone assays were run in total.

Design

SYSTAT 12.0 statistical software was used for all analyses, with a statistical threshold of $p<0.05$. Descriptive statistics are shown as mean (±SEM), unless otherwise noted. For the IGT, the 100 trials are broken down into 5 blocks of 20 trials, and within each block, the percentage of choices from the advantageous decks is the dependent variable of interest (van Honk et al., 2004).

Results

We found an effect of assay in which testosterone levels were higher in assay 2 than in assay 1 for men ($t(76)=-3.19$, $p<0.01$), and for women ($t(74)=-1.92$, $p=0.06$): Men: assay 1 (M = 98 pg/mL, SD = 44), assay 2 (M = 129 pg/mL, SD = 41); Women: assay 1 (M = 32 pg/mL, SD = 17), assay 2 (M = 39 pg/mL, SD = 15) (see Fig. 1). The distribution of testosterone for women in assay 1 was skewed and was log-transformed within this group as a result. Due to the assay concentration differences and log-transformation on a subset of the data, we created a median-split testosterone variable within each gender and each assay, which we subsequently used as the independent variable for the behavioral analyses (see also Mehta

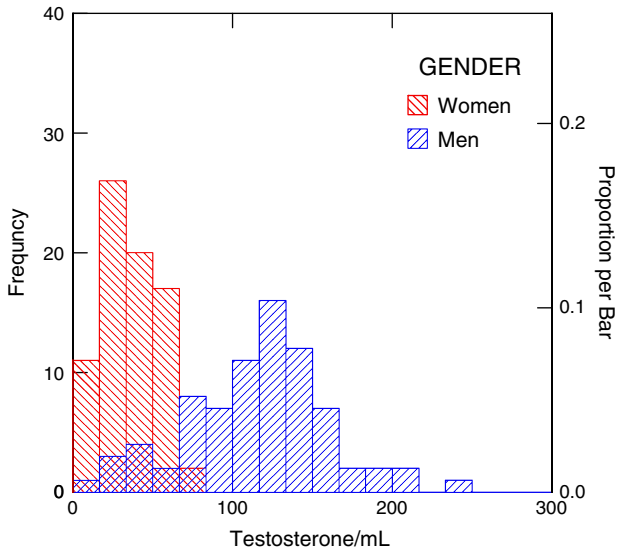

Fig. 1. Raw Salivary Testosterone Distribution. Shown is the bimodal distribution of raw salivary testosterone (in pg/mL) for the mixed-gender sample population.

et al., 2008 for related analysis strategies). While this controlled for both effects of gender and assay on testosterone, we also included dummy-coded variables for both gender and assay in the behavioral analyses to examine these predictors' effects on IGT performance.

To test the effects of testosterone on IGT performance, we ran a repeated-measures ANCOVA with testosterone (median-split) as our main between-subjects factor, assay and gender as covariates, and block as our within-subject factor. As past studies have shown, we found a significant within-subjects effect of block for all participants ($F(4,600) = 5.87$, $p < 0.001$). Gender and assay did not show significant main effects or interactions with block, all $ps > 0.05$. We found a significant main effect of testosterone ($F(1,150) = 8.30$, $p = 0.005$), indicating that low-testosterone individuals chose from more advantageous decks than did high-testosterone individuals (see Fig. 2). The interaction between testosterone and gender was not significant ($F(1,147) = 0.17$, $p = 0.68$). We also found a block × testosterone interaction ($F(4,600) = 3.59$, $p = 0.007$), which reflects the fact that in the first block there is essentially no difference between testosterone groups, but that over the duration of the task, the groups diverge in the percentage of advantageous choices that they make. Gender did not significantly moderate the block × testosterone effect.

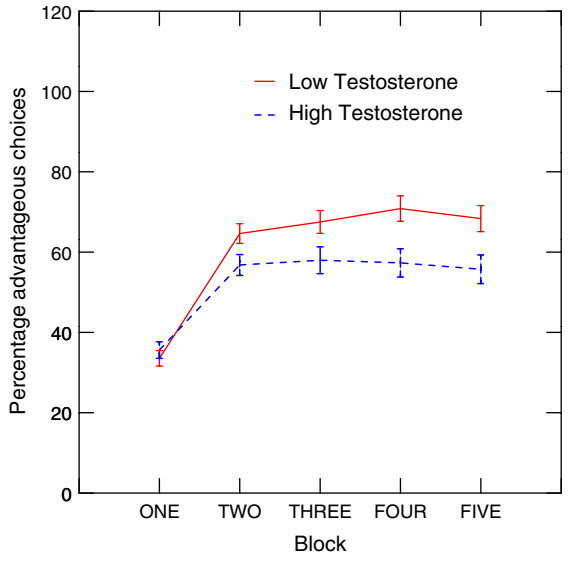

Fig. 2. Testosterone and Iowa Gambling Task performance. Shown is the time-course of the percentage of choices chosen from advantageous decks over the 5 blocks of the Iowa Gambling Task by subjects low (red, solid line) and high (blue, dashed line) in endogenous testosterone. Bars represent standard error.

As a test of the nature of the shape of the learning curve for participants, we tested the linear contrast effect of block and found a significant block × testosterone interaction for the linear effect ($F(1,150) = 6.39$, $p = 0.01$). We then tested the same linear effect independently in the high and low testosterone groups and found that the linear effect of time was highly significant in low-testosterone individuals ($F(1,75) = 6.73$, $p = 0.01$), and in contrast, was not significant in high-testosterone individuals ($F(1,73) = 0.59$, $p = 0.45$). No other polynomial effects were significant for high-testosterone individuals (all $Fs < 0.6$). This indicates that low-testosterone individuals showed a significant improvement in learning over the 5 blocks, whereas high-testosterone individuals did not show a significant improvement in learning over the 5 blocks.

In spite of the fact that gender did not account for a significant portion of the variance in the repeated-measures ANCOVA above, we also ran the same repeated-measures ANCOVA reported above separately for each gender, so that we could specifically characterize the effects of testosterone in each gender. For women, we found a significant main effect of testosterone ($F(1,73) = 6.70$, $p = 0.01$), and we also found a significant block × testosterone interaction ($F(4,292) = 3.74$, $p = 0.006$; see Fig. 3). For men, the main effect of testosterone was barely outside a trend level ($F(1,75) = 2.60$, $p = 0.11$)[1], and the block × testosterone interaction was not significant ($F(4,300) = 0.63$, $p = 0.64$; see Fig. 3). These findings demonstrate that in spite of the lost test power when splitting the sample by gender, the main effects of testosterone are similar in both genders[1].

We then analyzed the linear contrasts for each testosterone group within each gender separately. We found that the linear effect of time was significant in low-testosterone women ($F(1,36) = 16.01$, $p < 0.001$), and was not significant in high-testosterone women ($F(1,36) = 2.29$, $p = 0.14$). We found that the linear effect of time was significant in both low-testosterone men ($F(1,38) = 15.58$, $p < 0.001$), and in high-testosterone men ($F(1,37) = 21.05$, $p < 0.001$).

Discussion

In confirmation of our principal hypothesis, high-testosterone individuals took greater risks than low-testosterone individuals in the IGT. This finding supports the common hypothesis that testosterone is positively associated with greater risk taking in economic domains. Moreover, this finding is consistent with the notion that testosterone and risk taking are positively associated beyond the social domain. One significant caveat of prior research is that only one gender was tested within a single study, which left open questions regarding the generalizability of the findings to the other gender. In the present research, we not only tested both genders, but also found that the relationship between endogenous testosterone and risk taking was similar in both genders in which high-testosterone individuals took greater risks. When the analyses are split by gender, by the standard of null hypothesis significance testing, the effect of testosterone is significant in women only (Cohen, 1994). However, the lack of an

[1] Both testosterone assays had odd numbers of men included. Thus, when performing the median splits for men's high- and low-testosterone groups in each assay, the middle case in both assays had to be assigned to a particular group. The group can be chosen randomly and the middle case was assigned to the low-testosterone group for both assays. By doing so, the results are as reported in the body of the manuscript. Alternatively, the 2 middle cases could have been randomly assigned to the high-testosterone group. Had that been done, the main effect of testosterone group in men would have been closer to significance ($F(1,75) = 3.68$, $p = 0.059$). This bolsters our confidence in the similarity between genders for the main effect of testosterone on IGT performance.

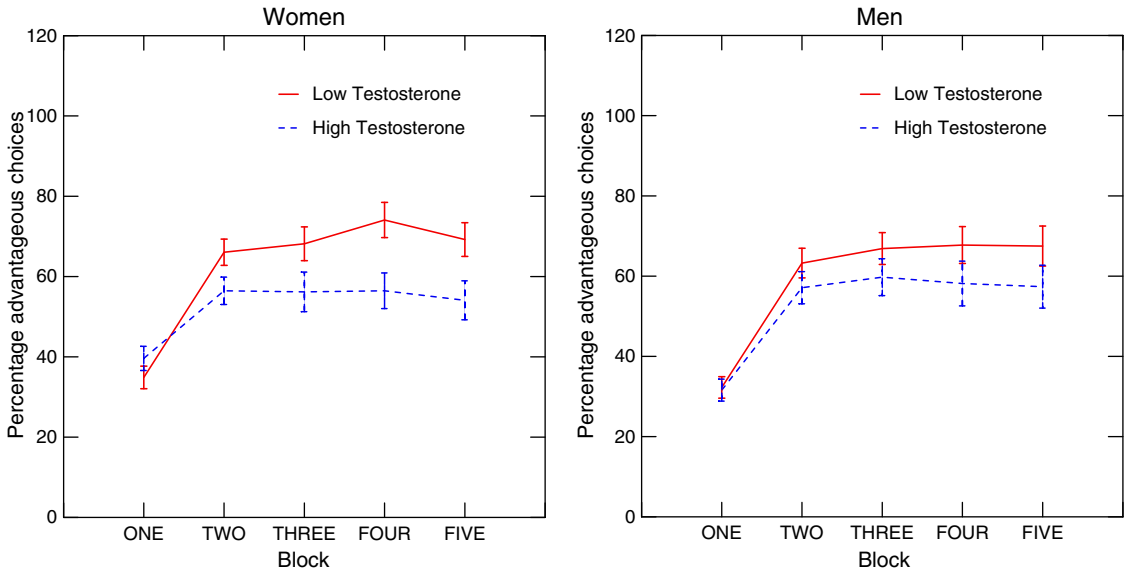

Fig. 3. Gender, testosterone, and Iowa Gambling Task performance. Shown is the time-course of the percentage of choices chosen from the advantageous decks over the 5 blocks of the Iowa Gambling Task by subjects low (red, solid line) and high (blue, dashed line) in endogenous testosterone for women (left panel) and men (right panel). Bars represent standard error.

interaction between testosterone group and gender shows that while the main effect of testosterone in men is not significant when tested separately, the difference in magnitude of the testosterone effect between men and women is not significant (see Fig. 2)[1]. This across-gender finding stands in contrast to Sapienza et al. (2009) who reported that there was a negative relationship between risk aversion and testosterone in women but not in men. A notable difference between the present study and that of Sapienza et al. (2009) is that their subject population was composed entirely of graduate students in business school who might approach risk analysis differently from the general population.

In general, participants choose increasingly from the advantageous decks over the course of the IGT (Bechara et al., 1994, 2005). In confirmation of this normative trend of IGT choices, our participants also demonstrated improvement over the course of the experiment as an entire group. However, when split into low and high-testosterone groups, it was most intriguing that high-testosterone individuals did not show statistically-significant improvement (i.e. learning) over the course of the IGT, whereas low-testosterone individuals did. This lack of improvement over time was notable in high-testosterone women. Others have argued that testosterone reduces sensitivity to punishment and increases sensitivity to reward in humans (van Honk et al., 2004) and in non-human mammals (Wood, 2004). van Honk et al. (2004) used the IGT and testosterone administration in women to demonstrate this phenomenon. They found that when women were administered testosterone, they chose significantly more often from the disadvantageous decks with sporadic large rewards but also frequent higher punishments. Specifically, with testosterone administration their female subjects proceeded to choose increasingly from advantageous decks from blocks 1–3, but then actually reverted back to choosing from progressively disadvantageous decks on blocks 4 and 5 (van Honk et al., 2004). Thus, our data support this finding using endogenous testosterone as our predictor.

One possible mechanism for the performance deficits on the IGT may be that high levels of testosterone are suppressing activity in cortical structures related to self-regulation and impulse control, such as the medial orbitofrontal cortex (OFC; Mehta and Beer, 2010). This suppression could potentially lead to behavior driven by a high desire for reward with little concern for punishment. For instance, both high levels of testosterone (Reynolds et al., 2007) and low OFC activity (Volkow and Li, 2004) have been independently associated with drug abuse, a behavior driven by a combination of high reward sensitivity and low punishment sensitivity (Genovese and Wallace, 2007). The only study to date to test both testosterone and OFC activity's relation to impulsive behavior found that low OFC activity mediated the relationship between testosterone and impulsive aggression (Mehta and Beer, 2010). Alternatively, high levels of testosterone may lead to decrements in dopaminergic projections between the OFC and limbic substrates, as has been shown in midbrain dopaminergic neurons in rats (Johnson et al., 2010), which could also lead to lesser OFC activity. Thus, we speculate that testosterone could suppress activity in cortical regions associated with self-control, leading high-testosterone individuals to continually select cards based on their large initial rewards rather than their large subsequent punishments.

This study was limited by the use of only a single task, and thus, we do not have the ability to discuss the degree to which testosterone's positive association with risk taking generalizes to other economic decision making tasks. Future work could employ a design with multiple measures of risk taking to examine the relationship between testosterone and varying levels of risk, ambiguity, and loss (Platt and Huettel, 2008). Moreover, the study was limited to examining the association with testosterone only, but it is plausible that estradiol could also play a role in risk taking in women (Bröder and Hohmann, 2003). In the social domain, power (dominance) motivation is positively associated with basal estradiol in women (Stanton and Edelstein, 2009; Stanton and Schultheiss, 2007), and power motivation is broadly associated with risk taking (Schultheiss, 2008). Gender differences (or similarities) in the relationship between testosterone and human behavior are likely to be of ongoing interest, which in our opinion is a motivating factor for researchers to study both genders in the same study when possible.

In conclusion, endogenous testosterone is positively associated with increases in risk taking among both men and women as evidenced through the IGT. In addition, low-testosterone individuals learned to avoid monetary punishment via losses over the course of the task, whereas high-testosterone individuals did not. Together these findings suggest that individuals with high levels of endogenous testosterone are more likely to take greater economic risks and are less likely to learn from and be responsive to monetary loss or punishment. The degree to which this pattern extends to real-world domains, such as choosing stocks for one's retirement portfolio, the extent to which professional

investors may take significant risks in spite of large potential losses, or the likelihood that one will engage in gambling, are promising questions for future research (Coates and Herbert, 2008).

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References

Apicella, C.L., Dreber, A., Campbell, B., Gray, P.B., Hoffman, M., Little, A.C., 2008. Testosterone and financial risk preferences. Evol. Hum. Behav. 29 (6), 384–390.
Bechara, A., Damasio, A.R., 2005. The somatic marker hypothesis: a neural theory of economic decision. Games Econ. Behav. 52 (2), 336–372.
Bechara, A., Damasio, A.R., Damasio, H., Anderson, S.W., 1994. Insensitivity to future consequences following damage to human prefrontal cortex. Cognition 50 (1–3), 7–15.
Bechara, A., Tranel, D., Damasio, H., 2000. Characterization of the decision-making deficit of patients with ventromedial prefrontal cortex lesions. Brain 123 (Pt 11), 2189–2202.
Bechara, A., Damasio, H., Tranel, D., Damasio, A.R., 2005. The Iowa Gambling Task and the somatic marker hypothesis: some questions and answers. Trends Cogn. Sci. 9 (4), 159–162 discussion 162–154.
Bröder, A., Hohmann, N., 2003. Variations in risk taking behavior over the menstrual cycle: an improved replication. Evol. Hum. Behav. 24 (6), 391–398.
Coates, J.M., Herbert, J., 2008. Endogenous steroids and finncial risk taking on a London trading floor. Proc. Natl Acad. Sci. USA 105 (16), 6167–6172.
Cohen, J., 1994. The earth is round ($p<.05$). Am. Psychol. 49, 997–1003.
Genovese, J.C., Wallace, D., 2007. Reward sensitivity and substance abuse in middle school and high school students. The Journal of Genetic Psychology 168 (4), 465–469.
Goudriaan, A.E., Lapauw, B., Ruige, J., Feyen, E., Kaufman, J.-M., Brand, M., et al., 2010. The influence of high-normal testosterone levels on risk-taking in healthy males in a 1-week letrozole administration study. Psychoneuroendocrinology 35, 1416–1421.
Johnson, M.L., Day, A.E., Ho, C.C., Walker, Q.D., Francis, R., Kuhn, C.M., 2010. Androgen decreases dopamine neurone survival in rat midbrain. J. Neuroendocrinol. 22 (4), 238–247.
Mazur, A., Booth, A., 1998. Testosterone and dominance in men. Behav. Brain Sci. 21 (3), 353–363 discussion 363–397.
Mehta, P.H., Beer, J., 2010. Neural mechanisms of the testosterone-aggression relation: The role of orbito-frontal cortex. Journal of Cognitive Neuroscience 22 (10), 2357–2368.
Mehta, P.H., Jones, A.C., Josephs, R.A., 2008. The social endocrinology of dominance: basal testosterone predicts cortisol changes and behavior following victory and defeat. J. Pers. Soc. Psychol. 94 (6), 1078–1093.
Middleman, A.B., DuRant, R.H., 1996. Anabolic steroid use and associated health risk behaviours. Sports Med. 21 (4), 251–255.
Platt, M.L., Huettel, S.A., 2008. Risky business: the neuroeconomics of decision making under uncertainty. Nat. Neurosci. 11 (4), 398–403.
Price, L.F., 2005. The biology of risk taking. Educ. Leadership 62 (7), 22–26.
Reavis, R., Overman, W.H., 2001. Adult sex differences on a decision-making task previously shown to depend on the orbital prefrontal cortex. Behav. Neurosci. 115 (1), 196–206.
Reynolds, M.D., Tarter, R., Kirisci, L., Kirillova, G., Brown, S., Clark, D.B., et al., 2007. Testosterone levels and sexual maturation predict substance use disorders in adolescent boys: A prospective study. Biological Psychiatry 61 (11), 1223–1227.
Sapienza, P., Zingales, L., Maestripieri, D., 2009. Gender differences in financial risk aversion and career choices are affected by testosterone. Proc. Natl Acad. Sci. 106 (36), 15268–15273.
Schultheiss, O.C., 2008. In: John, O.P., Robins, R.W., Pervin, L.A. (Eds.), Implicit Motives, 3 rd ed. : Handbook of Personality Psychology: Theory and Research. Guilford Press, New York, NY US, pp. 603–633.
Schultheiss, O.C., Stanton, S.J., 2009. Assessment of salivary hormones. In: Harmon-Jones, E., Beer, J.S. (Eds.), Methods in Social Neuroscience. Guilford Press, New York, NY, pp. 17–44.
Schultheiss, O. C., Patalakh, M., Rawolle, M., Liening, S. H., & Macinnes, J. J. (in press). Referential competence is associated with motivational congruence. *J. Res. Pers.*
Stanton, S.J., Edelstein, R.S., 2009. The physiology of women's power motive: implicit power motivation is positively associated with estradiol levels in women. J. Res. Pers. 43 (6), 1109–1113.
Stanton, S.J., Schultheiss, O.C., 2007. Basal and dynamic relationships between implicit power motivation and estradiol in women. Horm. Behav. 52 (5), 571–580.
Stanton, S.J., Schultheiss, O.C., 2009. The hormonal correlates of implicit power motivation. J. Res. Pers. 43 (5), 942.
Steinberg, L., 2008. A social neuroscience perspective on adolescent risk-taking. Dev. Rev. 28 (1), 78–106.
van Honk, J., Schutter, D.J., Hermans, E.J., Putman, P., Tuiten, A., Koppeschaar, H., 2004. Testosterone shifts the balance between sensitivity for punishment and reward in healthy young women. Psychoneuroendocrinology 29 (7), 937–943.
Volkow, N.D., Li, T.K., 2004. Drug addiction: the neurobiology of behaviour gone awry. Nature Reviews Neuroscience 5 (12), 963–970.
Wood, R.I., 2004. Reinforcing aspects of androgens. Physiol. Behav. 83 (2), 279–289.
Zethraeus, N., Kocoska-Maras, L., Ellingsen, T., von Schoultz, B., Hirschberg, A.L., Johannesson, M., 2009. A randomized trial of the effect of estrogen and testosterone on economic behavior. Proc. Natl Acad. Sci. USA 106 (16), 6535–6538.