Low- and High-Testosterone Individuals Exhibit Decreased Aversion to Economic Risk

Steven J. Stanton, O'Dhaniel A. Mullette-Gillman, R. Edward McLaurin, Cynthia M. Kuhn, Kevin S. LaBar, Michael L. Platt and Scott A. Huettel

Psychological Science published online 10 March 2011
DOI: 10.1177/0956797611401752

Psychological Science OnlineFirst, published on March 10, 2011 as doi:10.1177/0956797611401752

Research Report

Psychological Science
XX(X) 1–7

DOI: 10.1177/0956797611401752
http://pss.sagepub.com

Low- and High-Testosterone Individuals Exhibit Decreased Aversion to Economic Risk

Steven J. Stanton[1,2,3], O'Dhaniel A. Mullette-Gillman[1,2], R. Edward McLaurin[1], Cynthia M. Kuhn[4], Kevin S. LaBar[1,3], Michael L. Platt[1,2,5], and Scott A. Huettel[1,2,3]

[1]Center for Cognitive Neuroscience, [2]Center for Neuroeconomic Studies, [3]Department of Psychology and Neuroscience, [4]Department of Pharmacology and Cancer Biology, and [5]Department of Neurobiology, Duke University

Abstract

Testosterone is positively associated with risk-taking behavior in social domains (e.g., crime, physical aggression). However, the scant research linking testosterone to economic risk preferences presents inconsistent findings. We examined the relationship between endogenous testosterone and individuals' economic preferences (i.e., risk preference, ambiguity preference, and loss aversion) in a large sample (N = 298) of men and women. We found that endogenous testosterone levels have a significant U-shaped association with individuals' risk and ambiguity preferences, but not loss aversion. Specifically, individuals with low or high levels of testosterone (more than 1.5 *SD* from the mean for their gender) were risk and ambiguity neutral, whereas individuals with intermediate levels of testosterone were risk and ambiguity averse. This relationship was highly similar in men and women. In contrast to received wisdom regarding testosterone and risk, the present data provide the first robust evidence for a nonlinear association between economic preferences and levels of endogenous testosterone.

Keywords

testosterone, hormones, risk, ambiguity, loss aversion, neuroeconomics, behavioral economics

Received 8/25/10; Revision accepted 12/1/10

Testosterone has been positively associated with aggressive, risky behaviors in a wide range of real-world domains (Mazur & Booth, 1998). Trial lawyers, who take constant risks in the courtroom, have higher testosterone levels than non-trial lawyers (Dabbs, Alford, & Fielden, 1998). Among criminals, testosterone is positively associated with the likelihood of having committed a violent crime (Dabbs, Frady, Carr, & Besch, 1987). In a sample of more than 4,000 veterans of the U.S. Army, testosterone was positively associated with alcohol abuse, drug use, violence, illicit behavior, and sexual promiscuity (Mazur, 1995). More than 50 other studies have also shown that testosterone is positively associated with interpersonal dominance and aggression, both of which engender associated social and physical risks (Archer, 2006; Mazur & Booth, 1998; Stanton & Schultheiss, 2009). The associations of testosterone with aggressive, dominating, and risky behaviors suggest that increased levels of this hormone lead to a generalized decrease in risk aversion. However, it remains to be shown whether and how testosterone levels shape risk taking in economic contexts.

The few studies that have examined the link between testosterone levels and economic decision making have yielded inconsistent results. Notably, these studies have varied in whether testosterone was measured endogenously or manipulated exogenously, in whether and how choices involved real economic incentives, and in whether one or both genders were included in the study sample (Apicella et al., 2008; Sapienza, Zingales, & Maestripieri, 2009; van Honk et al., 2004; Zethraeus et al., 2009).

In a study reported by Apicella et al. (2008), endogenous testosterone levels in men were positively correlated with choosing to make a risky investment in a single-trial gamble. Participants could gamble any percentage of a $250 endowment; a successful coin toss would multiply whatever was bet by 2.5, whereas failure meant loss of the bet amount. In

Corresponding Author:
Scott A. Huettel, Duke University, Center for Cognitive Neuroscience, B203 LSRC Building, Research Dr., Box 90999, Durham, NC 27708-0999
E-mail: scott.huettel@duke.edu

contrast, Sapienza et al. (2009) used an incentive-compatible algorithm (Holt & Laury, 2002) in which subjects chose between a 50/50 gamble with $0 and $200 outcomes and varying guaranteed payments ($50–$120). In this study, endogenous testosterone levels were not associated with men's risk preferences but were negatively correlated with risk aversion in women.

Alternatively, exogenous administration allows examination of how changes in testosterone levels affect decision making. Results have been similarly inconclusive: Although van Honk et al. (2004) found that testosterone induces reduced risk aversion in a gambling task with hypothetical rewards, Zethraeus et al. (2009) failed to find an effect of testosterone administration in a task using an incentive-compatible version of Holt and Laury's (2002) algorithm. Because testosterone administration effectively pushes all participants into a supraphysiological range of testosterone concentration (Tuiten et al., 2000), it may mask underlying associations between endogenous testosterone levels and risk preferences, such as potential nonlinear effects within the normal physiological range. Thus, it remains unclear what influence, if any, testosterone levels exert on economic risk preferences.

In the study reported here, we investigated the relationship between endogenous testosterone levels and economic decision making in a large sample of men and women. We examined individual choice preferences using three canonical, incentive-compatible paradigms: risk preference, ambiguity preference, and loss aversion (Fig. 1). Our approach and sample size allowed us to address many of the challenges raised by previous work: We included both genders simultaneously, compared linear and nonlinear models, and used incentive-compatible tasks to examine economic preferences.

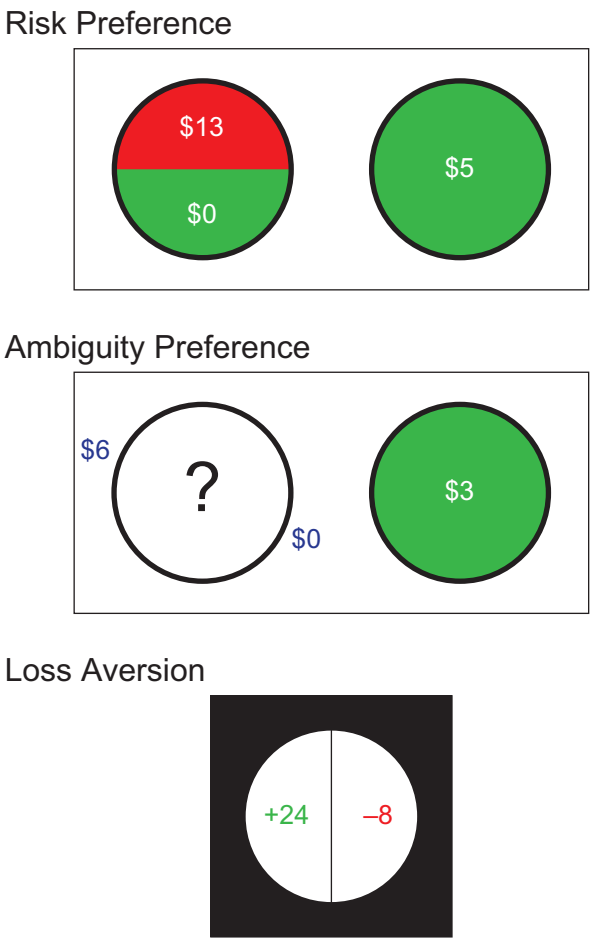

Fig. 1. Example stimuli for the risk-preference, ambiguity-preference, and loss-aversion tasks. On each trial of the risk-preference task, participants chose between a certain outcome of defined value and a gamble of known probability (e.g., $5 for sure vs. a 50/50 chance of winning $0 or $13). On each trial of the ambiguity-preference task, participants chose between a certain outcome of defined value and a gamble of unknown probability (e.g., $3 for sure vs. a gamble with potential outcomes of $0 or $6). In the loss-aversion task, participants started with an endowment of $20 and then chose between accepting or declining to play a gamble of known probability (e.g., a 50/50 chance of winning $24 or losing $8).

Method

Participants

Data were collected in Durham, North Carolina, from 298 participants (142 men, 156 women; age range = 18–48 years, M = 22.1 years, SD = 4.2 years). All participants provided informed consent under a protocol approved by the Duke University Medical Center Institutional Review Board.

Procedure

Participants were tested between 1:00 p.m. and 5:15 p.m. During a single session, participants completed economic decision-making tasks, provided a saliva sample, and completed questionnaires unrelated to this report.

Economic decision-making tasks

The *risk preference* of each subject was determined through 120 trials in which the subject selected between a certain outcome and a risky gamble (Fig. 1, top panel). Across trials, the values of the certain outcome were $3, $4, $5, $6, and $7. Each certain outcome was used in 24 trials; the accompanying risky gambles were randomly selected (without replacement) from a set determined by three possible probabilities of winning (25%, 50%, and 75%) and eight ratios of the expected value of the gamble (EV_G) to the value of the certain option (V_C). The included EV_G/V_C ratios were 0.5, 1.0, 1.3, 1.6, 1.9, 2.2, 2.5, and 3.0.

The *ambiguity preference* of each subject was measured in an additional 35 trials (intermixed with the risk-preference trials) in which participants selected between a certain outcome ($3, $4, $5, $6, or $7) and a gamble with an unknown probability of winning (Fig. 1, middle panel). The expected value of the ambiguous gamble was calculated using a probability of

.5. The included EV_G/V_C ratios were 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, and 6.0 (see the Supplemental Material available online for additional details about this task).

Loss aversion was measured using a task based on a previous study by Tom, Fox, Trepel, and Poldrack (2007). Subjects were endowed with $20 and then presented with 64 trials; on each trial, they were offered a gamble in which they could lose part or all of their endowment or could gain a larger amount (Fig. 1, bottom panel). Trials were constructed from the factorial combination of losses ranging from $6 to $20 ($2 increments) and gains ranging from $12 to $40 ($4 increments).

No feedback was provided until the end of the experimental session; this eliminated the possibility of intertrial changes in preferences based on outcomes.

Testosterone measurement

Saliva samples were collected and stored using standard methods and were assessed with solid-phase Siemens Healthcare Diagnostics (Los Angeles, CA) Coat-A-Count[125] I radioimmunoassay for testosterone (see the Supplemental Material for details on the assay protocol; Schultheiss & Stanton, 2009). For samples of known concentration (45 pg/mL and 115 pg/mL), interassay coefficients of variation (CVs) were 14.1% and 5.2%, respectively. Analytical sensitivity, or the lower limit of detection, was 1.2 pg/mL. Saliva samples were counted in duplicate and had a mean intra-assay CV of 10.8%, a value consistent with findings of past studies (Newman, Sellers, & Josephs, 2005; Wirth & Schultheiss, 2007). Testosterone levels were not associated with time of day ($r = .07$, $p = .29$).

Data analysis

SYSTAT 12.0 statistical software (Systat Software Inc., Chicago, IL) was used for all statistical analyses. The statistical threshold for all analyses was a p value of .05.

Results

Risk and ambiguity preferences

We estimated economic preferences for both risk and ambiguity using a psychophysical indifference-point approach. We measured the percentage of choices of the uncertain option as a function of the EV_G/V_C ratio (see Method). When plotted, choices followed monotonic, ogival curves typical of psychophysical data. We calculated participants' risk preference and ambiguity preference as the EV_G/V_C ratio at which their choice function showed indifference between the certain and uncertain options (i.e., choice of the uncertain option crossed the 50% mark). We refer to this as the indifference point; that is, a value of 1.0 would reflect risk or ambiguity neutrality, with increasing scores indicating greater aversion (see the Supplemental Material for additional information on the computation of participants' risk and ambiguity preferences; cf. Levy, Snell, Nelson, Rustichini, & Glimcher, 2010).

The indifference-point values were transformed to risk and ambiguity premiums: the percentage of additional expected value of the gamble necessary for the subject to be indifferent between the two options. On average, participants' risk premium was 46% ($SEM = 4\%$), and their ambiguity premium was 160% ($SEM = 9\%$; see Fig. S1 in the Supplemental Material). Thus, participants were indifferent between the two options when the gamble had an expected value 46% greater than the certain payment on risk-aversion trials and 160% greater than the certain payment on ambiguity-aversion trials. Participants were significantly more ambiguity averse than risk averse, $t(209) = -15.69$, $p < .001$. Risk aversion was significantly correlated with ambiguity aversion ($r = .42$, $p < .001$).

Gender effects on risk and ambiguity preferences and on testosterone levels

Women were significantly more risk averse than men, $t(271) = -2.35$, $p = .02$ (risk premium for men: $M = 38\%$, $SEM = 5\%$; risk premium for women: $M = 54\%$, $SEM = 5\%$) and also more ambiguity averse than men, $t(214) = -2.92$, $p = .004$ (ambiguity premium for men: $M = 135\%$, $SEM = 11\%$; ambiguity premium for women: $M = 183\%$, $SEM = 12\%$).

Mean salivary testosterone concentrations were 86.5 pg/mL ($SD = 26.0$) for men and 14.2 pg/mL ($SD = 7.0$) for women; the effect of gender was significant, $t(283) = 32.3$, $p < .001$. Because of this gender difference, we used z scores for testosterone levels (i.e., each individual's testosterone level relative to the distribution for his or her gender) in all subsequent analyses (Mehta, Jones, & Josephs, 2008).

Effects of testosterone on risk and ambiguity preferences

To examine the effects of endogenous testosterone on risk and ambiguity preferences, we used regression models to which we progressively added a priori independent variables. Model 1 included only testosterone as a linear predictor variable, Model 2 added testosterone as a quadratic predictor, and Model 3 added gender. Risk and ambiguity preferences were analyzed in separate models.

Neither risk preference nor ambiguity preference had a significant linear relationship with testosterone (Model 1; Tables 1 and 2). In the next step (Model 2), we found highly significant U-shaped relationships between endogenous testosterone level and risk and ambiguity preferences (Fig. 2, Tables 1 and 2): Whereas individuals with intermediate levels of testosterone were risk and ambiguity averse, as is typically found, individuals with high or low levels of testosterone (i.e., individuals with testosterone levels more than 1.5 *SD*s above or below the mean within their gender) were risk and ambiguity neutral (see the Supplemental Material for additional analyses using other regression models and covariates).

Table 1. Regression Models Examining the Linear and Nonlinear Relationships Between Testosterone and Risk Preference

	Predictor			
Model	Testosterone (linear)	Testosterone (quadratic)	Gender	Regression statistics
Model 1	−0.05 (.44)			$F(1, 256) = 0.59, p = .44$
Model 2	−0.02 (.74)	−0.19 (.002)		$F(2, 255) = 5.00, p = .002$
Model 3	−0.01 (.84)	−0.18 (.003)	0.15 (.02)	$F(3, 254) = 5.35, p = .001$

Note: The table reports standardized beta coefficients, with the corresponding *p* values in parentheses. Gender was dummy-coded (male = 0, female = 1).

Table 2. Regression Models Examining the Linear and Nonlinear Relationships Between Testosterone and Ambiguity Preference

	Predictor			
Model	Testosterone (linear)	Testosterone (quadratic)	Gender	Regression statistics
Model 1	−0.03 (.64)			$F(1, 202) = 0.22, p = .64$
Model 2	0.01 (.94)	−0.16 (.03)		$F(2, 201) = 2.68, p = .07$
Model 3	0.01 (.85)	−0.15 (.03)	0.20 (.004)	$F(3, 200) = 4.69, p = .003$

Note: The table reports standardized beta coefficients, with the corresponding *p* values in parentheses. Gender was dummy-coded (male = 0, female = 1).

When gender was included as an additional factor (Model 3), the quadratic effect of testosterone on risk preference and on ambiguity preference was still significant, as was the effect of gender itself (Tables 1 and 2). When we separated the analyses by gender, the quadratic relationship between testosterone and risk preference was similar for women ($\beta = -0.17$, $p = .05$) and men ($\beta = -0.21$, $p = .02$). Although the quadratic relationship between testosterone and ambiguity preference was not significant in each gender independently, the beta coefficients for men ($\beta = -0.15$, $p = .12$) and women ($\beta = -0.13$, $p = .22$) were of similar magnitude to the coefficient for the whole sample.

Effects of testosterone on loss aversion

We also examined the relation between testosterone and loss aversion, the relative weighting of possible economic losses and gains (Tversky & Kahneman, 1992). We calculated loss aversion (λ) for each individual participant as follows: the unstandardized logistic regression coefficient for loss divided by the unstandardized regression coefficient for gain (Tom et al., 2007). Men and women did not differ in their loss aversion, $t(269) = 1.3$, $p = .2$ (men: median $\lambda = 1.9$, 25th–75th percentile = 1.4–3.1; women: median $\lambda = 1.9$, 25th–75th percentile = 1.4–4.0).

Testosterone had no linear association with loss aversion ($r = -.03$, $p = .62$) and no quadratic association with loss aversion, both when testosterone was the only predictor ($\beta = 0.07$, $p = .30$) and when gender was added to the regression model ($\beta = 0.06$, $p = .36$).

Discussion

Despite the common view that high testosterone levels lead to risky decisions across numerous domains, we found that testosterone has a quadratic relationship with economic risk preferences: Individuals with low and high levels of testosterone (within their gender) were risk and ambiguity neutral, whereas individuals with intermediate levels of testosterone were risk and ambiguity averse. Moreover, our study provides the first data documenting the effects of testosterone on ambiguity preferences. The parallel U-shaped effects for risk and ambiguity suggest that testosterone levels are associated with preferences for economic uncertainty, regardless of whether probability is known (risk) or unknown (ambiguity). Even though women and men differed both in their risk and ambiguity premiums and in their testosterone levels, testosterone levels had similar effects on risk premiums and on ambiguity premiums within each gender independently. Notably, the within-gender differences in risk and ambiguity premiums between individuals with intermediate testosterone levels (< 0.5 *SD* from the mean) and those with extreme levels of testosterone (> 1.5 *SD* from the mean) were approximately twice as large as the between-gender difference in risk and ambiguity premiums.

Note that there were no linear effects of testosterone. In contrast, Apicella et al. (2008) found that endogenous testosterone was positively associated with risk taking in men, and Sapienza et al. (2009) found that endogenous testosterone was negatively associated with risk aversion in women, but not in men. Differences between our study and past studies could

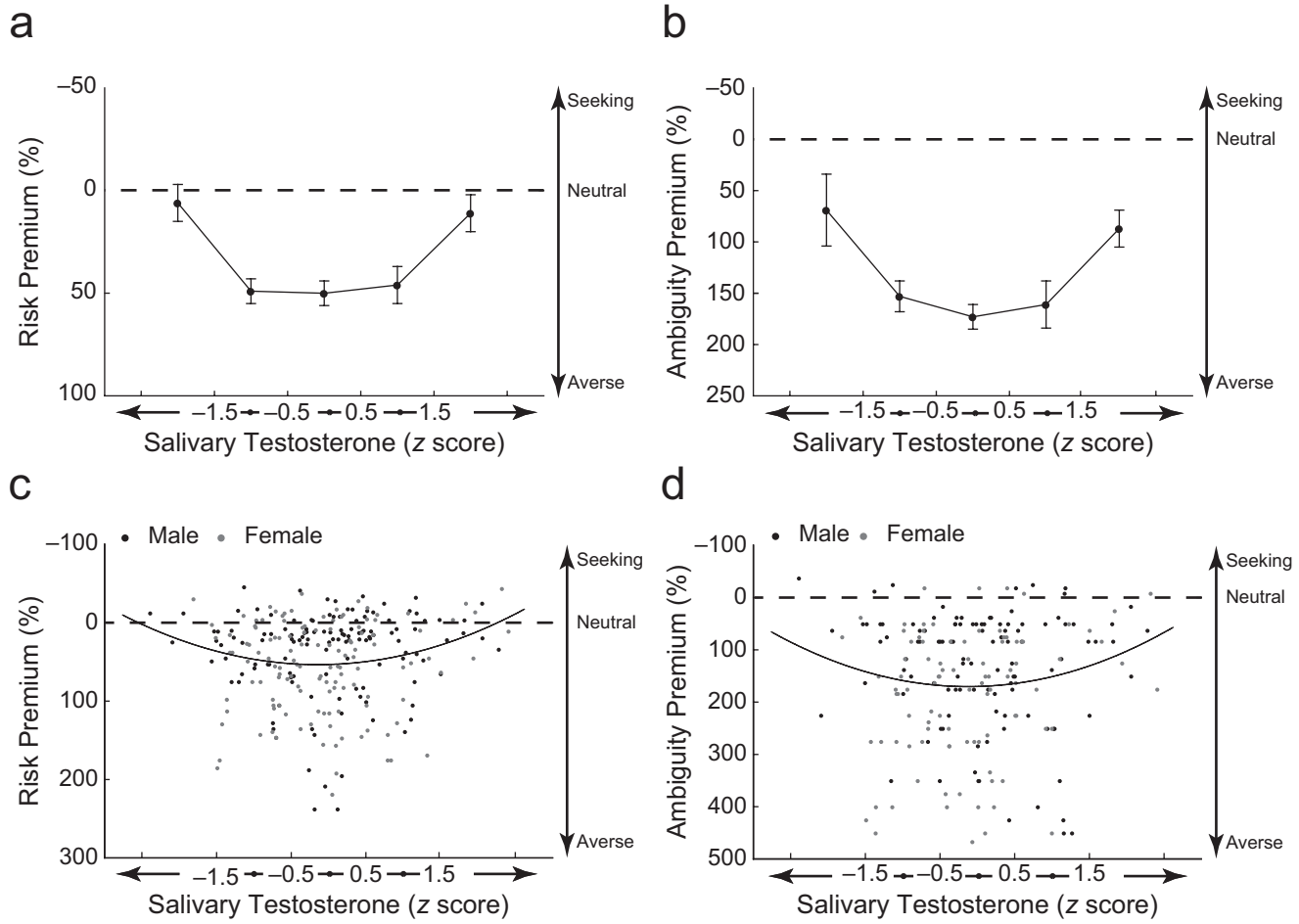

Fig. 2. Risk and ambiguity premiums as a function of testosterone level. Endogenous testosterone levels were standardized within each sex independently. The top row shows results for (a) risk and (b) ambiguity for the sample overall; error bars represent standard errors. The scatter plots in the bottom row show the relationship between endogenous testosterone levels and (c) risk and (d) ambiguity premiums for individual male and female participants; the curves are quadratic-fit regression lines.

contribute to the inconsistency in the findings. For example, Apicella et al. used a single-trial task that had limited incentive compatibility (only a single, randomly picked subject out of the entire sample population would be paid). Sapienza et al. recruited a sample of graduate business-school students who were trained at risk calculation and whose risk preferences may not be representative of the greater population. Yet, given the current results, it is notable that Sapienza et al. suggested that testosterone could have nonlinear effects even though they did not test for specific nonlinear effects in their data. The nonlinear relation we found may also account for reported effects of testosterone administration (van Honk et al., 2004), in that supraphysiological testosterone levels would move most participants from risk averse to risk neutral in their preferences, overshadowing the underlying U-shaped association that exists within the normal physiological range (van Honk et al., 2004; Zethraeus et al., 2009).

Our finding that high levels of testosterone are related to risk-seeking economic choices is consistent with the literature on the relationship between testosterone and risk in other domains (Mazur & Booth, 1998). More striking is the finding that individuals with low testosterone levels are also more risk seeking than are those with intermediate levels. From a neurobiological perspective, the U-shaped association could arise through several mechanisms. One possible contributor is suggested by studies showing that androgen receptor density can vary with testosterone levels (Doumit, Cook, & Merkel, 1996). Androgens bind not only to androgen receptors but also to neurotransmitter receptors (e.g., the GABA-A receptor) that have been associated with decision preferences in humans (Lane & Gowin, 2009). Depending on the brain region, androgens can either amplify or diminish the effects of GABA (Jorge-Rivera, McIntyre, & Henderson, 2000, 2007; Masonis & McCarthy, 1996), and this could contribute to GABA-mediated, curvilinear associations between testosterone and behavior. Curvilinear associations with testosterone may reflect biological optimization, which has been previously reported for testosterone in both cognitive domains (e.g., spatial cognitive abilities; Moffat &

Hampson, 1996) and physiological domains (e.g., cardiovascular health; Laughlin, Goodell, & Barrett-Connor, 2010). Because the extent to which specific economic risk preferences are optimal is likely to vary across contexts (e.g., risk seeking may become adaptive when resources are scarce), the greater variability in preferences among individuals with intermediate levels of testosterone (see Figs. 2c and 2d) could itself reflect that adaptive flexibility.

Beyond the administration of testosterone, a variety of real-world events are known to change testosterone levels; consequently, such events could drive transient changes in risk preferences. For instance, winning or losing a sports match as an athlete (Booth, Shelley, Mazur, Tharp, & Kittok, 1989) or a political election as a voter (Stanton, Beehner, Saini, Kuhn, & LaBar, 2009) can change one's testosterone levels, as can watching a dramatic action movie (Schultheiss, Wirth, & Stanton, 2004). Studying the effects of transient changes in testosterone that accompany such events would facilitate a broader understanding of the effects of testosterone on real-world economic decisions.

Acknowledgments

We thank Rosie Phillips and Anna Beck for assistance in testing participants.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Funding

This research was supported by a Duke Institute for Brain Sciences Incubator Award (to S.A.H. and M.L.P.), by National Institute of Mental Health Grant RC1-088680 (to S.A.H.), and by the McClelland Postdoctoral Fellowship from the Hay Group (to S.J.S.).

Supplemental Material

Additional supporting information may be found at http://pss.sagepub.com/content/by/supplemental-data

References

Apicella, C.L., Dreber, A., Campbell, B., Gray, P.B., Hoffman, M., & Little, A.C. (2008). Testosterone and financial risk preferences. *Evolution and Human Behavior*, *29*, 384–390.

Archer, J. (2006). Testosterone and human aggression: An evaluation of the challenge hypothesis. *Neuroscience & Biobehavioral Reviews*, *30*, 319–345.

Booth, A., Shelley, G., Mazur, A., Tharp, G., & Kittok, R. (1989). Testosterone, and winning and losing in human competition. *Hormones and Behavior*, *23*, 556–571.

Dabbs, J.M., Jr., Alford, E.C., & Fielden, J.A. (1998). Trial lawyers and testosterone: Blue-collar talent in a white-collar world. *Journal of Applied Social Psychology*, *28*, 84–94.

Dabbs, J.M., Jr., Frady, R.L., Carr, T.S., & Besch, N.F. (1987). Saliva testosterone and criminal violence in young adult prison inmates. *Psychosomatic Medicine*, *49*, 174–182.

Doumit, M.E., Cook, D.R., & Merkel, R.A. (1996). Testosterone up-regulates androgen receptors and decreases differentiation of porcine myogenic satellite cells in vitro. *Endocrinology*, *137*, 1385–1394.

Holt, C.A., & Laury, S.K. (2002). Risk aversion and incentive effects. *The American Economic Review*, *92*, 1644–1655.

Jorge-Rivera, J.C., McIntyre, K.L., & Henderson, L.P. (2000). Anabolic steroids induce region- and subunit-specific rapid modulation of GABA(A) receptor-mediated currents in the rat forebrain. *Journal of Neurophysiology*, *83*, 3299–3309.

Jorge-Rivera, J.C., McIntyre, K.L., & Henderson, L.P. (2007). Retraction. *Journal of Neurophysiology*, *98*, 1841.

Lane, S.D., & Gowin, J.L. (2009). GABAergic modulation of human social interaction in a prisoner's dilemma model by acute administration of alprazolam. *Behavioural Pharmacology*, *20*, 657–661.

Laughlin, G.A., Goodell, V., & Barrett-Connor, E. (2010). Extremes of endogenous testosterone are associated with increased risk of incident coronary events in older women. *Journal of Clinical Endocrinology & Metabolism*, *95*, 740–747.

Levy, I., Snell, J., Nelson, A.J., Rustichini, A., & Glimcher, P.W. (2010). Neural representation of subjective value under risk and ambiguity. *Journal of Neurophysiology*, *103*, 1036–1047.

Masonis, A.E.T., & McCarthy, M.P. (1996). Effects of the androgenic/anabolic steroid stanozolol on GABA(A) receptor function: GABA-stimulated Cl-36(-) influx and [S-35] TBPS binding. *Journal of Pharmacology and Experimental Therapeutics*, *279*, 186–193.

Mazur, A. (1995). Biosocial models of deviant behavior among male army veterans. *Biological Psychology*, *41*, 271–293.

Mazur, A., & Booth, A. (1998). Testosterone and dominance in men [Target article and discussion]. *Behavioral and Brain Sciences*, *21*, 353–397.

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. *Journal of Personality and Social Psychology*, *94*, 1078–1093.

Moffat, S.D., & Hampson, E. (1996). A curvilinear relationship between testosterone and spatial cognition in humans: Possible influence of hand preference. *Psychoneuroendocrinology*, *21*, 323–337.

Newman, M.L., Sellers, J.G., & Josephs, R.A. (2005). Testosterone, cognition, and social status. *Hormones and Behavior*, *47*, 205–211.

Sapienza, P., Zingales, L., & Maestripieri, D. (2009). Gender differences in financial risk aversion and career choices are affected by testosterone. *Proceedings of the National Academy of Sciences, USA*, *106*, 15268–15273.

Schultheiss, O.C., & Stanton, S.J. (2009). Assessment of salivary hormones. In E. Harmon-Jones & J.S. Beer (Eds.), *Methods in social neuroscience* (pp. 17–44). New York, NY: Guilford Press.

Schultheiss, O.C., Wirth, M.M., & Stanton, S.J. (2004). Effects of affiliation and power motivation arousal on salivary progesterone and testosterone. *Hormones and Behavior*, *46*, 592–599.

Stanton, S.J., Beehner, J.C., Saini, E.K., Kuhn, C.M., & LaBar, K.S. (2009). Dominance, politics, and physiology: Voters' testosterone

changes on the night of the 2008 United States presidential election. *PLoS ONE*, *4*, e7543. Retrieved July 1, 2010, from http://www.plosone.org/article/info:doi%2F10.1371%2Fjournal.pone.0007543

Stanton, S.J., & Schultheiss, O.C. (2009). The hormonal correlates of implicit power motivation. *Journal of Resarch in Personality*, *43*, 942–949.

Tom, S.M., Fox, C.R., Trepel, C., & Poldrack, R.A. (2007). The neural basis of loss aversion in decision-making under risk. *Science*, *315*, 515–518.

Tuiten, A., Van Honk, J., Koppeschaar, H., Bernaards, C., Thijssen, J., & Verbaten, R. (2000). Time course of effects of testosterone administration on sexual arousal in women [Target article and discussion]. *Archives of General Psychiatry*, *57*, 149–153.

Tversky, A., & Kahneman, D. (1992). Advances in prospect theory: Cumulative representation of uncertainty. *Journal of Risk and Uncertainty*, *5*, 297–323.

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*, 937–943.

Wirth, M.M., & Schultheiss, O.C. (2007). Basal testosterone moderates responses to anger faces in humans. *Physiology & Behavior*, *90*, 496–505.

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. *Proceedings of the National Academy of Sciences, USA*, *106*, 6535–6538.