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Individual Differences in Testosterone Predict Persistence in Men

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Abstract: Persistence is an important predictor of future successes. The present research addresses the relationship between testosterone and persistence in men. One hundred eighteen men were randomly assigned to win or lose a competitive number tracing task against a confederate or complete the task alone in a non-competitive control condition. Saliva samples were collected prior to and after the competition or control conditions. Participants were then given a maximum time of 30 min to spend attempting to solve unsolvable puzzles, with the option to quit at any time. In contrast to our prediction, changes in testosterone concentrations in response to the competitive interaction did not predict persistence behaviour. However, individual differences in testosterone concentrations (pre-competition/non-competition) were positively correlated with persistence. These findings are the first to examine associations between neuroendocrine function and persistence behaviour in people and suggest that testosterone should also be considered when predicting persistence-related outcomes. Copyright © 2014 European Association of Personality Psychology

Key words: testosterone; persistence; dominance; competition

Stephen King's first novel, Carrie, was rejected repeatedly by publishers prior to its initial publication in 1973. After the 30th rejection of the book, Stephen King threw the manuscript in the trash, but again resubmitted it for publication at his wife's recommendation. From childhood, Stephen King submitted many short stories to publishers and magazines, which were ultimately rejected. All of the rejection letters he received were hung on a nail on the wall. By the time he reached the age of 14 years, the nail no longer supported the weight of all the rejection slips, so he replaced the nail with a large spike and continued writing (King, 2000).

Aside from sheer luck, persisting in the face of obstacles, failures and rejection is an important route in gaining higher status and achieving goals. By definition, persistent individuals are less likely to submit and give in to obstacles in their path to achievement. A popular belief in western society is that hard work and perseverance can lead to upward social mobility and increased status (e.g. Furnham, 1989; Weber, 1905). Accordingly, being persistent can lead to increased academic success (Reardon, Arshan, Atteberry, & Kurlaender, 2010), creativity (McKeown & Lindorff, 2011) and greater likelihood of employment (Shalley, Zhou, & Oldham, 2004), among other important successes.

Why do some individuals persevere in the face of failure, adversity and repeated rejection when others do not? Researchers have examined many explanations of human persistence behaviours, including self-control (e.g. Barber, Grawitch, & Munz, 2012; Baumeister, Bratslavsky, Muraven, & Tice, 1998), having a low-level construal (e.g. Agrawal & Wan, 2009), previous positive evaluations (Reardon et al., 2010), increased intrinsic motivation (e.g. Shalley et al., 2004), conscientiousness (Duckworth, Peterson, Matthews, & Kelly, 2007) and temporal expectations (McGuire & Kable, 2012).

In addition to these factors, testosterone could be one predictor of persistence behaviours. Endogenous testosterone concentrations are linked to dominance and aggressive behaviours in nonhuman animals (e.g. Beehner, Bergman, Cheney, Seyfarth, & Whitten, 2006; Gould & Ziegler, 2007; Wingfield, Hegner, Dufty, & Ball, 1990). Additionally, experimental and correlational research in nonhuman animals (specifically, chicks, rats and mice) suggests that testosterone increases basic forms of persistence behaviour, measured as persistence in searching for food and social investigation (Andrew & Rogers, 1972; Archer, 1977; van Hest, van Haaren, & van de Poll, 1989; Thompson & Wright, 1979; Thor, 1980). This experimental work has comprised injecting testosterone into either immature animals (Andrew & Rogers, 1972), castrated adults (Archer, 1977) or non-castrated adults (Thompson & Wright, 1979).

Will higher levels of endogenous, baseline[1] testosterone concentrations lead to higher levels of persistence within humans? Meta-analytic evidence suggests that baseline testosterone concentrations show a positive, yet weak, relationship with dominance behaviours, particularly aggression, in humans (Archer, Graham-Kevan, & Davies, 2005).

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[1]We refer to endogenous testosterone concentrations as 'baseline' because when measured at the same time of day, testosterone concentrations are relatively stable (Liening, Stanton, Saini, & Schultheiss, 2010).

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However, context-dependent changes in testosterone have been thought to be more strongly correlated with aggression (see Carré, McCormick, & Hariri, 2011 for a review), and to fine-tune dominance-related behaviour (Mazur, 1985). Men's testosterone concentrations generally fluctuate in response to winning or losing a competition, with testosterone decreasing in losers and remaining elevated in winners (Archer, 2006; Carré, Campbell, Lozoya, Goetz, & Welker, 2013). These changes in testosterone after competitive outcomes have been found to map onto future dominance behaviours, such as reactive aggression (Carré et al., 2013), willingness to compete with others (Carré & McCormick, 2008) and the desire to compete with others again after a competitive defeat (Mehta & Josephs, 2006). Thus, in addition to individual differences in 'baseline' testosterone concentrations, it may be critical to examine the extent to which testosterone reactivity to competitive interactions predicts persistence behaviours.

Although baseline testosterone and testosterone reactivity predict dominance and desire to compete, they also may predict persistence behaviours in men. The goal of this study was to examine if baseline testosterone, competitive outcomes and testosterone reactivity would predict persistence behaviour in men. We hypothesized that baseline testosterone would be positively related to persistence behaviour. We also hypothesized that competitive outcomes and testosterone reactivity to these competitive outcomes would predict persistence behaviour. Similar to Carré and colleagues (2013), this hypothesis holds that winners would show an increase in testosterone that would in turn be associated with greater persistence, whereas losers would show decreases in testosterone that would be associated with less persistence. However, on the basis of the work by other researchers (e.g. Mehta & Josephs, 2006), we also considered the possibility that variability in testosterone reactivity within winners and losers may predict persistence as well. To test these hypotheses and aims, the present research randomly assigned men to win or lose a competition with a confederate, or complete the competitive task alone, with salivary testosterone measured before and after the task. Then, as a measure of persistence, participants were timed at how long they persisted in attempting to solve puzzles with no possible solution.

METHOD

Participants and design

Because of recent work suggesting that testosterone responses to competition predict subsequent aggression in men, but not women (Carré et al., 2013; Carré, Putnam, & McCormick, 2009), we recruited only male participants. Participants were 118 undergraduate men ($M_{age} = 20.28$, $SD = 2.06$) who participated for partial course credit. The sample was diverse, consisting of 41.5% Caucasians, 20.3% African American, 9.3% Asian, .8% Native American, 10.2% Middle Eastern, 5.1% Multiracial and 10.2% others. Power analyses (G*power 3; Faul, Erdfelder, Lang, & Buchner, 2007) using the metric of Pearson's r and a two-tailed alpha of .05 indicated that this sample size is adequately powered to detect large effects ($r = .50$, power .99) and medium-sized effects ($r = .3$, power = .92), but not small effect sizes ($r = .1$, power = .19). Participants were randomly assigned to lose a number tracing task (NTT) (Schultheiss, Campbell, & McClelland, 1999) competition against a confederate, win an NTT competition against a confederate, or a control condition where participants performed the NTT alone, thus not competing.

Materials and procedure

Participants arrived in the laboratory and provided informed consent. Participants then provided saliva samples via passive drool into a polystyrene tube. These samples were later assayed for testosterone concentrations. To limit the effects of diurnal variation on testosterone concentrations, all participants were run between the hours of 11 am and 5 pm.

Number tracing task

Participants were taken to the testing room and seated in front of another participant they would compete with, who unbeknownst to them was a confederate. Participants then competed with the confederate to solve the NTT puzzles first. This task consists of 10 puzzles, each containing a grid of numbers. Participants were instructed to trace through the numbers in ascending order as fast and as accurate as possible until a highlighted number is reached. The first person that reached the highlighted number won the specific round. However, as an experimental manipulation of competitive outcome, the competition was rigged so that half of participants won seven out of 10 matches (win, $N = 40$), another half won three out of 10 matches (lose, $N = 40$). A separate group of participants were randomly assigned to a control condition where they performed the NTT alone ($N = 38$). Regardless of condition, all participants were told that performance on the NTT 'has been linked to important outcomes including IQ, leadership skills and social status'. Participants completed filler questionnaires for 10 min after completing the NTT and provided a second saliva sample via passive drool.

Persistence task

The researcher then told the participant that the next part of the study would involve collecting preliminary data for another study investigating problem solving ability. Specifically, participants were told that they would be helping the researchers determine if high school and university students differed in their problem solving abilities. Unlike the NTT, participants were not informed that their performance on the persistence task was relevant to their intelligence, leadership skills or social status. The problem solving task was adapted from Baumeister et al. (1998). This task consisted of geometric figures that participants were instructed to trace with a line without retracing or stopping the line. Participants traced these shapes by drawing lines on images using the Microsoft Office Powerpoint® software (Microsoft One Microsoft Way Redmond, WA 98052–6399). To ensure that

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participants completed the task correctly, the researcher used the computer monitoring software Teamviewer® (TeamViewer Inc. 3001 N. Rocky Pt. Dr. E. Ste. 200 Tampa, FL 33607 USA) to watch all of the participants' actions from a separate computer. The participants were given two practice puzzles to complete that could be solved. However, all of the rest of the puzzles were impossible to solve. Participants were instructed to complete as many puzzles as they would like, and that they may ring a bell to signal the research assistant if they no longer wished to continue the task. The researcher used a stopwatch to track how long participants worked on the puzzles, and if the participants reached 30 min of puzzle solving, the researcher stopped the task. The amount of time spent on the unsolvable puzzles served as the measure of persistence. Participants, on average, used a moderate amount of this allowed time to work on the puzzles ($M = 17.27$ min, $SD = 9.09$), with 26 participants continuing to the maximum of 30 min.

Salivary samples and assays

Saliva samples were stored at −20 °C until assayed using commercially available enzyme immunoassay kits (DRG International (DRG International, Inc. 841 Mountain Avenue, Springfield, New Jersey 07081, USA)). Average intra-assay and inter-assay coefficients of variation were 9.19% and 16.59%, respectively.

Analytic strategy

Analyses of variance, analyses of covariance and regression analyses were used to evaluate effects of the experimental manipulation. Testosterone reactivity was also assessed using percent change scores, calculated as $((T2 - T1)/T1) \times 100$. Two participants had change in testosterone scores that were more than four SDs from the mean and were thus removed in analyses investigating testosterone reactivity. Inclusion of these outliers did not change the significance of any findings. Eight participants did not provide sufficient saliva for hormone assay. Because of a clerical error, time spent working on the persistence task was not recorded for two participants. Given the diurnal variation in testosterone, we also controlled for the time of day data were collected as a secondary analysis to the presented results.

In one case mentioned in the results, the data were found to violate the assumption of homoscedasticity in regression. Homoscedasticity, or the statistical assumption that the conditional variance of residuals is constant across all values of the predictor (Cohen, Cohen, West, & Aiken, 2003) can bias the estimates of standard errors, which impacts conclusions of statistical significance. To correct for these violations of assumptions, bootstrapping was used to verify the significance of these analyses. Bootstrapping is a nonparametric resampling procedure that is appropriate when data do not conform to the distributional assumptions of parametric statistical analyses or if distribution shapes are unknown (Adèr, Mellenbergh, & Hand, 2008; Wu, 1986). Bootstrapping randomly samples the original dataset with replacement to estimate a distribution of the tested statistical parameters. From these resampled distributions, confidence intervals can be generated to test hypotheses using the empirical bootstrap distributions generated from the resampling. Our bootstrapping analysis used 5000 bootstrapped iterations to generate 95% bias-corrected and accelerated confidence intervals to verify the results of our parametric analyses.

RESULTS

Correlations and descriptive statistics of the study variables are presented in Table 1. In addition to percent change in testosterone, we also computed testosterone reactivity by residualized changed (using regression to predict T2 from T1 and saving the unstandardized change. As is displayed in Table 1, all indices of testosterone change were highly consistent ($rs \geq .72$). Analyses conducted on residualized testosterone change did not alter the significance or pattern of any reported findings, with one minor exception where the association between testosterone reactivity and persistence was positive and significant in the control condition (Supporting information). Controlling for time of day did not alter the significance of any findings in the succeeding texts, and time of day did not moderate any of our findings (Supporting information).

Relationship between 'baseline' testosterone and persistence

Bivariate regression analysis revealed that men's baseline testosterone concentrations significantly predicted time spent working on puzzles, $\beta = .23$, $t(107) = 2.48$, $p = .015$, $R^2 = .05$. A scatterplot of this relationship is presented in Figure 1. This figure shows that the variability in time spent on the

Table 1. Correlations and descriptive statistics for study variables

	T1	T2	Persistence	%ΔT	ResΔT	M	SD
T1 (pg/mL)	—					107.58	56.41
T2 (pg/mL)	.66***	—				100.31	44.93
Persistence	.24*	.14	—			17.26	9.02
%ΔT	−.46***	.26**	−.07	—		.02	.34
ResΔT	.04	.78***	−.02	.72***	—	−.97	33.90

Note: T1, time 1 testosterone concentration; T2, time 2 testosterone concentration; persistence, time spent on the puzzles in minutes; %ΔT, per cent change in testosterone; ResΔT, residualized change in testosterone. These correlations reflect the relationships among the study variables when the 2 testosterone change outliers were removed.

$^{\dagger}p < .09$. $*p < .05$. $**p < .01$. $***p < .001$.

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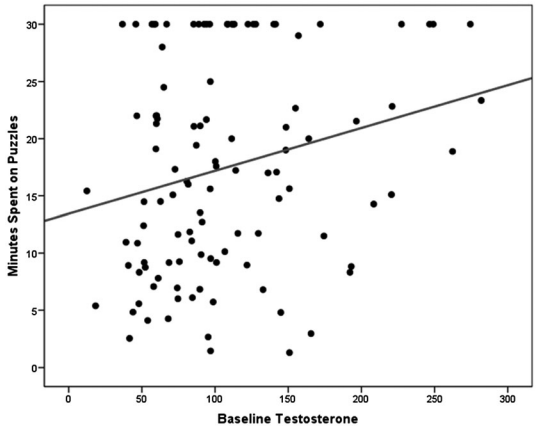

Figure 1. Persistence as a function of baseline testosterone.

puzzle is higher at low concentrations of testosterone compared with high concentrations of testosterone, indicating the presence of heteroscedasticity, a violation of the homoscedasticity assumption of regression analysis. To correct for this problem, we computed a 95% bias-corrected and accelerated bootstrapped confidence interval from 5000 resamples. This confidence interval did not include 0 (95% CI: .01, .06), indicating that testosterone significantly predicted time spent on the unsolvable puzzles. Although the relationship between baseline testosterone and persistence was only significant in the loss condition ($r = .38$, $p = .026$) and nonsignificant in the control ($r = .16$, $p = .345$) and win conditions ($r = .18$, $p = .274$), the effects were in a similar positive direction across conditions. Using moderated regression analysis to explore whether the simple slopes differed across all pairwise combinations of conditions revealed that the experimental conditions did not significantly moderate the relationship between baseline testosterone and persistence ($|t|$s $\leq .61$ ps $\geq .547$). Thus, the effect of baseline testosterone and persistence did not vary as function of experimental condition.

Effects of competitive outcome and testosterone reactivity on persistence

An analysis of variance revealed no effect of experimental condition on testosterone reactivity, $F(2, 105) = .67$, $p = .513$ (See Figure 2A). Another analysis of variance was used to test whether the experimental conditions affected persistence. No effect of experimental condition was found for persistence, $F(2, 111) = .59$, $p = .555$ (See Figure 2B). Because competitive outcome did not affect testosterone reactivity in this study, and testosterone reactivity did not predict persistence, testosterone reactivity was not examined as a mediator of the relationship between competitive outcome and persistence.

Because researchers have also examined whether testosterone reactivity within samples of winners and losers predicts willingness to compete again with others (e.g. Mehta & Josephs, 2006), we also examined whether testosterone reactivity within the experimental conditions predicted persistence. Testosterone reactivity was not found to predict persistence in the loss condition ($\beta = -.23$, $t(31) = -1.31$, $p = .198$), win condition ($\beta = -.08$, $t(36) = .25$, $p = .621$), or control condition ($\beta = .18$, $t(34) = 1.05$, $p = .302$).[2]

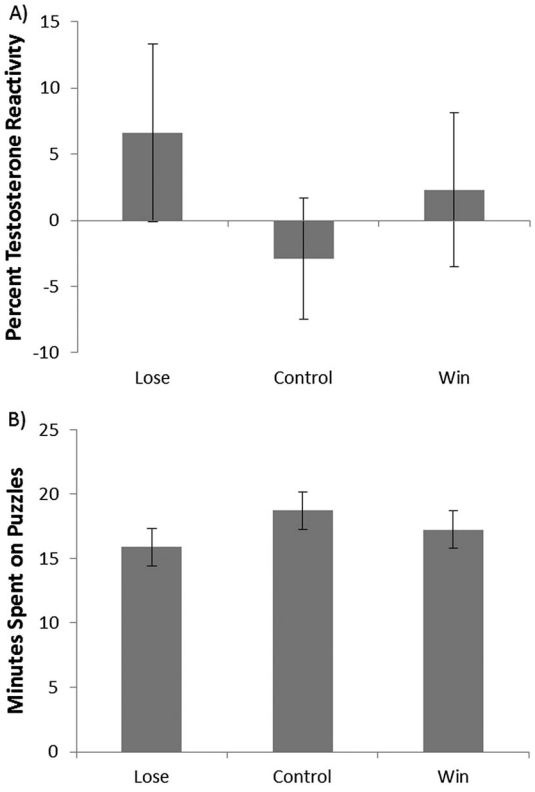

Figure 2. Mean percent testosterone reactivity and persistence as a function of experimental competition condition. Note: error bars represent standard errors of the mean.

DISCUSSION

The present research found that baseline testosterone concentrations predicted persistence on unsolvable puzzles in men. This is the first research to suggest that testosterone predicts persistence behaviour in men. These findings have implications for the link between testosterone and dominance, suggesting that high testosterone men are less likely to quit in the face of challenging task. Given the importance of persistence in accomplishing career and academic successes (McKeown & Lindorff, 2011; Reardon et al., 2010; Shalley et al., 2004), testosterone may be a useful predictor of whether individuals strive for higher social status through

[2]Because those in the winning and losing conditions showed nonsignificant, higher percent testosterone reactivity (Ms = .02 and .07, respectively) and decreased persistence (Ms = 17.25 and 16.15, respectively) compared with participants in the control condition (Ms = −.03 for T-reactivity and 18.42 for persistence), we tested planned comparisons where the values of testosterone reactivity and persistence in conditions with competition (win condition and loss condition combined) were compared with the values of those in the control condition. Testosterone reactivity ($t(105) = -1.06$, $p = .294$) and ($t(111) = -.02$, $p = .343$) persistence in the conditions where participants competed with others (win condition and loss condition combined) did not differ from participants in the control group. These comparisons were also nonsignificant for absolute and residualized testosterone reactivity (ps $\geq .333$).

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increased persistence. However, the causal direction of this relationship is unclear.

A wide range of literature suggests that testosterone reactivity can be modulated by competitive outcomes such as those of video games (Carré et al., 2013) and athletic competitions (see Archer, 2006 for meta-analysis). The current study used the NTT, which has been used in multiple studies examining relationships between hormones and competitive behaviour (e.g. Mehta & Josephs, 2006; Schultheiss et al., 1999). Although both Schultheiss and colleagues (1999) and Mehta and Josephs (2006) did not find that the NTT outcomes affect testosterone reactivity, Schultheiss and colleagues (1999) did find, however, that the effect of the NTT outcomes on testosterone reactivity is moderated by implicit power motive. On the other hand, Mehta and Josephs (2006) find that desire to compete again following a competitive loss is predicted by testosterone reactivity in losers. To the extent that choosing to compete again after a competitive loss is a measure of persistence behaviour—we expected to find a similar association in the current study. We suggest that it is possible that individual difference factors (e.g. power motive; Schultheiss et al., 1999) may play a key role in moderating the effect of testosterone reactivity on subsequent persistence behaviour. Future research will be required to test this possibility. On the basis of these findings and the current research, the relationship between testosterone reactivity and persistence may not occur in the manner of Carré and colleagues' observed effects of testosterone reactivity on aggressive behaviour (2009, 2013), but instead may be modulated by individual differences or specific competitive outcomes.

The current research did not find that testosterone reactivity to competitive outcomes predicted persistence. However, it is important to note that this may be due to the failure of the NTT to produce testosterone reactivity to competitive outcomes. Thus, it is possible that other researchers may find effects of testosterone reactivity on persistence using research paradigms that are potentially more robust modulators of testosterone reactivity than the NTT such as video game competitions (e.g. Carré et al., 2013) or aggressive provocation (Carré, Iselin, Welker, Hariri, & Dodge, in press). It is also possible that longer durations of testosterone reactivity assessment, occurring 15–20 min after the win or loss manipulation, may capture effects of testosterone reactivity from winning and losing the NTT. This possibility is unlikely, however, as previous work using the same task has reported decreases in T in male winners and losers when T concentrations were measured 15 min after the competition (Mehta & Josephs, 2006).

The current work features the largest known sample size used studying competitive outcomes and testosterone reactivity with the NTT and is the most adequately powered to test the effects of competitive outcome on testosterone reactivity. On the other hand, robust main effects of competitive outcome on testosterone reactivity have been observed in athletic competitions (e.g. Archer, 2006) and motion-controlled video games (Carré et al., 2013). It is possible that certain individuals are not as motivated to win the NTT compared with other competitive interactions, or that physically engaging tasks more robustly affect testosterone reactivity.

One limitation of the current research is that it did not measure whether individuals were sensitive to whether the puzzle task was unsolvable or not. Previous researchers have distinguished between *productive persistence*—persistence resulting in success—and self-defeating *non-productive persistence*—persistence resulting in frustration and wasted effort (e.g. Baumeister & Scher, 1988; McFarlin, Baumeister, & Blascovich, 1984). In particular, there are several individual differences that predict whether individuals engage in non-productive persistence, such as self-esteem (McFarlin, 1985), optimism (Aspinwall & Richter, 1999) and self-mastery (Aspinwall & Richter, 1999). In addition to measuring whether participants realize the puzzles are unsolvable, researchers of the relationship between testosterone and persistence may want to take these predictors into account.

A second limitation of the current study is that this work did not include a sample of women. The extent to which testosterone reactivity and/or baseline testosterone concentrations predict persistence behaviour in women is not clear. Previous work indicates that relationships between testosterone reactivity and aggressive behaviour in women are small and nonsignificant, compared with men (e.g. Carré et al., 2009, 2013). However, other research indicates that baseline testosterone concentrations in women can predict competitive performance (Mehta, Wuerrhman, & Josephs, 2009) and decision making (Mehta, Jones, & Josephs, 2008). Previous work suggests that women are more prone to distraction on an attentional task compared with men, (Stoet, 2010). To the extent that persistence is negatively related to distraction (as suggested by research in animal models), we may predict that individual differences in testosterone may also underlie one's ability to resist distraction and persist towards a goal/reward (e.g. solving a difficult puzzle). Thus, it will be important for future work to examine the extent to which men and women differ in their persistence behaviour on the puzzle solving task, and whether variation in testosterone concentrations partially mediate the effect.

Although the correlational nature of the relationship between baseline testosterone concentrations and persistence limits our ability to make strong causal claims, the reported relationship suggests that high testosterone may contribute to persistence behaviour—a key factor involved in the attainment of social dominance. However, it is important to note that despite the observed relationship between testosterone and psychological dominance (Archer et al., 2005), high testosterone males have been found to hold lower occupational statuses (Dabbs, de la Rue, & Williams, 1990). Although persistence may be a status-seeking behaviour, not all persistence behaviours may actually result in increased status. For instance, in the face of obstacles, some individuals may persist antisocially (e.g. pestering a rejecting employer and harassing a former romantic partner after rejection), whereas others may not persist antisocially (e.g. continuing to apply to other jobs and seeking out a different partner). Therefore, future research is needed to determine moderators and predictors of whether individuals will persevere prosocially or antisocially, and whether persistence is likely to result in success.

Additionally, future work is needed to investigate the potential moderating role of social context in these findings.

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Previous work suggests that basal testosterone is associated with decreased cognitive performance when social contexts are cooperative in nature (Mehta et al., 2009). This concept is supported by work demonstrating that testosterone decreases cooperation by promoting egocentric decision making (Wright et al., 2012). The present study suggests that basal testosterone is positively associated with persistence behaviours, but these findings occur in the context of a competitive task. Thus, it is possible that testosterone may be inversely related to persistence when in the context of collaborating with others. Relatedly, if participants were also informed that the persistence task was indicative of how individuals work well with others, testosterone may be negatively associated with persistence on this task.

Broadly, the construct of persistence also needs to be further developed by researchers. Although this study assessed persistence on a puzzle task, other researchers of persistence behaviours have operationalized persistence in other ways, such as the extent to which chicks search for food (Andrew & Rogers, 1972), individuals' perseverance and passionate for long-term goals (Duckworth et al., 2007), maintaining performance over long periods of work (Johnson & Layng, 1992) or time spent solving mathematics puzzles (Battle, 1965). On the other hand, it is also possible that assessments of distractability (e.g. Stoet, 2010) also capture the absence of persistence. The results of this study show that men's baseline testosterone concentrations predict one of these operationalizations of persistence. However, given that testosterone is broadly thought to be related to a host of status-seeking behaviours (Eisenegger, Haushofer, & Fehr, 2011; Mazur, 1985; Mazur & Booth, 1998; Mehta & Josephs, 2006; Wingfield et al., 1990), testosterone may indeed be related to other forms of persistence, such as to acquire resources (e.g. money or employment) or academic achievement.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's web-site.

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