Supplemental Materials

The Causal Effect of Testosterone on Men's Competitive Behavior is Moderated by Basal Cortisol and Cues to an Opponent's Status: Evidence for a Context-Dependent Dual Hormone Hypothesis

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Supplementary Methods

Participants

Exclusion Criteria.

We briefly reported screening and recruitment procedures in the main document. Here we provide a full list of exclusion conditions in the screening process. After being read the list, the participants self-reported if any of the conditions were true in a pre-experiment phone call:

- Student-athlete or other professional for whom steroid hormone use is prohibited.
- Mental illness, including recurrent major depression, antisocial personality disorder, Schizophrenia, bipolar disorder, Tourette's syndrome, conduct disorder, serious emotional disturbance, intermittent explosive disorder
- Alcohol or drug dependency, including opiates, LSD, methamphetamine, cocaine, solvents, cannabis, or barbiturates
- A major neurologic condition such as recent head injury with loss of consciousness, tumor, stroke, or other brain lesions.
- History of autonomic failure
- History of clinically significant liver, heart, lung, obstructive respiratory, kidney, cerebrovascular disease, or metabolic syndrome
- Current periodontitis
- Diabetes
- Irregular sleep/wake rhythm (e.g., regular nightshifts or cross timeline travel)
- Any hormone disorders
- Any immune disorders
- Medical conditions affecting testosterone concentrations (such as hypogonadism or prostate cancer), taking psychotropic medications (such as SSRIs), or receiving medical treatment for conditions affecting cerebral metabolism and blood flow (such as hypertension)
- Receiving psychiatric treatment
- Receiving endocrine treatment, such as hormone replacement therapy
- Regularly using corticosteroids, like hydrocortisone
- Regularly using anabolic steroids

Participants who acknowledged that any of these situations, conditions, or disorders were true were excluded from recruitment for participation in the study.

Participant Diversity

We aimed to maximize the diversity of our sample by recruiting participants on campus and within the community. Participants self-reported race/ethnicity information, their current student status and educational attainment, and several indicators of objective socioeconomic status (i.e., parents' and own education level and the estimated annual income of the participant, his parents, and his family). Over 28% of our sample identified as non-white, which generally reflects the diversity of the community in which the experiment was run (26.7% non-white; (United States Census Bureau, 2010). A majority of the participants reported being a current student (94%) but the range of degrees attained varied, with 73% reporting have not received a

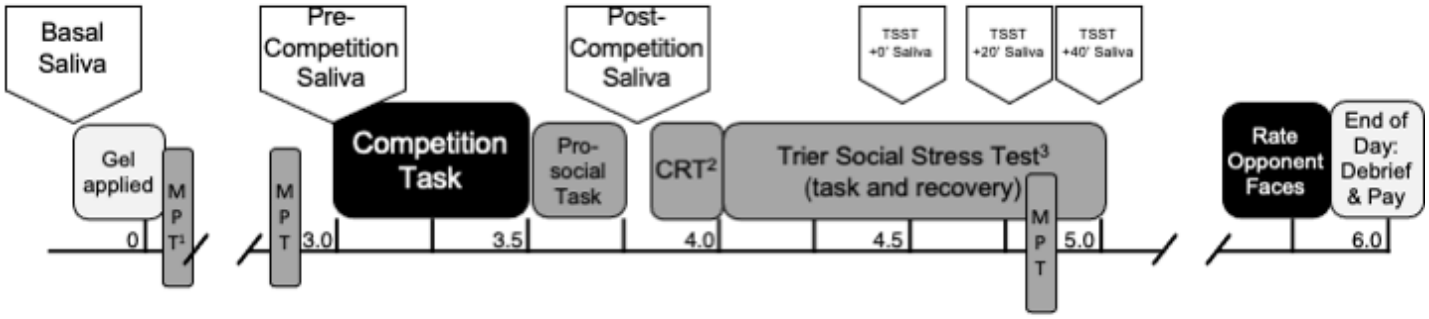

Figure S1. Timeline of experimental protocol. Time is listed in hours from gel application and are approximations. Black boxes with white font are the portions of the protocol during which data were collected for this report. Saliva samples (downward-pointing pentagons) analyzed in the present report were collected at three time points; three additional timepoints (smaller pentagons) associated with a stress task are reported elsewhere (the post-competition saliva sample was labeled as "Pre-stress" in one prior report; Knight et al., 2017). The pro-social task consisted of a dictator game decision-making task (unpublished). MPT = motivated persistence task, in which participants are asked to squeeze a hand-grip device for as long as they can. Instructions for each task were given immediately prior to the start of each task, with the exception of the competition and pro-social tasks, which were described approximately an hour prior to the start of the competition task (not pictured). No instructions or detailed descriptions of task were given prior to the collection of basal saliva. Prior reports (denoted with superscripts): 1) Knight, 2017; 2) Knight, McShane, et al., 2020; 3) Knight et al. 2017

post-secondary degree. Our sample also self-reported relatively diverse socioeconomic demographics, including a wide array of parental educational attainment (e.g., 49% of mothers obtained less than a college degree) and annual incomes (e.g., 33% of participants' family annual incomes reported below $50,000; Table S1).

Protocol

Timeline

We have included a timeline of the full-day experimental protocol (Figure S1).

Competition Task Tutorial

As part of the competition task, participants were guided through a tutorial of the task and completed an in-person, multiple-choice, verbal quiz based on the information covered in the tutorial. If a participant gave an incorrect answer, the experimenter provided feedback and described why his answer was incorrect. The quiz consisted of the following questions:

1. In COMPETE rounds, how much money can you earn?
    a. $4 per point
    b. $4 per point, but only if you win that round
    c. $4 total
    d. $4 total, but only if you win that round

2. In PIECE RATE rounds, how much money can you earn per point?
    a. $2 per point, but only if you win that round
    b. $2 per point
    c. $4 total
    d. $2 total

3. Describe a mandatory compete round
    a. A round where the computer chooses for you to compete
    b. A round where you have chosen to compete
    c. A piece rate round
    d. Any round where you competed

4. What happens after the feedback portion where you make choices to either compete again or play for a piece rate?
    a. The experiment ends.
    b. You then play out all of your choices.
    c. You then play out one randomly drawn choice.

5. How will you be paid based on your decisions in this task at the end of the day?
    a. I will not be paid based on my decisions in this task.
    b. I will be paid based upon my total earnings in this task.
    c. I will be paid one round from each condition selected at random, plus the round after the feedback portion.

Participants did not finish the tutorial until all questions had been successfully answered.

Subjective Ratings of Opponents.

To investigate gender differences in subjective ratings of opponents, we submitted participants' ratings and the follow-up sample's ratings to separate multilevel models for each rating. In order to account for variance due to rater and target and avoid problems inherent to arbitrarily aggregating across raters or targets (Judd et al., 2012), we included a random intercept and slope for gender for each participant and a random intercept for each opponent. Thus, for opponent *i* and participant *j*, our models consisted of the following:

Level 1:

$$Rating_{ij} = \beta_0 + \beta_1 Gender_i + r_{ij}$$

Level 2:

$$\beta_0 = \gamma_{00} + e_{0i} + e_{0j}$$

$$\beta_1 = \gamma_{10} + e_{1j}$$

In a follow-up analyses, we examined the effect of opponent gender controlling for the prior competition outcome (win = 1, loss = 0) and, combining data across both sets of raters, we included a term to denote which sample a rater was from (testosterone administration participant versus follow-up male sample) and the cross-level interaction between sample and gender.

Power Simulations

We examined the power to detect a range of possible logit effect sizes associated with the three-way interaction between testosterone treatment, cortisol, and opponent status (defined by opponent gender or prior win/lose feedback) given a sample size of n = 120 split evenly between treatment groups and assuming weak effects (logit(p) = 0.2) for all lower-order main effects, interactions, and covariates. Cortisol was simulated as a normally distributed variable across the sample. Random intercepts and slopes (i.e., for the effects of opponent status and public/private trials) per participant were included with assumed covariance of 0 and variance of 0.5 for each random variable. The model was simulated 1000 times at each logit value between logit(p) = 0.2 and logit(p) = 1.0 in increments of 0.1. Each model contained k = 16 simulated trials (50% lower status opponent) for each participant. Results from these simulations indicate that the experiment was 80% powered to detect a three-way interaction of logit(p) = 0.7 (OR = 2.0; Figure S2). When Fisher's Z estimates of this effect and a prior correlational study (Mehta & Josephs, 2010) were calculated, the effect size that the experiment was 80% powered to detect (Fisher's Z = 0.250) was determined to be smaller than the prior correlational results (Fisher's Z = 0.303).

For comparison to a one-shot competition task, in which a participant makes a single decision to compete or not, we ran a simulation that mirrored our principal simulations. We examined a simulated sample of n = 120 participants split evenly between testosterone treatment and placebo. Cortisol values were randomly generated from a standard normal distribution. Half of the participants were assumed to be exposed to a high-status opponent and half to a low-status

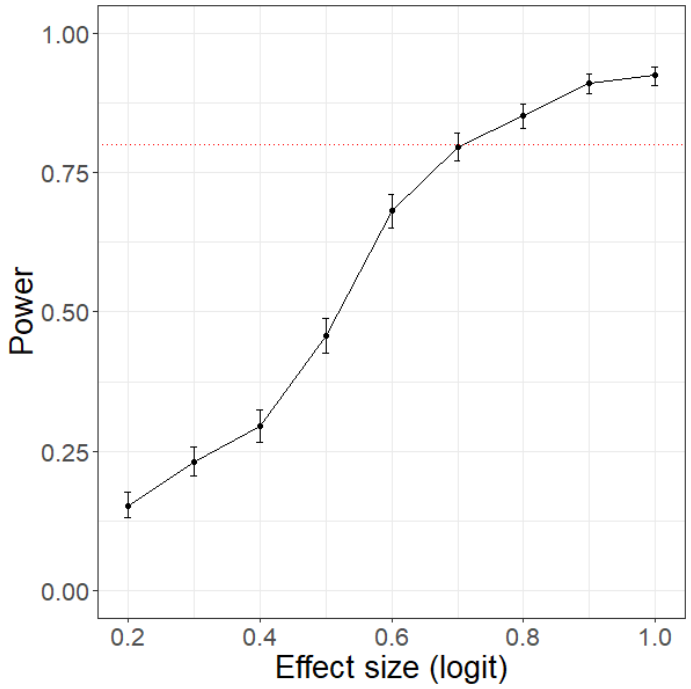

Figure S2. Power simulation results. Red dotted line indicates 80% power. Error bars represent 95% confidence intervals of the power to detect a given effect size. See OSF page for code to run this simulation.

opponent. We used the results from the simulation above (i.e., logit(p) = 0.7) as coefficient for the three-way interaction between testosterone treatment, cortisol, and opponent status within a (single-level) binomial linear regression model. The results from this comparison simulation indicate that a one-shot study design would have had 10.6% power to detect the effect that our principal simulations indicate that we were 80% powered to detect in our within-subjects approach. Hence, although evidence indicates that higher-order interactions are generally underpowered in the social psychological literature (Blake & Gangestad, 2020), the within-subjects approach helps maintain high power.

Supplementary Results

Hormone Concentration Distributions

We measured testosterone and cortisol in saliva collected at baseline (i.e., basal measures), immediately before, and approximately 15 minutes after the competition task. Distributions of raw testosterone and cortisol concentrations for each of these samples are illustrated in Figure S3.

Main Effects Not Reported in the Main Document

Basal Cortisol

Basal cortisol was not robustly associated with decisions to compete in the initial phase (*OR* = 1.22, [0.86, 1.73], *p* = .273) or in the feedback phase of the competition task (*OR* = 1.29, [0.93, 1.79], *p* = .124).

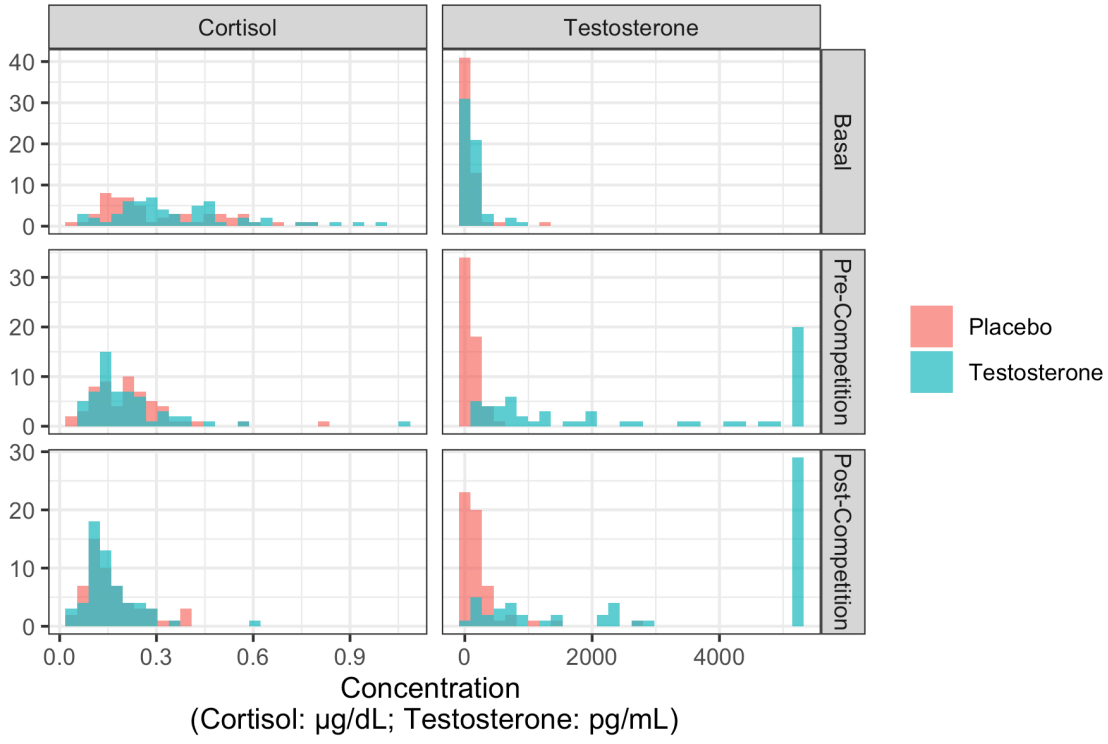

Figure S3. Distribution of hormone concentrations at three time points.

Blinding Manipulation

We examined the direct effect the experimental blinding manipulation – that is, a participant being told whether they had received testosterone or placebo or not – had on decisions to compete. The experimental blinding manipulation did not affect decisions to compete in the initial phase (OR = 1.07, [0.55, 2.07], p = .841) or in the feedback phase of the competition task (*OR* = 0.82, [0.42, 1.61], *p* = .572).

Social-Evaluative Manipulation

As discussed in the main document, the experimental task attempted to manipulate social-evaluation by including public and private conditions within the competitive task (Cottrell et al., 1968; Grush, 1978). We explored whether a social-evaluative condition might enhance testosterone's effects on behavior based on prior theorizing that testosterone directs motivations and behavior meant to seek or maintain social status. Specifically, having an audience was predicted to boost the stakes of the competition for men given testosterone treatment in terms of the competition's effect on social status. We therefore included this manipulation (i.e., the words "Public" or "Private" with open or closed eyes on the screen; Haley & Fessler, 2005) as an exploration of the extent to which having an evaluative audience might alter testosterone treatment's effects on decisions to enter competitions and decisions to re-enter competitions after feedback.

The social-evaluative manipulation did not moderate testosterone treatment's direct effects on decisions to enter competitions (T × Social Evaluation: *OR* = 0.76, 95%CI[0.47, 1.23], *p* = 0.262), did not moderate the interactive effects of testosterone treatment and basal cortisol (T × Cortisol × Social Evaluation: *OR* = 0.79, 95%CI[0.47, 1.32], *p* = 0.369) or opponent gender (T × Opponent Gender × Social Evaluation: *OR* = 0.68, 95%CI[0.27, 1.70], *p* = 0.410), and did not moderate the three-way interaction between testosterone treatment, basal cortisol, and opponent gender (T × Cortisol × Opponent Gender × Social Evaluation: *OR* = 1.50, 95%CI[0.56, 4.01], *p* = 0.422).

Similarly weak effects were found in the feedback portion of the experiment, in which the social-evaluative manipulation did not moderate testosterone's direct effects on decisions to re-enter competitions (T × Social Evaluation: *OR* = 0.87, 95%CI[0.50, 1.50], *p* = 0.610), did not moderate the interactive effects of testosterone treatment and basal cortisol (T × Cortisol × Social Evaluation: *OR* = 0.72, 95%CI[0.40, 1.27], *p* = 0.254) or prior competitive outcome (T × Prior Outcome × Social Evaluation: *OR* = 2.29, 95%CI[0.72, 7.32], *p* = 0.161), and did not moderate the three-way interaction between testosterone treatment, basal cortisol, and prior competitive outcome (T × Cortisol × Prior Outcome × Social Evaluation: *OR* = 0.67, 95%CI[0.18, 2.50], *p* = 0.550).

These null effects of social evaluations on testosterone's effects on behavior may be interpreted in several ways; we provide a non-exhaustive list here to help inform future research on the topic. First and most parsimoniously, perhaps testosterone's effects on competitive behavior are not altered by cues that indicate social evaluation, in line with some recent work on competitive motivation (Losecaat Vermeer et al., 2020) but in contrast to other recent work on charitable donations (Wu et al., 2020). Second, the manipulation itself may have failed to elicit the desired feelings of social evaluation. That is, there may be effects of social-evaluative versus non-social evaluative competitions, but our manipulation failed to evoke the desired valence or magnitude of an effect. Finally, the social-evaluative cues may have altered behavior in some

complex, interactive way that our study was underpowered to test. Future research might consider examining more explicit social-evaluative conditions (i.e., having rounds of competitions with an experimenter or other participants in the room versus playing competitions alone) and running larger studies to better estimate the effects of social-evaluative contexts on testosterone's link with social behaviors.

Dual-hormone Effects with Other Cortisol Measures

Exploratory analyses revealed an unexpected, weak testosterone treatment × cortisol change interaction on decisions to compete (Initial phase: *OR* = 2.22, [1.07, 4.58], *p* = .032; Feedback phase: *OR* = 2.28, [0.92, 5.67], *p* = .077; Tables S6 and S7). When the models were re-run without moderation by opponent status cues as an exploratory follow-up, the testosterone treatment × cortisol change interaction effects were somewhat weaker and non-significant (Initial phase: *OR* = 1.95, [0.99, 3.84], *p* = .055; Feedback phase: *OR* = 1.80, [0.90, 3.61], *p* = .095). The pattern of this interaction indicates that men given testosterone treatment with relatively high cortisol change (i.e. less of a circadian decline or a slight increase in cortisol) were more likely to compete, whereas men given testosterone with relatively low cortisol change (circadian decline in cortisol) were less likely to compete.

This weak interaction effect may be interpreted in several ways; we provide a non-exhaustive list of challenges with interpretation to help inform future research. First, this interaction may be a false positive; after all, it was unexpected, weak, and not robust in all analyses. Second, if this interaction is real, the causal direction is unclear. That is, it is not clear if testosterone interacted with cortisol change to influence competitive behavior, or perhaps testosterone interacted with competitive behavior to influence changes in cortisol in response to the competitive task. Third, cortisol decreased, on average, from before to after the competitive task consistent with circadian decline (Table S1). Thus, it remains unclear whether these cortisol changes were influenced by the competitive task at all or whether they were influenced primarily by circadian rhythms. Further complicating the interpretation is the unrelated decision-making task that occurred immediately after the competition task and immediately before the final cortisol measure. Future work interested in examining testosterone treatment's interaction with cortisol change dynamics as predictors of competitive decision-making will require study designs that measure or manipulate acute cortisol change prior to a competitive decision-making task (Prasad et al., 2017, 2019).

Replication of Testosterone Treatment, Basal Cortisol, and Opponent Status Interactions Across Blinding Conditions

In the main document, we reported analyses controlling for blinding condition. Here we examine the four-way interactions among testosterone treatment condition, basal cortisol, opponent status (opponent gender or prior outcome), and blinding condition. This four-way interaction was not robust in the initial phase (*OR* = 0.97, [0.32, 2.95], *p* = 0.954) or in the feedback phase (*OR* = 0.78, [0.02, 25.81], *p* = 0.891). Further, when point estimates of the three-way interactions were investigated after splitting the sample by blinding condition, the pattern of effects was evident across each condition (initial phase, double blind: *OR* = 2.84, [1.23, 6.56], *p* = 0.015; initial phase, single blind: *OR* = 2.70, [1.25, 5.83], *p* = 0.011; feedback phase, double blind: *OR* = 9.77, [1.07, 89.33], *p* = 0.044; feedback phase, single blind: *OR* = 11.43, [0.68,

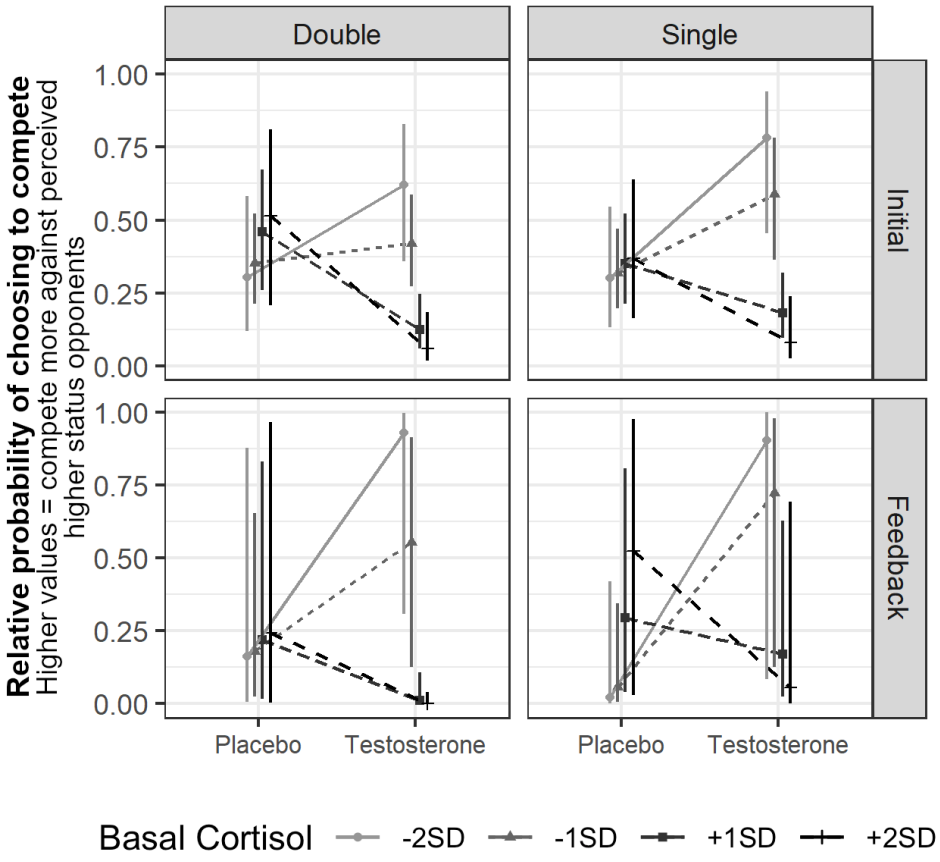

Figure S4. The simple slopes comparing probabilities of competing against high and low status opponents plotted for the testosterone and placebo groups at +/-1 and 2 SD. Higher values indicate a higher probability of competing against male opponents compared to female opponents in the initial phase and a higher probability of competing against prior winners compared to prior losers in the feedback phase. Probabilities were calculated from simple slope logits extracted from the three-way interactions. For illustrative purposes and to better match the prior literature, the probabilities were inverted (i.e., "1 – *p*(Compete)"). A probability of 0.50 (marked by the dotted line) indicates no preference for competing against higher or lower status opponents. Error bars represent 95% confidence intervals.

191.9], $p = 0.091$; Figure S4). These analyses demonstrate that the context-dependent dual-hormone hypothesis replicated internally across two experimental blinding conditions, indicating the robustness of this complex pattern of results.

Trait Dominance

We explored trait dominance as a moderator of testosterone's effects on decisions to compete in both phases of the competition task. None of the analyses provided strong evidence that trait dominance moderated the effect of testosterone on men's decisions to compete, either alone or in interaction with basal cortisol or opponent status cues (Table S9).

Subjective Ratings of the Opponent

The main document reports the effects of opponent gender on ratings of whether an opponent was "good at…math." Here we report eight other variables on which the participants rated opponents: Attractive, dominant, intelligent, mature, warm, "I feel close to this person," respect, and "I performed better than this person in the competition." Among these rating categories, only "I performed better" was associated with a robust effect of gender – participants rated female opponents as higher on this variable (B = 0.35, [0.14, 0.56], p = .013), indicative of having performed better than female opponents on average (Table S10B). The remaining variables were estimated with relatively high variance among participants, suggesting that participants did not readily agree on gender stereotypes among the remaining variables.

Model Fit Statistics

We report model fit statistics (AIC and BIC) for each of the principal models (Table S12). In each phase of the task, the context-dependent dual-hormone hypothesis model (that is, the model that contained the testosterone treatment by basal cortisol by opponent status interaction term) was considered the best fitting according to having the lowest AIC score. BIC penalizes model complexity more than AIC and so higher-order interaction models had consistently higher BIC scores than lower-order models. Of the three-way interactions modeled in the feedback phase (that is, testosterone treatment × basal cortisol × opponent gender or prior win/lose), the interaction with prior win/lose was found to be better fitting (lower BIC score) than the opponent gender model, suggesting prior win/lose is the more parsimonious result of the two.

Supplementary Discussion

The results of this experiment support the context-dependent dual-hormone hypothesis in showing that the causal effects of testosterone on competitive decisions depend on basal cortisol levels and two opponent status cues (opponent gender and win/lose feedback). Future research will be helpful for confirming the nature of the three-way interactions. The patterns reveal an internal replication of the context-dependent dual-hormone interaction as demonstrated by the meta-analysis, the global patterns shown in Figure 4, and the point estimates in the simple slopes analyses.

There was also a pattern in the simple slopes analyses suggesting that the influence of testosterone treatment (versus placebo) on decisions to compete against female relative to male opponents was somewhat stronger for the high-cortisol side of the basal cortisol distribution, whereas the influence of testosterone treatment (versus placebo) on the propensity to re-compete against low-status opponents (prior losers) relative to high-status opponents (prior winners) was somewhat stronger for the low-cortisol side of the distribution. We interpret these slight differences as driven by noise that is unlikely to be theoretically meaningful. We draw this conclusion for the following reasons. First, the overall patterns of the three-way interactions were clearly very similar as revealed in Figure 4. Second, our best guess for any particular effect is the point estimate, and the point estimates in the simple slopes analyses indicate that the three-

way interactions were driven by both the low- and high-cortisol sides of the basal cortisol distribution. Third, which side of the basal cortisol distribution showed a somewhat stronger effect of testosterone was different in the two three-way interactions, indicating that the patterns were unstable and did not replicate. Fourth, there is no strong theoretical reason to expect divergent patterns in the two three-way interactions, whereas there is reason to expect slight differences in patterns due to normal statistical variation. We welcome additional studies that further investigate these three-way interactions.

Cues to Perceived Opponent Status in Other Domains

Some evidence suggests humans infer status by a universal set of gender-differentiated characteristics (Buss et al., 2020; Durkee et al., 2020), but the exact cues that signal perceived status in a competitive setting likely depend on the nature of the competition. A competition based on a domain in which women are stereotyped to be more skilled than men – for example, based on word puzzles or other verbal task instead of math (Dreber et al., 2014; Hausmann et al., 2009; Josephs et al., 2003; Niederle & Vesterlund, 2011; Wozniak et al., 2014) or based on a jewelry-making task instead of physical strength in a hunter-gatherer population (Apicella & Dreber, 2015) may cause men with high testosterone and high cortisol levels to pursue male opponents as easy targets and avoid female opponents. Given our 1) theorizing on testosterone-cortisol profiles producing status-seeking versus status-loss avoidance motivation, 2) our focus on context-dependence, and 3) the results indicating the impermanence of subjective status cues, we believe it is likely that testosterone and cortisol will flexibly direct decisions to compete based on domain-specific stereotypes, rather than generally targeting women. Future research that includes multiple competitive domains will be able to test this possibility directly.

Trait Dominance

Exogenous testosterone's effects on decisions to compete did not appear to be moderated by trait dominance in the present experiment. An interaction between testosterone and trait dominance was explored because of prior work suggesting that testosterone's effects on status-relevant behavior (Carré et al., 2009, 2017; Losecaat Vermeer et al., 2020; Mehta et al., 2015; Slatcher et al., 2011) and on responses to status-relevant stress (Knight et al., 2017) are heightened among individuals who are high in trait dominance. However, as discussed in the main document (Methods section), other findings within this domain are nuanced. For instance, trait dominance interactions with exogenous testosterone may be specific to certain contextual aspects of a competitive setting (Losecaat Vermeer et al., 2020), may operate as part of a broader set of risk factors (Geniole et al., 2019), or may not be evident (Kutlikova et al., 2021; Welker et al., 2019). In at least two instances, an overall interaction term between testosterone and trait dominance (and cortisol) was not-significant but follow-up analyses suggested that an effect of testosterone (and cortisol) was more evident among men who are higher in trait dominance (Losecaat Vermeer et al., 2020; Pfattheicher, 2017).

Several factors may help explain the nuanced results in the literature and the lack of robust effects in the present experiment. First, the focus on testosterone and trait dominance is relatively less developed than other theoretical frameworks such as the challenge hypothesis or the dual-hormone hypothesis. As such, the known findings on testosterone's interactions with

trait dominance may be part of an initial exploratory phase for the field before more and larger studies can provide a better understanding of the theoretical framework. The relatively small size of the literature also leaves open the possibility that the initial effects reported may be prone to publication bias.

Second, the definition of trait dominance, and in turn, the scale used to measure trait dominance varies across studies. This possible "jingle fallacy" – in which separate psychological constructs are given the same name despite inherent differences (Block, 1995) – could lead to inconsistent findings in the field. In the present experiment, we used a trait dominance scale based on a definition of dominance as the use of force, fear, and intimidation to earn status (Cheng et al., 2013; e.g. "I am willing to use aggressive tactics to get my way."). Prior research indicates that trait dominance measured with this scale moderated the effect of exogenous testosterone on aggressive behavior (Carré et al., 2017; Geniole et al., 2019) and emotional states related to aggression such as hostility (Knight et al., 2017), but not other types of status-relevant behaviors such as competitive persistence (Kutlikova et al., 2021). Other researchers have employed trait dominance scales that focus on assertiveness and a desire for positions of authority and status, rather than force, fear tactics, and intimidation (e.g., the PRF dominance scale, "I would like to be an executive with power over others"; Jackson, 1984). Trait dominance measured with these scales did show some evidence of strengthening testosterone's effects on competitive behavior (Losecaat Vermeer et al., 2020; Mehta et al., 2015; Slatcher et al., 2011). Based on this pattern of results, trait dominance measured with scales that focus dominance as the use of force, fear, and intimidation to gain high rank may be more likely to heighten the effects of testosterone in studies that measure these types of anti-social dominant behaviors (e.g. aggressive behavior). But trait dominance measured with scales that focus on a desire to attain high-status positions may accentuate testosterone's effect on behaviors such as competitive decision-making (Mehta et al., 2015). However, no work to our knowledge has rigorously examined testosterone's interactions with various measures of trait dominance across different types of status-relevant behaviors.

Third, the psychopharmacogenetic approach used by Geniole and colleagues (2019) also found that trait dominance worked within a broader personality risk factor that accentuated the effects of testosterone on aggressive behavior. As discussed in the main document, this same experiment did not find a significant moderating effect of trait dominance on its own, although the effects were of a similar magnitude and direction as the broader personality risk factor. Combined with our speculation above about measurement of trait dominance, these results suggest that a broader approach that combines dominance-relevant traits may be necessary to find stable moderating influences of explicit, self-reported personality constructs on testosterone's association with behavior. By examining only one scale that may be part of a broader personality risk factor, results may be prone to instability.

Fourth, in this same psychopharmacogenetic work (Geniole et al., 2019), testosterone and trait dominance's effects on aggressive behavior depended on a gene polymorphism that alters efficacy of the androgen receptor [the cytosine-adenine-guanine (CAG) repeat in exon 1 of the androgen receptor]. Fewer CAG repeats, reflective of more effective androgen receptors (Chamberlain et al., 1994), heightened the interactive effects of testosterone treatment and trait

dominance on aggressive behavior. Hence, trait dominance's interactions with testosterone may further depend on factors that were not measured in the present experiment.

This non-exhaustive and non-exclusive set of possibilities suggests that more work is necessary. Work focused on these issues may need to administer several forms of explicit trait dominance, other related personality measures, consider other relevant moderators (e.g. androgen receptor gene) within varying behavioral assays to improve our understanding of trait dominance and its interactions with endocrine systems. Studying multiple forms of trait dominance across multiple behavioral assays will also help determine the specificity (or malleability) of the putative interactions between trait dominance and testosterone. Research could also attempt to experimentally heighten or reduce trait dominance levels (Roberts et al., 2017) in order to better understand causal, mechanistic pathways linking testosterone, cortisol, and trait dominance with status-relevant behavior.

Supplementary Tables

Table S1. Indicators of racial/ethnic and socioeconomic diversity

Self-identified Race/Ethnicity	
White/European-American	73%
African-American	2%
Asian/Asian-American	12%
Hispanic/Latino	8%
Middle Eastern/Middle-Eastern American	3%
Native American	1%
Pacific Islander	1%
Other	2%
Total non-white	28%

Education[1]	**Mother**	**Father**	**Self**
Some high school	8%	7%	
High School diploma or GED	18%	14%	73%
Some college	10%	13%	
Associate degree	13%	6%	16%
Bachelors degree	34%	32%	8%
Masters degree	11%	12%	1%
PhD or Professional School degree	6%	14%	1%
Unsure or do not know	0%	2%	

Income	**Mother**	**Father**	**Self**	**Family**
<$24,999	32%	13%	86%	15%
$25,000 to $49,999	27%	17%	3%	18%
$50,000 to $74,999	21%	18%	2%	8%
$75,000 to $99,999	9%	14%	0%	8%
>$100,000	8%	32%	0%	41%
Unsure or do not know	3%	7%	10%	20%

Note:

1. Response options to questions about parent and own educational attainment differed. Blank cells in the "Self" column were not available options for participant responses.

Table S2: Effects of testosterone treatment, basal cortisol, and opponent gender on initial phase decisions to enter competitions

	Decisions to compete: Main Effects			Decisions to compete: T/P × Cortisol			Decisions to compete: T/P × Gender			Decisions to compete: T/P × Cortisol × Gender		
	Odds Ratio	*CI*	*p*	*Odds Ratio*	*CI*	*p*	*Odds Ratio*	*CI*	*p*	*Odds Ratio*	*CI*	*p*
Fixed Effects												
(Intercept)	1.13	0.60 – 2.14	.709	1.12	0.59 – 2.12	.737	1.24	0.64 – 2.38	.525	1.25	0.65 – 2.40	.499
Testosterone Treatment (T/P)	1.67	0.86 – 3.27	.132	1.69	0.86 – 3.32	.125	1.39	0.67 – 2.87	.375	1.45	0.71 – 2.96	.308
Basal Cortisol	1.22	0.86 – 1.73	.273	1.15	0.71 – 1.88	.567	1.20	0.85 – 1.71	.300	1.24	0.74 – 2.10	.412
Opponent Gender	2.09	1.56 – 2.79	**<.001**	2.07	1.54 – 2.78	**<.001**	1.78	1.21 – 2.63	**.003**	1.75	1.22 – 2.52	**.003**
Observed	1.16	0.90 – 1.49	.264	1.16	0.90 – 1.50	.258	1.16	0.90 – 1.49	.267	1.15	0.89 – 1.49	.281
Blinding	1.07	0.55 – 2.07	.841	1.07	0.55 – 2.06	.848	1.07	0.55 – 2.08	.833	1.06	0.55 – 2.04	.872
T/P × Cortisol				1.13	0.54 – 2.34	.753				0.70	0.34 – 1.42	.318
T/P × Gender							1.40	0.81 – 2.42	.227	1.36	0.81 – 2.28	.252
Cortisol × Gender										0.88	0.61 – 1.28	.506
T/P × Cortisol × Gender										2.54	1.47 – 4.37	**<.001**
σ^2	3.29			3.29			3.29			3.29		
Observations	1840			1840			1840			1840		
Marginal R^2 / Conditional R^2	0.041 / 0.487			0.042 / 0.488			0.041 / 0.487			0.059 / 0.490		

Table S3: Time of day, time since awakening, and math skill as covariates in initial phase decisions to enter competitions

	Decisions to Compete: Time Since Awakening			Decisions to Compete: Time of Day			Decisions to Compete: Math Skill			Decisions to Compete: All Covariates		
Predictors	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*
(Intercept)	1.24	0.64 – 2.40	0.517	1.27	0.66 – 2.45	0.478	0.04	0.01 – 0.19	**<0.001**	0.03	0.01 – 0.16	**<0.001**
Testosterone Treatment (T/P)	1.47	0.71 – 3.05	0.301	1.42	0.68 – 2.94	0.347	1.42	0.73 – 2.79	0.306	1.35	0.68 – 2.69	0.391
Basal Cortisol	1.23	0.72 – 2.11	0.457	1.25	0.74 – 2.11	0.403	1.24	0.76 – 2.03	0.390	1.32	0.80 – 2.19	0.277
Opponent Gender	1.75	1.21 – 2.52	**0.003**	1.75	1.22 – 2.52	**0.003**	1.74	1.21 – 2.50	**0.003**	1.75	1.21 – 2.51	**0.003**
Observed	1.15	0.89 – 1.49	0.291	1.15	0.89 – 1.49	0.288	1.19	0.93 – 1.54	0.168	1.21	0.94 – 1.56	0.139
Blinding	1.06	0.55 – 2.06	0.858	1.05	0.54 – 2.03	0.892	1.24	0.68 – 2.28	0.485	1.22	0.67 – 2.25	0.515
T/P × Cortisol	0.69	0.34 – 1.41	0.310	0.70	0.34 – 1.44	0.338	0.66	0.34 – 1.30	0.230	0.68	0.34 – 1.33	0.255
T/P × Opponent Gender	1.35	0.80 – 2.28	0.254	1.36	0.81 – 2.28	0.249	1.33	0.79 – 2.24	0.282	1.34	0.80 – 2.26	0.270
Cortisol × Opponent Gender	0.88	0.61 – 1.28	0.505	0.88	0.61 – 1.28	0.505	0.89	0.61 – 1.29	0.539	0.89	0.61 – 1.29	0.545
T/P × Cortisol × Opponent Gender	2.54	1.47 – 4.37	**0.001**	2.54	1.47 – 4.38	**0.001**	2.51	1.46 – 4.33	**0.001**	2.51	1.46 – 4.33	**0.001**
Time since awakening	0.96	0.66 – 1.41	0.840							1.22	0.83 – 1.78	0.307
Time of Day				1.05	0.74 – 1.48	0.786				0.94	0.67 – 1.32	0.728
Math Skill							3.06	1.92 – 4.88	**<0.001**	3.26	2.02 – 5.28	**<0.001**
σ^2	3.29			3.29			3.29			3.29		
Observations	1840			1840			1840			1840		
Marginal R^2 / Conditional R^2	0.058 / 0.490			0.059 / 0.490			0.144 / 0.493			0.151 / 0.496		

Table S4: Effects of testosterone treatment, basal cortisol, opponent gender, and prior outcome on decisions to re-enter competitions after feedback

	Decisions to Compete Again: Main Effects			Decisions to Compete Again: T x C			Decisions to Compete Again: T x Gender			Decisions to Compete Again: T x W/L		
	OR	*CI*	*p*	*OR*	*CI*	*p*	*OR*	*CI*	*p*	*OR*	*CI*	*p*
(Intercept)	0.50	0.25 – 0.98	**0.044**	0.50	0.25 – 0.99	**0.045**	0.45	0.23 – 0.91	**0.025**	0.45	0.21 – 0.94	**0.035**
Testosterone Treatment (T/P)	1.04	0.54 – 2.02	0.906	1.04	0.54 – 2.02	0.905	1.26	0.62 – 2.58	0.523	1.27	0.53 – 3.02	0.596
Basal Cortisol	1.25	0.89 – 1.77	0.203	1.30	0.80 – 2.11	0.298	1.25	0.89 – 1.77	0.202	1.25	0.88 – 1.77	0.207
Opponent Gender	1.90	1.45 – 2.49	**<0.001**	1.90	1.45 – 2.49	**<0.001**	2.31	1.57 – 3.40	**<0.001**	1.90	1.45 – 2.49	**<0.001**
Observed	1.10	0.85 – 1.44	0.462	1.10	0.85 – 1.44	0.463	1.10	0.85 – 1.44	0.468	1.10	0.85 – 1.44	0.461
Prior Outcome (W/L)	4.48	1.91 – 10.52	**0.001**	4.49	1.91 – 10.55	**0.001**	4.47	1.90 – 10.50	**0.001**	6.03	1.79 – 20.31	**0.004**
Blinding	0.90	0.46 – 1.74	0.747	0.90	0.46 – 1.75	0.758	0.89	0.46 – 1.73	0.735	0.90	0.47 – 1.75	0.763
T/P × Cortisol				0.93	0.46 – 1.88	0.840						
T/P × Opponent Gender							0.68	0.40 – 1.16	0.156			
T/P × W/L										0.56	0.10 – 3.00	0.498
Cortisol × W/L												
σ^2	3.29			3.29			3.29			3.29		
Observations	1808			1808			1808			1808		
Marginal R^2 / Conditional R^2	0.073 / 0.679			0.073 / 0.679			0.074 / 0.680			0.075 / 0.679		

Table S4 (continued)

	Decisions to Compete Again: T x C x WL			Decisions to Compete Again: T x C x Gender			Decisions to Compete Again: T x C x Gender x WL		
	OR	*CI*	*p*	*OR*	*CI*	*p*	*OR*	*CI*	*p*
(Intercept)	0.46	0.22 – 0.95	**0.037**	0.46	0.23 – 0.91	**0.026**	0.42	0.20 – 0.89	**0.024**
Testosterone Treatment (T/P)	1.33	0.57 – 3.14	0.509	1.26	0.62 – 2.57	0.529	1.52	0.61 – 3.79	0.368
Basal Cortisol	1.56	0.84 – 2.91	0.162	1.31	0.77 – 2.22	0.314	1.57	0.81 – 3.04	0.186
Opponent Gender	1.91	1.45 – 2.50	**<0.001**	2.31	1.56 – 3.41	**<0.001**	2.33	1.46 – 3.71	**<0.001**
Observed	1.10	0.84 – 1.44	0.478	1.10	0.85 – 1.44	0.469	1.11	0.85 – 1.44	0.462
Prior Outcome (W/L)	5.35	1.63 – 17.51	**0.006**	4.47	1.90 – 10.52	**0.001**	5.42	1.53 – 19.18	**0.009**
Blinding	0.93	0.48 – 1.81	0.836	0.90	0.46 – 1.74	0.746	0.92	0.47 – 1.80	0.814
T/P × Cortisol	0.45	0.19 – 1.07	0.071	0.93	0.44 – 1.98	0.860	0.46	0.18 – 1.16	0.101
T/P × Opponent Gender				0.68	0.40 – 1.18	0.168	0.76	0.39 – 1.47	0.412
T/P × W/L	0.52	0.10 – 2.65	0.429				0.60	0.10 – 3.47	0.572
Cortisol × W/L	0.56	0.17 – 1.90	0.355				0.58	0.16 – 2.12	0.407
T/P × Cortisol × W/L	9.55	1.75 – 52.20	**0.009**				9.63	1.53 – 60.53	**0.016**
Cortisol × Opponent Gender				0.98	0.66 – 1.47	0.934	1.00	0.62 – 1.60	0.992
T/P × Cortisol × Opponent Gender				0.98	0.56 – 1.72	0.952	0.95	0.49 – 1.83	0.872
Opponent Gender × W/L							0.94	0.40 – 2.22	0.896

	Decisions to Compete Again: T x C x WL			Decisions to Compete Again: T x C x Gender			Decisions to Compete Again: T x C x Gender x WL		
	OR	*CI*	*p*	*OR*	*CI*	*p*	*OR*	*CI*	*p*
T/P × Opponent Gender × W/L							0.77	0.24 – 2.52	0.667
Cortisol × Opponent Gender × W/L							0.95	0.39 – 2.35	0.920
T/P × Cortisol × Opponent Gender × W/L							0.96	0.27 – 3.47	0.948
σ^2		3.29			3.29			3.29	
Observations		1808			1808			1808	
Marginal R^2		0.114 / 0.682			0.074 / 0.680			0.114 / 0.683	

Table S5: Time of day, time since awakening, and math skill as covariates of decisions to re-enter competitions after feedback

	Decisions to Compete Again: Time Since Awakening			Decisions to Compete Again: Time of Day			Decisions to Compete Again: Math Skill			Decisions to Compete Again: All Covariates		
	OR	*CI*	*p*	*OR*	*CI*	*p*	*OR*	*CI*	*p*	*OR*	*CI*	*p*
(Intercept)	0.42	0.20 – 0.89	**0.023**	0.43	0.21 – 0.91	**0.027**	0.04	0.01 – 0.18	**<0.001**	0.04	0.01 – 0.18	**<0.001**
Testosterone Treatment (T/P)	1.50	0.63 – 3.59	0.363	1.44	0.60 – 3.43	0.411	1.28	0.57 – 2.88	0.551	1.43	0.62 – 3.28	0.399
Basal Cortisol	1.40	0.74 – 2.65	0.308	1.54	0.82 – 2.87	0.177	1.54	0.85 – 2.77	0.151	1.46	0.79 – 2.67	0.223
Prior Outcome (W/L)	5.36	1.64 – 17.50	**0.005**	5.27	1.61 – 17.27	**0.006**	5.02	1.54 – 16.40	**0.008**	4.94	1.51 – 16.12	**0.008**
Opponent Gender	1.91	1.45 – 2.50	**<0.001**	1.91	1.45 – 2.50	**<0.001**	1.91	1.46 – 2.51	**<0.001**	1.91	1.46 – 2.51	**<0.001**
Observed	1.10	0.84 – 1.44	0.477	1.10	0.84 – 1.44	0.476	1.10	0.84 – 1.43	0.480	1.10	0.84 – 1.44	0.477
Blinding	1.00	0.51 – 1.94	0.991	0.97	0.50 – 1.90	0.937	1.05	0.56 – 1.98	0.868	1.12	0.59 – 2.11	0.724
T/P × Cortisol	0.43	0.18 – 1.02	0.056	0.42	0.18 – 1.01	0.054	0.43	0.19 – 0.98	**0.044**	0.04	0.01 – 0.18	**<0.001**
T/P × W/L	0.51	0.10 – 2.61	0.418	0.53	0.10 – 2.71	0.443	0.49	0.10 – 2.52	0.396	1.43	0.62 – 3.28	0.399
Cortisol × W/L	0.57	0.17 – 1.91	0.360	0.56	0.17 – 1.89	0.352	0.59	0.17 – 1.98	0.391	1.46	0.79 – 2.67	0.223
T/P × Cortisol × W/L	9.53	1.75 – 51.92	**0.009**	9.61	1.75 – 52.69	**0.009**	9.40	1.73 – 51.05	**0.009**	4.94	1.51 – 16.12	**0.008**
Time since awakening	0.76	0.53 – 1.09	0.140							0.04	0.01 – 0.18	**<0.001**
Time of Day				0.83	0.58 – 1.17	0.286				0.84	0.60 – 1.19	0.326
Math Skill							2.31	1.44 – 3.71	**0.001**	2.28	1.41 – 3.68	**0.001**
σ^2	3.29			3.29			3.29			3.29		
Observations	1808			1808			1808			1808		
Marginal R^2 / Conditional R^2	0.119 / 0.681			0.117 / 0.683			0.155 / 0.686			0.158 / 0.686		

Table S6: Other indices of cortisol level as moderators of testosterone treatment and opponent gender on initial phase decisions to enter competitions

	Decisions to compete: Pre to Post Task Cortisol			Decisions to compete: AUC_G		
	Odds Ratio	*CI*	*p*	*Odds Ratio*	*CI*	*p*
(Intercept)	1.24	0.65 – 2.35	.516	1.23	0.64 – 2.34	.536
Testosterone Treatment (T/P)	1.43	0.71 – 2.87	.320	1.44	0.71 – 2.93	.308
Cortisol	0.78	0.46 – 1.32	.353	1.27	0.77 – 2.10	.354
Opponent Gender	1.78	1.20 – 2.63	**.004**	1.77	1.22 – 2.58	**.003**
Observed	1.16	0.89 – 1.49	.271	1.17	0.91 – 1.52	.225
Blinding	1.08	0.56 – 2.10	.816	1.09	0.56 – 2.14	.791
T/P × Cortisol	2.22	1.07 – 4.58	**.031**	0.50	0.24 – 1.02	.056
T/P × Opponent Gender	1.43	0.82 – 2.48	.206	1.40	0.83 – 2.38	.209
Cortisol × Opponent Gender	1.06	0.70 – 1.61	.797	0.99	0.69 – 1.43	.963
T/P × Cortisol × Opponent Gender	0.74	0.41 – 1.33	.317	2.16	1.25 – 3.74	**.006**
σ^2		3.29			3.29	
Observations		1824			1824	
Marginal R^2 / Conditional R^2		0.055 / 0.495			0.053 / 0.496	

Table S7: Other indices of cortisol level as moderators of testosterone treatment and opponent gender on decisions to compete after feedback

	Decisions to Compete Again: Pre to Post Task Cortisol			Decisions to Compete Again: AUCg		
Predictors	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*
(Intercept)	0.44	0.22 – 0.89	**0.023**	0.45	0.21 – 0.93	**0.032**
Testosterone Treatment (T/P)	1.36	0.59 – 3.13	0.469	1.34	0.57 – 3.16	0.498
Cortisol	1.09	0.57 – 2.07	0.799	1.29	0.71 – 2.36	0.400
Prior Outcome (W/L)	5.72	1.76 – 18.62	**0.004**	5.89	1.73 – 20.04	**0.005**
Opponent Gender	1.88	1.45 – 2.43	**<0.001**	1.90	1.45 – 2.50	**<0.001**
Observed	1.09	0.85 – 1.40	0.498	1.09	0.83 – 1.42	0.528
Blinding	0.97	0.51 – 1.84	0.926	0.96	0.49 – 1.88	0.907
T/P × Cortisol	1.81	0.73 – 4.45	0.197	0.49	0.21 – 1.15	0.100
T/P × W/L	0.55	0.11 – 2.82	0.473	0.51	0.10 – 2.74	0.435
Cortisol × W/L	0.89	0.26 – 3.02	0.849	1.00	0.29 – 3.41	0.999
T/P × Cortisol × W/L	0.58	0.10 – 3.26	0.539	3.45	0.63 – 18.94	0.154
σ^2		3.29			3.29	
Observations		1792			1792	
Marginal R^2 / Conditional R^2		0.079 / 0.683			0.087 / 0.681	

Table S8: Effects of testosterone treatment, basal cortisol, and opponent gender on competition metrics

	Score			**Score**			**Satisfaction Rating**			**Satisfaction Rating**		
	Estimates	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	2.50	2.18 – 2.82	**<0.001**	2.59	2.23 – 2.95	<0.001	3.14	2.94 – 3.34	**<0.001**	3.18	2.97 – 3.40	**<0.001**
Testosterone Treatment (T/P)	0.16	-0.20 – 0.52	0.377	0.02	-0.42 – 0.46	0.922	-0.00	-0.22 – 0.22	0.984	0.06	-0.19 – 0.31	0.634
Basal Cortisol	-0.12	-0.38 – 0.15	0.382	-0.05	-0.37 – 0.27	0.776	-0.10	-0.26 – 0.06	0.227	-0.18	-0.36 – 0.00	0.056
Opponent Gender	0.08	-0.12 – 0.27	0.455	0.24	-0.08 – 0.56	0.140	0.12	0.04 – 0.20	**0.005**	0.07	-0.06 – 0.20	0.306
Observed	-0.01	-0.14 – 0.12	0.886	-0.00	-0.14 – 0.13	0.968	-0.04	-0.11 – 0.03	0.278	-0.04	-0.11 – 0.03	0.296
Blinding	-0.08	-0.40 – 0.24	0.631	-0.09	-0.41 – 0.24	0.597	-0.08	-0.29 – 0.13	0.472	-0.08	-0.29 – 0.13	0.467
T/P × Cortisol	0.05	-0.31 – 0.42	0.766	0.00	-0.43 – 0.44	0.990	0.01	-0.22 – 0.23	0.936	0.02	-0.24 – 0.27	0.906
T/P × Gender	-0.13	-0.41 – 0.15	0.358	-0.37	-0.85 – 0.10	0.124	-0.01	-0.12 – 0.11	0.915	-0.06	-0.25 – 0.14	0.575
Cortisol × Gender	-0.01	-0.21 – 0.19	0.931	0.12	-0.22 – 0.45	0.502	0.05	-0.03 – 0.13	0.224	0.16	0.02 – 0.29	**0.025**
T/P × Cortisol × Gender	0.20	-0.08 – 0.48	0.152	0.07	-0.45 – 0.58	0.800	0.06	-0.05 – 0.18	0.286	-0.03	-0.24 – 0.17	0.753
Choice (Compete vs. Piece rate)				-0.15	-0.45 – 0.15	0.329				-0.09	-0.22 – 0.04	0.164
T/P × Choice				0.24	-0.19 – 0.66	0.273				-0.09	-0.26 – 0.09	0.327
Cortisol × Choice				-0.11	-0.43 – 0.21	0.491				0.15	0.02 – 0.28	**0.028**
Choice × Gender				-0.23	-0.64 – 0.18	0.268				0.10	-0.07 – 0.26	0.247
T/P × Cortisol × Choice				0.08	-0.34 – 0.51	0.698				-0.03	-0.21 – 0.15	0.765
T/P × Gender × Choice				0.33	-0.26 – 0.91	0.275				0.06	-0.18 – 0.29	0.649
Cortisol × Choice × Gender				-0.16	-0.58 – 0.26	0.451				-0.19	-0.36 – -0.01	**0.035**

	Score			Score			Satisfaction Rating			Satisfaction Rating		
	Estimates	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
T/P × Cortisol × Gender × Choice				0.16	-0.46 – 0.78	0.604				0.15	-0.11 – 0.40	0.255
σ^2	2.00			2.00			0.33			0.33		
Observations	1840			1840			1838			1838		
Marginal R^2 / Conditional R^2	0.006 / 0.254			0.011 / 0.263			0.016 / 0.509			0.024 / 0.522		

Table S8 (con't)

	Likelihood of Winning			Likelihood of Winning		
	Odds Ratios	*CI*	*p*	*Odds Ratios*	*CI*	*p*
(Intercept)	1.46	1.05 – 2.04	**0.026**	1.47	0.97 – 2.21	0.067
Testosterone Treatment (T/P)	1.16	0.79 – 1.68	0.453	1.12	0.67 – 1.88	0.669
Basal Cortisol	0.89	0.67 – 1.17	0.391	0.91	0.62 – 1.32	0.619
Opponent Gender	1.66	1.22 – 2.24	**0.001**	1.44	0.90 – 2.31	0.128
Observed	1.02	0.84 – 1.25	0.837	1.02	0.84 – 1.25	0.839
Blinding	0.81	0.59 – 1.12	0.211	0.82	0.59 – 1.12	0.212
T/P × Cortisol	1.03	0.70 – 1.50	0.887	0.86	0.51 – 1.44	0.561
T/P × Gender	0.94	0.62 – 1.44	0.789	0.86	0.43 – 1.74	0.684
Cortisol × Gender	0.94	0.70 – 1.28	0.705	0.96	0.58 – 1.57	0.863
T/P × Cortisol × Gender	1.40	0.91 – 2.15	0.131	1.48	0.68 – 3.19	0.323
Choice (Compete vs. Piece rate)				1.00	0.64 – 1.54	0.983
T/P × Choice				1.06	0.58 – 1.96	0.849

	Likelihood of Winning			Likelihood of Winning		
	Odds Ratios	*CI*	*p*	*Odds Ratios*	*CI*	*p*
Cortisol × Choice				0.96	0.61 – 1.51	0.849
Choice × Gender				1.23	0.67 – 2.26	0.505
T/P × Cortisol × Choice				1.39	0.75 – 2.60	0.300
T/P × Gender × Choice				1.07	0.44 – 2.57	0.882
Cortisol × Choice × Gender				0.98	0.52 – 1.84	0.951
T/P × Cortisol × Gender × Choice				0.82	0.32 – 2.12	0.680
σ^2	3.29			3.29		
Observations	1840			1840		
Marginal R^2 / Conditional R^2	0.025 / 0.151			0.028 / 0.146		

Table S9: Secondary analyses of trait dominance as moderator of testosterone's effects on competitive behavior

Table S9.A: Initial phase

	Decisions to Compete: T/P × Dominance			Decisions to Compete: T/P × Dominance × Opponent Gender			Decisions to Compete: T/P × Dominance × Basal Cortisol		
Predictors	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*
(Intercept)	1.16	0.61 – 2.20	0.651	1.27	0.66 – 2.45	0.479	1.13	0.60 – 2.14	0.701
Testosterone Treatment (T/P)	1.61	0.83 – 3.12	0.162	1.34	0.65 – 2.74	0.429	1.66	0.85 – 3.21	0.136
Trait Dominance	1.44	0.90 – 2.31	0.126	1.52	0.91 – 2.54	0.113	1.38	0.86 – 2.22	0.180
Basal Cortisol	1.23	0.87 – 1.73	0.247	1.22	0.86 – 1.73	0.259	1.20	0.74 – 1.96	0.450
Opponent Gender	2.10	1.57 – 2.80	**<0.001**	1.78	1.21 – 2.62	**0.003**	2.08	1.55 – 2.79	**<0.001**
Observed	1.12	0.86 – 1.45	0.394	1.12	0.86 – 1.45	0.397	1.14	0.88 – 1.47	0.329
Blinding	1.09	0.57 – 2.09	0.799	1.09	0.57 – 2.10	0.789	1.07	0.55 – 2.06	0.845
T/P × Dominance	0.75	0.40 – 1.42	0.375	0.70	0.35 – 1.41	0.321	0.72	0.38 – 1.37	0.316
T/P × Opponent Gender				1.41	0.81 – 2.43	0.222			
Dominance × Opponent Gender				0.92	0.62 – 1.35	0.658			
T/P × Dominance × Opponent Gender				1.12	0.66 – 1.91	0.674			
T/P × Cortisol							0.98	0.48 – 2.04	0.967
Dominance × Cortisol							0.87	0.52 – 1.45	0.585
T/P × Dominance × Cortisol							1.46	0.76 – 2.81	0.252
σ^2	3.29			3.29			3.29		
Observations	1840			1840			1840		
Marginal R^2 / Conditional R^2	0.050 / 0.491			0.051 / 0.492			0.057 / 0.488		

Table S9.B: Feedback phase

	Decisions to Compete Again: T/P × Dominance			Decisions to Compete Again: T/P × Dominance × Opponent Gender			Decisions to Compete Again: T/P × Dominance × Basal Cortisol		
Predictors	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*
(Intercept)	0.49	0.25 – 0.98	**0.043**	0.46	0.22 – 0.97	**0.042**	0.50	0.25 – 0.99	**0.047**
Testosterone Treatment (T/P)	1.05	0.54 – 2.04	0.876	1.23	0.50 – 2.98	0.653	1.06	0.54 – 2.04	0.874
Trait Dominance	1.35	0.84 – 2.16	0.211	0.85	0.46 – 1.58	0.602	1.34	0.84 – 2.16	0.219
Basal Cortisol	1.32	0.93 – 1.86	0.118	1.31	0.93 – 1.85	0.128	1.32	0.81 – 2.14	0.268
Prior Outcome (W/L)	4.58	1.95 – 10.77	**<0.001**	5.57	1.68 – 18.47	**0.005**	4.66	1.97 – 11.03	**<0.001**
Opponent Gender	1.95	1.47 – 2.59	**<0.001**	1.93	1.46 – 2.55	**<0.001**	1.95	1.47 – 2.59	**<0.001**
Observed	1.11	0.84 – 1.47	0.461	1.11	0.84 – 1.47	0.449	1.11	0.84 – 1.47	0.458
Blinding	0.85	0.44 – 1.64	0.623	0.85	0.44 – 1.65	0.631	0.82	0.42 – 1.61	0.565
T/P × Dominance	0.82	0.43 – 1.57	0.548	1.28	0.54 – 3.04	0.572	0.89	0.46 – 1.72	0.722
T/P × W/L				0.65	0.12 – 3.47	0.615			
Dominance × W/L				3.79	1.12 – 12.78	**0.032**			
T/P × Dominance × W/L				0.28	0.05 – 1.45	0.129			
T/P × Cortisol							1.09	0.53 – 2.22	0.822
Dominance × Cortisol							0.94	0.57 – 1.54	0.792
T/P × Dominance × Cortisol							0.85	0.44 – 1.65	0.640
σ^2	3.29			3.29			3.29		
Observations	1808			1808			1808		
Marginal R^2 / Conditional R^2	0.081 / 0.686			0.102 / 0.687			0.084 / 0.688		

Table S10: Perceptions of opponent status in competition

Table S10.A: Ratings of extent to which opponent was "good at simple math tasks" from participants and follow-up raters

	Participants			**Participants**			**Follow-up Raters**			**Participants & Follow-ups**		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	4.87	4.66 – 5.07	**<0.001**	4.98	4.78 – 5.19	**<0.001**	4.62	4.28 – 4.96	**<0.001**	4.74	4.51 – 4.97	**<0.001**
Opponent Gender (Female = 0)	-0.41	-0.68 – -0.15	**0.021**	-0.36	-0.63 – -0.10	**0.039**	-0.62	-1.09 – -0.16	**0.038**	-0.52	-0.81 – -0.23	**0.008**
Prior Outcome (W/L)				-0.29	-0.39 – -0.20	**<0.001**						
Sample: Participant vs. Follow-ups[1]										-0.25	-0.54 – 0.04	0.157
Opponent Gender x Sample										-0.21	-0.49 – 0.07	0.225
σ^2	0.71			0.65			0.54			0.69		
ICC	0.30 $_{\text{Participant}}$			0.32 $_{\text{Participant}}$			0.35 $_{\text{Rater}}$			0.30 $_{\text{Rater}}$		
	0.08 $_{\text{Opponent}}$			0.09 $_{\text{Opponent}}$			0.12 $_{\text{Opponent}}$			0.09 $_{\text{Opponent}}$		
Observations	1872			1792			256			2128		
Marginal R^2 / Conditional R^2	0.035 / 0.419			0.053 / 0.420			0.093 / 0.485			0.052 / 0.432		

Notes:

1. Sample source was contrast coded (participant sample = -0.5, follow-up rater sample = 0.5) so that the estimate of the effect of opponent gender would reflect the mean gender difference across the two samples.

Table S10.B: Other ratings of participants' perceptions of opponents in competition task

	Attractive			**Dominant**			**Intelligent**			**Mature**		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	3.64	3.21 – 4.08	**<0.001**	3.87	3.54 – 4.19	**<0.001**	4.84	4.59 – 5.09	**<0.001**	4.37	4.13 – 4.61	**<0.001**
Opponent Gender (Female = 0)	0.36	-0.23 – 0.95	0.330	-0.20	-0.65 – 0.25	0.469	-0.30	-0.63 – 0.03	0.160	0.17	-0.16 – 0.49	0.412
σ^2		0.98			1.10			0.85			0.86	
ICC		0.32 $_{\text{Participant}}$			0.24 $_{\text{Participant}}$			0.25 $_{\text{Participant}}$			0.24 $_{\text{Participant}}$	
		0.23 $_{\text{Opponent}}$			0.15 $_{\text{Opponent}}$			0.11 $_{\text{Opponent}}$			0.11 $_{\text{Opponent}}$	
Observations		1872			1871			1872			1871	
Marginal R^2 / Conditional R^2		0.015 / 0.555			0.005 / 0.435			0.016 / 0.399			0.005 / 0.377	

	Warm			**"I Feel Close"**			**Respect**			**"I Performed Better"**		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	3.86	3.60 – 4.11	**<0.001**	3.04	2.84 – 3.23	**<0.001**	4.42	4.27 – 4.58	**<0.001**	3.94	3.74 – 4.14	**<0.001**
Opponent Gender (Female = 0)	0.17	-0.18 – 0.52	0.433	0.11	-0.10 – 0.32	0.415	0.02	-0.14 – 0.17	0.868	0.35	0.14 – 0.56	**0.013**
σ^2		0.94			0.80			0.51			1.17	
ICC		0.21 $_{\text{Participant}}$			0.48 $_{\text{Participant}}$			0.52 $_{\text{Participant}}$			0.42 $_{\text{Participant}}$	
		0.12 $_{\text{Opponent}}$			0.03 $_{\text{Opponent}}$			0.02 $_{\text{Opponent}}$			0.02 $_{\text{Opponent}}$	
Observations		1872			1871			1871			1868	
Marginal R^2 / Conditional R^2		0.005 / 0.339			0.002 / 0.520			0.000 / 0.547			0.014 / 0.466	

Table S11. Comparison of simpler and more complex models for testosterone treatment × basal cortisol × prior outcome effect (win/lose)

	Simplified Model (i.e., as reported in text and Table S4)			**More Complex Model (singular fit)**		
Predictors	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*
(Intercept)	0.46	0.22 – 0.95	**0.037**	0.47	0.23 – 0.99	**0.047**
Testosterone Treatment (T/P)	1.33	0.57 – 3.14	0.509	1.28	0.53 – 3.06	0.582
Basal Cortisol	1.56	0.84 – 2.91	0.162	1.57	0.84 – 2.92	0.158
Opponent Gender	5.35	1.63 – 17.51	**0.006**	5.12	1.56 – 16.76	**0.007**
Observed	1.91	1.45 – 2.50	**<0.001**	1.96	1.48 – 2.59	**<0.001**
Prior Outcome (W/L)	1.10	0.84 – 1.44	0.478	1.12	0.85 – 1.48	0.418
Blinding	0.93	0.48 – 1.81	0.836	0.85	0.43 – 1.67	0.639
T/P × Cortisol	0.45	0.19 – 1.07	0.071	0.47	0.20 – 1.13	0.091
T/P × W/L	0.52	0.10 – 2.65	0.429	0.60	0.11 – 3.11	0.539
Cortisol × W/L	0.56	0.17 – 1.90	0.355	0.56	0.17 – 1.87	0.344
T/P × Cortisol × W/L	9.55	1.75 – 52.20	**0.009**	10.21	1.84 – 56.55	**0.008**
σ^2		3.29			3.29	
Observations		1808			1808	
Marginal R^2 / Conditional R^2		0.114 / 0.682			0.279 / NA	

Table S12. Model fit statistics

	AIC	BIC
Initial Phase		
Main effects	2008.9	2075.1
Testosterone treatment (T/P) × Cortisol	2010.8	2082.5
T/P × Gender	2009.5	2081.2
T/P × Cortisol × Gender	1999.2	2087.5
Feedback Phase		
Main effects	1838.9	1893.9
T/P × Cortisol	1840.9	1901.4
T/P × Gender	1838.9	1899.4
T/P × Prior Outcome (W/L)	1840.5	1901
T/P × Cortisol × W/L	1837.8	1914.8
T/P × Cortisol × Gender	1844.8	1921.8
T/P × Cortisol × W/L × Gender	1849.3	1964.8

Note: These model fits refer to the models found in Tables S2 and S4

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