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Anticipating Peer Ranking Causes Hormonal Adaptations That Benefit Cognitive Performance

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Abstract

Performance ranking is common across a range of professional and recreational domains. Even when it has no economic consequences but does order people in terms of their social standing, anticipating such performance ranking may affect how people feel and perform. We examined this possibility by asking human subjects to execute a simple cognitive task while anticipating their performance being ranked by an outside evaluator. We measured baseline and postperformance levels of testosterone and cortisol. We find that (1) anticipating performance ranking reduces testosterone and increases cortisol, (2) both these hormonal responses benefit cognitive performance, which explains why (3) anticipation of being ranked by a peer increases cognitive performance.

Keywords

performance ranking, testosterone, cortisol, hormonal response, cognitive performance

People often want to know where they stand relative to others. They compete to estimate relative strength, curiously scrutinize the performance of others, and become upset when their social standing is undermined or otherwise below their expectations. Indeed, the drive to enhance and protect one's standing within groups and organizations is at the core of social cognition and behavior (Festinger, 1954; Jost et al., 2004;

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Taylor & Lobel, 1989). It is also seen in other social animals who show off their strength, battle for high standing, and suffer when falling behind (Sapolsky, 2005, 2017; Twenge et al., 2010). In fact, in human groups and societies social comparisons are continuously and routinely made and are an intricate and institutionalized part of life. Whether at work, in the classroom, or when recreating, humans anticipate being compared and ranked for their performance.

While omnipresent and seemingly unavoidable, whether and how the anticipation of being ranked affects performance is poorly understood. In earlier work, the anticipation of performance ranking invariably coincided with economic incentives, thus clouding interpretation (Anderson et al., 2013; Buckert et al., 2015; Buser et al., 2017). Some studies suggest that anticipating performance ranking may deteriorate cognitive performance. For example, preparing for a competitive (vs cooperative) interaction enhances cognitive rigidity and reduces creative thinking (Chen et al., 2012; De Dreu & Nijstad, 2008; Gneezy & Rustichini, 2000; Pashler et al., 2001; Staw et al., 1981), and being observed by others increases stress reactions that slows down task performance (Kelsey et al., 2000; Schmader et al., 2008). Other, more recent, studies suggest that anticipating performance ranking may improve cognitive effort and performance (Brandts et al., 2020; Schram et al., 2019). For example, relative to working alone, competitive incentives can be arousing (Harrison et al., 2001), and some level of socially induced stress can promote cognitive performance (Oei et al., 2006). Thus, how and why socioeconomic incentives, and their absence, influence cognitive effort and performance remains poorly understood (Radl and Miller, this issue). Accordingly, our first goal here was to examine whether the anticipation of being ranked influences cognitive performance in pure absence of economic incentives to outperform others. Our second goal was to explore the possible mechanisms evoked by the anticipation of being ranked, focusing on adaptations in two key hormones—testosterone and cortisol. Testosterone belongs to the hypothalamic–pituitary–gonadal axis and has a well-documented role in the regulation of social status and dominance-related behavior (Cooke et al., 2014; Eisenegger et al., 2010; Newman et al., 2005; Sapolsky, 2005). The possible effects of performance ranking on (changes in) testosterone release have not been examined. There is, however, considerable research on changes in testosterone during or while anticipating competition (e.g., Bateup et al., 2002; Mehta & Josephs, 2006), showing that testosterone associates with increased risk taking (Apicella et al., 2014; Coates et al., 2009; Cueva et al., 2015; Mazur & Booth, 1998; Stanton et al., 2011), and with more heuristic thought processes and reduced cognitive performance (Gouchie & Kimuram, 1991). However, the precise linkage between (changes in) testosterone and cognitive performance remains poorly understood (Hua et al., 2016). Hua et al. (2016) conclude from their systematic review that the variability in results may be due to different methods for testosterone measurement and disparate measures of cognitive function used, but nevertherless they find promising associations between cognition and testosterone supplementation in men with low testosterone levels (also see Thilers et al., 2006). Whereas we expected that changes in testosterone accompany the effects of performance ranking on cognitive performance, it remains to be seen whether such associations are particularly strong for men compared with women.

Cortisol belongs to the hypothalamic–pituitary–adrenal axis. Cortisol has a well-documented role in stress regulation (Dickerson & Kemeny, 2004; Sapolsky, 2005). Although the possible effects of performance ranking on (changes in) cortisol release have not been examined either, a negative correlation between status and cortisol levels has recently been observed (Sherman & Mehta 2020). Moreover, stress-induced cortisol responses can augment cognitive control and analytical performance (Chrousos, 2009; Goldfarb et al., 2016; Schwabe et al., 2012). For example, cortisol has been shown to predict specific performance factors, such as slowing down after making a mistake (Tops & Boksem, 2011), making fewer decision-making errors under threat (Akinola & Mendes, 2012), and reducing risk taking (Cueva et al., 2015). Changes in cortisol may thus accompany the effects of performance ranking on cognitive performance.

Although earlier work on the relationship between (changes in) testosterone and cortisol during cognitive performance returned somewhat mixed results, it also suggests that (1) reductions in testosterone during task execution may be associated with increases in cognitive performance and (2) increases in cortisol during task execution may be associated with increases in cognitive performance. If true, it would follow that (3) performance-enhancing effects of the anticipation of being ranked by a peer should be due to reduced levels of testosterone and increased levels of cortisol. To examine these possibilities, we assessed changes in salivary testosterone and cortisol between the beginning of the experiment and on completion of the cognitive performance task (and controlled for initial hormonal balance, gender, health, and lifestyle (Figure 1A-C).

Materials and Method

Participants

The experiment was run in June 2015 at the Center for Research in Experimental Economics and political Decision making (CREED) laboratory of the University of Amsterdam. An earlier study on performance ranking and cognitive performance, using the same experimental setup as used here, used sample sizes of 18 per treatment (Schram et al., 2019). Using the results from that study, we expected a medium effect size between $d = 0.5$ (conservative) and $d = 0.8$ (liberal) for the main comparison. G-Power 3.1 (Faul et al., 2007), with $\alpha = 0.05$ and $1 - \beta = 0.80$, yielded a required sample size of 53 and 21 for each treatment. These sample sizes are calculated for simple t tests. Instead, we will apply permutation t tests, which have much higher power and allow for valid inference for as few as eight observations per category (Moir, 1998; Schram et al. 2019). We will base most of our (mean-comparison) tests on categories of 47 to 48 subjects; for others, some of the categories have $N = 24$. These numbers are well above the sample sizes typically used in studies tracking neurohormonal responses in cognitive performance tasks. For all our tests, we will report the number of observations they are based on.

In total, we recruited 124 participants, mainly undergraduate students at the University of Amsterdam. All of the more than 2,000 potential participants in the

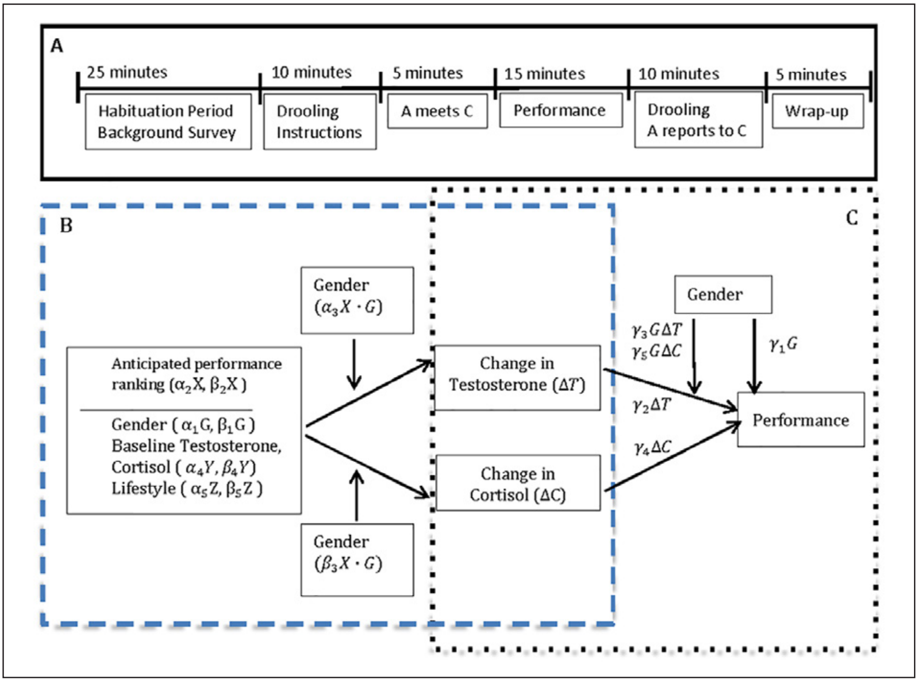

Figure 1. Overview of the experiment and model summary. (A) Timeline of the experimental procedures and measurements. (B/C) Hypothesized relations between anticipated performance ranking and cognitive performance through hormonal adaptations. Symbols represent the relationships defined in Equations (1). (B) Anticipated performance ranking predicts changes in testosterone and cortisol, controlling for gender, health, and lifestyle. (C) Changes in testosterone and cortisol predict cognitive performance, possibly moderated by participant gender.

CREED subject pool received an invitation to voluntary sign up, and participation was on a first-come first-serve basis. We organized eight sessions: four sessions with 13 and four with 18, for a total of 124 participants. Twenty-eight of these were passive C players as described below, and one participant (a type B player, see below) decided to leave during the experiment. This left us with 95 (active) participants for our data analysis. Unfortunately, data from one session of 12 participants became unusable due to a corrupted data set, thus leaving 83 participants to be used for our statistical analyses.

Experimental Procedures and Treatments

An outline of the experimental procedure is given in Figure 1A. In each session, before entering the laboratory, each participant is randomly assigned to one of three player types, denoted by A, B and C. Only types A and B enter the laboratory and do the computerized cognitive task described below.[1] For this reason, we call them "active participants." The instructions for both A and B players emphasize that this task has been shown to correlate positively with success in professional life. Participants were informed that evidence of this claim would be provided after the experiment if so desired. For this purpose, copies of Koedel and Tyhurst (2012) were available. The experimental software for this task was developed in Delphi at theCREED by Jos Theelen. The software is available from the authors on request.

C players are taken to separate rooms and act as peers in a passive observatory way, which is why we call them "inactive participants." In every session there are six A players and six B players (Supplemental Figure S1). Depending on the treatment (see below), there are either six or one C player(s). Active participants fill out a questionnaire, which assessed their current and past medical history, use of medication (including contraception), food intake (including alcohol, caffeine, nicotine), type and duration of physical activity in the past 24 hours, length and body weight, gender, and age.

At the beginning of a session, participants are told the rules of conduct. They are subsequently asked to open the closed envelop on their desk, which contains preliminary instructions. Participants read these privately, at their own pace. Instructions are reproduced in the Supplemental Material. The experiment consists of two stages, as implemented in Schram et al. (2019). In Stage I, active participants (both A and B types) undertake an individual cognitive task. In Stage II (not computerized), type A are required to report their result to a type C peer seated in a separate room (Supplemental Figure S1). Instructions for Stage II are distributed after Stage I has been completed. Sessions lasted approximately 80 minutes, and active-participant earnings were performance based, with an average of €21.69 (including a €7 show-up fee) for active participants. Inactive participants receive a flat fee of €20 (including a €7 show-up fee).

We implemented three treatments. For all treatments, Stage I involves the real-effort cognitive task with the monetary payoff based on the individual's score (see below). Type B participants form a baseline-treatment group (B-T) and only perform this task. Before performing this same task in Stage I, type A participants know that in Stage II they have to report to a peer seated in a separate room (Figure 1A). The way they report their performance to a peer (C type) depends on the treatment (see Supplemental Figure S1). In the "No-Ranking" treatment group (NR-T), each participant reports to a different peer and (truthfully) reads aloud the score, but not the rank. In this way, each C player only hears the performance of a single A player and can therefore not rank this performance against others'. In the "Performance Ranking" treatment group (PR-T), each participant individually and privately reports to the same peer and (truthfully) reads aloud his or her score as well as the ranking among the other participants in that treatment group. The peer in this treatment thus hears all A players' performances and ranks, which allows the peer to compare them. The distinction between these two treatments uses the fact that ranking is by definition positional to isolate the mere effects of having to report one's result to a peer from the effects of performance ranking—that is, being compared with others by a stranger (Heffetz & Frank, 2008).

In NR-T, after finishing the instructions, each type A participant is taken to a (distinct) C player (each seated in a separate room) and reads aloud a text stating that she or he will return after the task to report her or his performance (see Section 6 of the Supplemental Material). This is done to increase the anticipation of having to later report to the C player. At the end of Stage II, each type A participant reports (one at a time) to his or her C player and reads aloud their own score of performance in Stage I task. Participants know their ranking but do not report this ranking to the C player. In PR-T, each type A participant is also taken to a C player after finishing the instructions, but this C player is now the same peer for all. The type A participant reads aloud a text stating that she or he will return after the task to report her or his performance (see Section 6 of the Supplemental Material). After performing the task in Stage I, each type A reports, one at a time, to the same C player and reads aloud their own score and the rank among the type A participant from printed texts provided by the experimenter.

In both (NR-T and PR-T) treatments, C players are not informed about the task, but they are told that high scores indicate better performance than low scores. A players know that the C players do not know the task.

Cognitive Performance

In Stage I of the experiment, active participants are presented with a sequence of pairs of 10×10 matrices filled with two-digit numbers. These matrices appear at the bottom half of their computer monitor (Supplemental Figure S2). As described in Weber and Schram (2016), for each pair of matrices, each participant has to individually find the highest number in the left matrix and the highest number in the right matrix and to calculate the sum of these two numbers. This sum must be entered in the window at the center-top of the monitor (Supplemental Figure S2). A correct answer yields €1. We apply the piece-rate remuneration in all of our treatments, thus eliminating incentivized competition. After a number has been entered, two new matrices appear, regardless of whether the sum is correct or not.

The task continues for 15 minutes. Participants are informed that the numbers are "randomly generated." We do not draw from a uniform distribution, however, because this would lead with a high probability to very high sums. Instead, we first draw for each cell a random number between 40 and 99, say X. Subsequently, we drew a random number between 10 and X with equal probability.

Hormonal Measurement

Before the instructions of Stage I are distributed among the active participants, we collect their saliva samples using standard procedures (Bosch et al., 2011; Granger et al., 2004; Riad-Fahmy et al., 1987). To prevent abnormalities in salivary measures, participants were asked not to smoke, eat, or drink anything except water and to not brush their teeth 2 hours prior to participation. Participants provide saliva samples before they received instructions for Stage I and then again directly after completing

Stage II. Participants are handed a 25 mL sterile polypropylene tube, asked to swallow all the saliva in their mouths, and then to allow saliva to collect for 3 minutes, spitting once a minute. The first (baseline) sample is taken after a 25-minute habituation period, and the second sample is taken after the cognitive task has been completed. Collected samples were put on ice immediately and within an hour stored at −20 °C. On completion of the study, all samples were transported and analyzed for testosterone and cortisol at the University of Utrecht Medical Center.

Results

To start, we examined the simple relationship between experimental treatment, cognitive performance, and hormonal adaptations in two planned contrasts. The first compared baseline (B-T) against the two reporting treatments (NR-T and PR-T combined); this aims at studying whether the anticipation of having to report the score to a peer (which occurs in NR-T and PR-T) affects performance. The second compared performance ranking (PR-T) against the no-ranking treatments (NR-T and B-T combined); this aims to investigate whether performance is affected if it can be compared by the peer with that of others (which occurs only in PR-T). For these comparisons, we applied permutation *t* tests with 10,000 permutations (henceforth, PtT).

Cognitive performance is measured as the number of correct summations in the summation task. Figure 2A shows performance levels per treatment. Participants performed better when performance had to be reported rather than not (PtT; B-T vs. not B-T; $p = .045$; $N_1 = 41$; $N_2 = 42$). For change in testosterone (Figure 2B), we likewise find a stronger decline in testosterone when performance had to be reported rather than not (PtT; B-T vs. not B-T; $p = .004$; $N_1 = 41$; $N_2 = 42$). The testosterone change is also different when performance would be ranked rather than not (PtT; PR-T vs. not PR-T; $p = .023$; $N_1 = 59$; $N_2 = 24$). For changes in cortisol (Figure 2C), no significant effects were found. Furthermore, Figure 2D shows that decreasing testosterone (but not cortisol) positively relates to cognitive performance (Pearson's correlation coefficient; $r = -0.24$, $p = .032$ for testosterone; $r = -0.07$, $p = .519$ for cortisol). Note that for the effects of hormonal changes on performance, we follow the recent literature (e.g., Apicella et al., 2014; Cueva et al., 2015; Stanton et al. 2011) and consider absolute changes in hormone levels. Nominally similar, but statistically slightly weaker, results are obtained if we consider relative changes instead.

To account for interdependencies between anticipating performance ranking, hormonal adaptations, and cognitive performance, along with possible moderation by participant gender, health, and lifestyle (see Supplemental Material), we followed up these initial analyses with a simultaneous equations model, formalized in Equations (1):

$$\begin{cases} \Delta T = \alpha_0 + \alpha_1 G + \alpha_2 X + \alpha_3 X \cdot G + \alpha_4 Y + \alpha_5 Z + \varepsilon_1 \\ \Delta C = \beta_0 + \beta_1 G + \beta_2 X + \beta_3 X \cdot G + \beta_4 Y + \beta_5 Z + \varepsilon_2 \\ P = \gamma_0 + \gamma_1 G + \gamma_2 \Delta T + \gamma_3 \Delta T \cdot G + \gamma_4 \Delta C + \gamma_5 \Delta C \cdot G + \varepsilon_3 \end{cases} \tag{1}$$

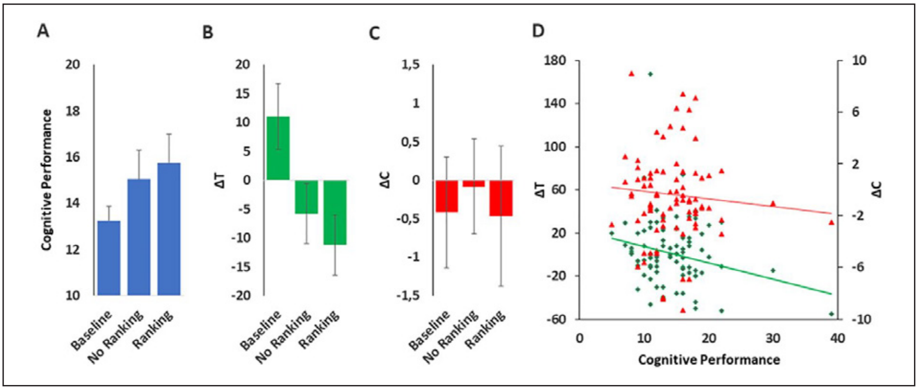

Figure 2. Responses to anticipated performance ranking. (A) Cognitive performance (number of correct responses) as a function of treatment (shown mean $\pm$ *SE*). (B) Changes in testosterone (pmol/L) from pre- to posttask (shown mean $\pm$ *SE*). (C) Changes in cortisol (nmol/L) from pre- to posttask (shown mean $\pm$ *SE*). (D) Correlations between change in testosterone (shown on left *y*-axis) and cortisol (shown on right *y*-axis) and cognitive performance. Green diamonds (red triangles) show individual pairings of cognitive performance and change in testosterone (cortisol). Green (red-dashed) line shows best-fitting linear regression of change in testosterone (cortisol) on cognitive performance, with coefficient = −1.52, p = .032, N = 83 and coefficient = −0.06, p = .519, N = 83, respectively.

The first two equations of (1) depict the relationships in Figure 1B, and the third equation depicts the relationship in Figure 1C. $\Delta T\left(\Delta C\right)$ denotes the change in testosterone (cortisol) level; G denotes gender (with 0 = *male*; 1 = *female*); X denotes anticipated performance ranking (represented by three treatment groups: B-T, NR-T, and PR-T); Y denotes initial hormone levels, and Z denotes a set of health and lifestyle variables[2]; and P denotes cognitive performance. The coefficients $\alpha_i, \beta_i, \gamma_i$ quantify the relationships indicated by arrows in Figure 1B and C and will be estimated using our experimental data. Note that some of these constitute vectors of coefficients. For example, because anticipated performance ranking (X) comprises a vector of two elements (the treatment dummies NR-T and PR-T, with B-T serving as a benchmark), α_2 and β_2 each constitute a vector of two coefficients. Our use of the interaction terms $\left(X \cdot G, \Delta T \cdot G, \Delta C \cdot G\right)$ allows the effects of anticipated performance ranking on hormonal change and the effects of hormonal change on performance to differ between men and women. Finally, the $\varepsilon_i, i = 1,2,3$ denote random disturbance terms. We cannot assume these to be independently distributed because of the simultaneous equations structure where the dependent variables of the first two equations enter as independent variables in the third.

To account for the correlations between independent variables and disturbances that follow from these simultaneous equations, we apply a three-stage least squares regression framework. The coefficients $\alpha_2, \alpha_3, \beta_2, \beta_3, \gamma_2, \gamma_3, \gamma_4, \gamma_5$ capture the main

Table 1. Results for the Simultaneous Equations Model (Equation [1]) Pertaining to the Relationships in Figure 1.

Relationship in Figure 1	Coefficient in Equations (1)	Estimated coefficient	Standard error
Anticipated performance ranking affects change in testosterone	α_2 (NR-T)	−8.33	9.58
	α_2 (PR-T)	−14.20	8.13*
Moderation of being female on performance ranking effect on testosterone	α_3 (NR-T)	−8.34	15.41
	α_3 (PR-T)	−0.32	14.84
Anticipated performance ranking affects change in cortisol	β_2 (NR-T)	2.49	1.22**
	β_2 (PR-T)	1.98	1.03*
Moderation of being female on performance ranking effect on cortisol	β_3 (NR-T)	−5.00	1.96**
	β_3 (PR-T)	−2.43	1.89
Effect of change in testosterone on performance	γ_2	−0.12	0.04***
Effect of change in cortisol on performance	γ_4	0.52	0.26**
$N = 83$			

Note. Coefficients of model (1) were estimated with three-stage least squares ($N = 83$). The full regression model includes a gender dummy (0 = *male*; 1 = *female*), health and lifestyle variables, and benchmark levels of testosterone and cortisol. A full overview of the estimates is in Supplementary Materials. Results for NR-T and PR-T are relative to the benchmark of conducting the task without reporting performance (B-T). NR-T = "No-Ranking" treatment group; PR-T = "Performance-Ranking" treatment group.
*The coefficient concerned is statistically significantly at the 10% level (Wald tests).
**The coefficient concerned is statistically significantly at the 5% level (Wald tests).
***The coefficient concerned is statistically significantly at the 1% level (Wald tests).

relationships of interest. A first estimation of the coefficients showed that we cannot reject the null hypotheses that $\gamma_3 = 0$ and $\gamma_5 = 0$. This means that there is no difference between men and women in how performance responds to hormonal adaptations. We therefore drop the interaction terms $\Delta T \cdot G, \Delta C \cdot G$ from the third equation in (1).

Table 1 presents the coefficients estimated for the remaining relationships. Consistent with the results shown in Figure 2, we find that anticipating performance ranking (measured by the α_2 and β_2 coefficients for PR-T) predicts a reduction in testosterone, and an increase in cortisol, and that reductions in testosterone and increases in cortisol enhance cognitive performance (as measured by γ_2 and γ_4). We observe no moderation of gender on the effects of anticipated performance ranking on changes in testosterone (α_3 for PR-T). For changes in cortisol, the effects are observed only for men (for women, $\beta_2 + \beta_3 \approx 0$ for PR-T). Finally, the increase in cortisol observed for NR-T and PR-T (β_2) are of similar size and both significant for men. Similarly, for women, $\beta_2 + \beta_3$ is not significantly different for NR-T and PR-T ($p = .245$). This means that for cortisol, but not for testosterone, simply reporting to a peer has the same effect as being ranked.

We concluded our analyses by examining the model fit. We did a 100-fold repetition of an out-of-sample estimation. For every repetition, we randomly selected an estimation group E and a prediction group P. Every participant had a 50% chance of being in either. In every repetition, we estimated the model on E and predicted the

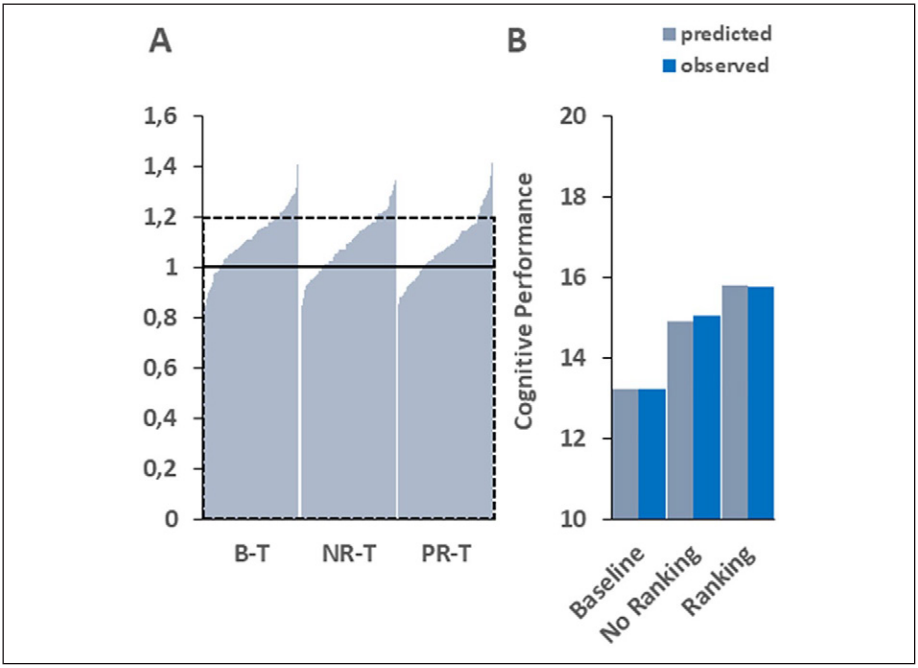

Figure 3. Predicted and observed performance. (A) Observed values per treatment, ordered from low to high. Perfect prediction is achieved when $F = 1.0$. Observed cases within the dashed area are predicted with 80% accuracy. (B). Out-of-sample predictions, showing the average performance for 100 subsamples of 50% of the data as estimated by the model (light blue) on the remaining 50% compared with their observed performance (dark blue).

number of correct summations for each participant in *P*. In every repetition, we then calculated for every participant in *P* a variable *F*, which is the predicted number of correct summations divided by the observed number. If the prediction for an individual is precise, then $F = 1$. A prediction that is 10% too high, for example, gives $F = 1.1$. For every repetition, we calculated the average *F* in *P*. We did so separately for each treatment (B-T, NR-T, PR-T). This gives 3 numbers per repetition and 300 in total. The observed values per treatment, ordered from low to high, show some overestimation (most values are larger than 1; Figure 3A), and that 82% of the predictions are between −20% and +20% of the observed number. Across all repetitions, the average prediction is very accurate (Figure 3B).

Discussion and Conclusion

Our estimation results show, taken together, that anticipating performance ranking causes a decrease of 14.20 pmol/L of testosterone and (for men) an increase of 1.98

nmol/L of cortisol, which accounts for an estimated ($-0.12 \times -14.20=$) 1.7 and ($0.52 \times 1.98=$) 1.0 correct summations, respectively. Put differently, the hormonal adaptions to anticipated performance ranking associate with 2.7 (1.7) additional correct summations for men (women), which is almost 19% (almost 13%) of the mean number of correct summations that males (females) have when they perform the task in isolation. Thus, the anticipation of being ranked by a peer decreases testosterone and increases cortisol, and through this combination of reduced testosterone and increased cortisol, cognitive performance can improve quite substantially. These findings are similar for males and females, but stronger for males, and remain so whether or not we control for a range of lifestyle variables. Accordingly, we conclude that anticipating performance ranking enhances cognitive performance because such anticipation affects hormonal adaptations in both testosterone and cortisol.

Others before us have observed effects of social comparison and performance ranking embedded in competitive incentive structures. Whereas competitive incentives can produce a surge of testosterone that in turn facilitates competitive performance, being observed has been associated with increased cortisol and, sometimes, reduced performance. Here, we find a diametrically different pattern of results when competitive incentives are eliminated. Merely anticipating being ranked on performance reduces testosterone and increases cortisol and increases cognitive performance. This suggests that the anticipation of performance ranking per se results in qualitatively different hormonal adaptations than does working under competitive incentives and when being observed by others. The effects we find are nontrivial, as under continued exposure to specific external pressures, such as social performance ranking, the associated hormonal adaptations of the kind observed here can exert structural effects on the brain and behavior (Sapolsky, 2005, 2017). As noted, performance ranking is omnipresent and an almost unavoidable fact of both professional and recreational life. Our results suggest that this formal and informal institutionalization of performance ranking can affect human cognitive performance. Even in the absence of economic incentives, merely anticipating performance ranking already increases cognitive performance when and probably because it increases cognitive effort, reduces overconfidence, and motivates people to go the extra mile.

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Author Contributions

CKWDD, KG, and AS designed the study, analyzed the data, discussed results, and wrote the article. AS and KG implemented the study.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Supplemental Material

Supplemental material for this article is available online.

Notes

1. As in Apascaritei et al. (this issue) and Aguiar et al. (also this issue), this is a real-effort task.
2. The health and lifestyle variable includes the number of hours slept on the previous night, the body mass index (BMI), a dummy indicating whether the participant is on medication, the average number of cigarettes smoked per day, minutes spent on sports in the past 24 hours, a dummy indicating sexual activity in past 24 hours, the number of glasses of alcohol in the past 24 hours, the number of cups of coffee in the past 24 hours, and (for women) a dummy variable indicating the use of an anticonceptive pill.

References

Akinola, M., & Mendes, W. B. (2012). Stress-induced cortisol facilitates threat-related decision making among police officers. *Behavioral Neuroscience*, *126*(1), 167-174. https://doi.org/10.1037/a0026657

Anderson, S., Ertac, S., Gneezy, U., List, J. A., & Maximiano, S. (2013). Gender, competitiveness, and socialization at a young age: Evidence from a matrilineal and a patriarchal society. *Review of Economic Statistics*, *95*(4), 1438-1443. https://doi.org/10.1162/REST_a_00312

Apicella, C. L., Dreber, A., & Mollerstrom, J. (2014). Salivary testosterone change following monetary wins and losses predicts future financial risk-taking. *Psychoneuroendocrinology*, *39*, 58-64. https://doi.org/10.1016/j.psyneuen.2013.09.025

Bateup, H. S., Booth, A., Shirtcliff, E. A., & Granger, D. A. (2002). Testosterone, cortisol, and women's competition. *Evolution and Human Behavior*, *23*(3), 181-192. https://doi.org/10.1016/S1090-5138(01)00100-3

Bosch, J. A., Veerman, E. C. I., de Geus, E. J., & Proctor, G. B. (2011). α-Amylase as a reliable and convenient measure of sympathetic activity: Don't start salivating just yet! *Psychoneuroendocrinology*, *36*(4), 449-53. https://doi.org/10.1016/j.psyneuen.2010.12.019

Brandts, J., Gërxhani, K., & Schram, A. (2020). Are there gender differences in status ranking aversion? *Journal of Behavioral and Experimental Economics*, *84*, 101485. https://doi.org/10.1016/j.socec.2019.101485

Buckert, M., Schwieren, C., Kudielka, B., & Fiebach, C. (2015). How stressful are economic competitions in the lab? *Journal of Economic Psychology*, *62*, 231-245. https://doi.org/10.1016/j.joep.2017.07.004

Buser, T., Dreber, A., & Mollerstrom, J. (2017). The impact of stress on tournament entry. *Experimental Economics*, *20*, 506-530. https://doi.org/10.1007/s10683-016-9496-x

Chen, C., Williamson, M. G., & Zhou, F. H. (2012). Reward system design and group creativity: An experimental investigation. *Accounting Review*, *87*(6), 1885-191. https://doi.org/10.2308/accr-50232

Chrousos, G. P. (2009). Stress and disorders of the stress system. *Nature Reviews Endocrinology*, *5*, 374-381. https://doi.org/10.1038/nrendo.2009.106

Coates, J. M., Gurnell, M., & Rustichini, A. (2009). Second-to-fourth digit ratio predicts success among high-frequency financial traders. *Proceedings of the National Academy of Sciences of the U S A*, *106*(2), 623-628. https://doi.org/10.1073/pnas.0810907106

Cooke, A., Kavussanu, M., McIntyre, D., & Ring, C. (2014). Effects of competition on endurance performance and the underlying psychological and physiological mechanisms. *Biological Psychology*, *86*(3), 370-378. https://doi.org/10.1016/j.biopsycho.2011.01.009

Cueva, C., Roberts, R., Spencer, T., Rani, N., Tempest, M., Tobler, P. N., Herbert, J., & Rustichini, A. (2015). Cortisol and testosterone increase financial risk taking and may destabilize markets. *Science Reports*, *5*, 11206. https://doi.org/10.1038/srep11206

De Dreu, C. K. W., & Nijstad, B. A. (2008). Conflict and creativity: Threat-rigidity or motivated focus? *Journal of Personality and Social Psychology*, *95*(3), 648-661. https://doi.org/10.1037/0022-3514.95.3.648

Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. *Psychological Bulletin*, *130*(3), 355-391. https://doi.org/10.1037/0033-2909.130.3.355

Eisenegger, C., Naef, M., Snozzi, R., Heinrichs, M., & Fehr, E. (2010). Prejudice and truth about the effect of testosterone on human bargaining behaviour. *Nature*, *463*, 356-359. https://doi.org/10.1038/nature08711

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*, 175-191. https://doi.org/10.3758/BF03193146

Festinger, L. (1954). A theory of social comparison. *Human Relations*, *7*(2), 117. https://doi.org/10.1177/001872675400700202

Gneezy, U., & Rustichini, A. (2000). Pay enough or don't pay at all. *Quarterly Journal of Economics*, *115*(3), 791-810. https://doi.org/10.1162/003355300554917

Goldfarb, E. V., Froboese, M. I., Cools, R., & Phelps, E. (2016). Stress and cognitive flexibility: Cortisol increases are associated with enhanced updating but impaired switching. *Journal of Cognitive Neuroscience*, *29*(1), 14-24. https://doi.org/10.1162/jocn_a_01029

Gouchie, C., & Kimura, D. (1991). The relationship between testosterone levels and cognitive-ability patterns. *Psychoneuroendocrinology*, *16*(4), 323-334. https://doi.org/10.1016/0306-4530(91)90018-O

Granger, D. A., Shirtcliff, E. A., Booth, A., Kivlighan, K. T, & Schwartz, E. B. (2004). The "trouble" with salivary testosterone. *Psychoneuroendocrinology*, *29*(10), 1229-1240. https://doi.org/10.1016/j.psyneuen.2004.02.005

Harrison, L. K., Denning, S., Easton, H. L., Hall, J. C., Burns, V. E., Ring, C., & Carroll, D. (2001). The effects of competition and competitiveness on cardiovascular activity. *Psychophysiology*, *38*(4), 601-606. https://doi.org/10.1111/1469-8986.3840601

Heffetz, O., & Frank, R. (2008). Preferences for status: Evidence and economic implications. In J. Benhabib, M. Jackson, & A. Bisin (Eds.), *Handbook of social economics* (Vol. 1A, pp. 69-91). Elsevier. https://doi.org/10.1016/B978-0-444-53187-2.00003-6

Hua, J. T., Hildreth, K. L., & Pelak, V. C. (2016). Effects of testosterone therapy on cognitive functioning in aging: A systematic review. *Cognitive and Behavioral Neurology*, *29*(3), 122-138. https://doi.org/10.1097/WNN.0000000000000104

Jost, J. T., Banaji, M. R., & Nosek, B. A. (2004). A decade of system justification theory: Accumulated evidence of conscious and unconscious bolstering of the status quo. *Political Psychology*, *25*(6), 881-919. https://doi.org/10.1111/j.1467-9221.2004.00402.x

Kelsey, R. M., Blascovich, J., Leitten, C. L., Schneider, T. R., Tomaka, J., & Wiens, S. (2000). Cardiovascular reactivity and adaptation to recurrent psychological stress: The moderating effects of evaluative observation. *Psychophysiology*, *37*(6), 748-756. https://doi.org/10.1111/1469-8986.3760748

Koedel, C., & Tyhurst, E. (2012). Math skills and labor-market outcomes: Evidence from a resume-based field experiment. *Economics of Education Review*, *31*(1), 131-140. https://doi.org/10.1016/j.econedurev.2011.09.006

Mazur, A., & Booth, A. (1998). Testosterone and dominance in men. *Behavioral and Brain Sciences*, *21*(3), 353-363. https://doi.org/10.1017/S0140525X98001228

Mehta, P. H., & Josephs, R. A. (2006). Testosterone change after losing predicts the decision to compete again. *Hormones and Behavior*, *50*(5), 684-692. https://doi.org/10.1016/j.yhbeh.2006.07.001

Moir, R. (1998). A Monte Carlo analysis of the Fisher randomization technique: Reviving randomization for experimental economists. *Experimental Economics, 1*(June), 87-100. https://doi.org/10.1023/A:1009961917752

Newman, M. L., Sellers, J. G., & Josephs, R. A. (2005). Testosterone, cognition, and social status. *Hormones and Behavior*, *47*(2), 205-211. https://doi.org/10.1016/j.yhbeh.2004.09.008

Oei, N. Y. L., Everaerd, W. T. A. M., Elzinga, B. M., Van Well, S., & Bermond, B. (2006). *Stress*, *9*(3), 133-141. https://doi.org/10.1080/10253890600965773

Pashler, H., Johnston, J. C., & Ruthruff, E. (2001). Attention and performance. *Annual Review of Psychology*, *52*, 629-651. https://doi.org/10.1146/annurev.psych.52.1.629

Riad-Fahmy, D., Read, G. F., Walker, R. F., Walker, S. M., & Griffiths, K. (1987). Determination of ovarian steroid hormone levels in saliva. An overview. *Journal of Reproductive Medicine*, *32*(4), 254-272.

Sapolsky, R. M. (2005). The influence of social hierarchy of primate health. *Science*, *308*(5722), 648-652. https://doi.org/10.1126/science.1106477

Sapolsky, R. M. (2017). *Behave: Humans at their best and worst*. Penguin. https://doi.org/10.1037/0033-295X.115.2.336

Schmader, T., Johns, M., & Forbes, C. (2008). An integrated process model of stereotype threat effects on performance. *Psychological Review*, *115*(2), 336-356. https://doi.org/10.1037/0033-295X.115.2.336

Schram, A. J. H. C., Brandts, J., & Gërxhani, K. (2019). Social-status ranking: A hidden channel to gender inequality under competition. *Experimental Economics*, *22*(2), 396-418. https://doi.org/10.1007/s10683-018-9563-6

Schwabe, L., Joels, M., Roozendaal, B., Wolf, O. T., & Oitzl, M. S. (2012). Stress effects of memory: An update and integration. *Neuroscience and Biobehavioral Reviews*, *36*(7), 1740-1749. https://doi.org/10.1016/j.neubiorev.2011.07.002

Sherman, G. D., & Mehta, P. H. (2020). Stress, cortisol, and social hierarchy. *Current Opinion in Psychology*, *33*, 227-232. https://doi.org/10.1016/j.copsyc.2019.09.013

Stanton, S. J., Liening, S. H., & Schultheiss, O. C. (2011). Testosterone is positively associated with risk taking in the Iowa Gambling Task. *Hormones and Behavior*, *59*(2), 252-256. https://doi.org/10.1016/j.yhbeh.2010.12.003

Staw, B. M., Sandelands, L. E., & Dutton, J. E. (1981). Threat-rigidity effects in organizational behavior: A multi-level analysis. *Administrative Science Quarterly*, *26*(2), 501-524. https://doi.org/10.2307/2392337

Taylor, S. E., & Lobel, M. (1989). Social-comparison activity under threat: Downward evaluation and upward contacts. *Psychological Review*, *96*(4), 569-575. https://doi.org/10.1037/0033-295X.96.4.569

Thilers, P. P., MacDonald, S. W. S., & Herlitz, A. (2006). The association between endogenous free testosterone and cognitive performance: A population-based study in 35-90 year old men and women. *Psychoneuroendocrinology*, *31*(5), 565-576. https://doi.org/10.1016/j.psyneuen.2005.12.005

Tops, M., & Boksem, M. A. S. (2011). Cortisol involvement in mechanisms of behavioral inhibition. *Psychophysiology*, *48*(5), 723-732. https://doi.org/10.1111/j.1469-8986.2010.01131.x

Twenge, J. M., Gentile, B., DeWall, C. N., Ma, D., Lacefield, K., & Schurtz, D. R. (2010). Birth cohort increases in psychopathology among young Americans, 1938-2007: A cross-temporal meta-analysis of the MMPI. *Clinical Psychology Review*, *30*(2), 145-154. https://doi.org/10.1016/j.cpr.2009.10.005

Weber, M., & Schram, A. J. H. C. (2016). The non-equivalence of labour market taxes: A real-effort experiment. *Economic Journal*, *127*(604), 2187-2215. https://doi.org/10.1111/ecoj.12365

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