Competitiveness and Stress

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This study explores the relationship between competitiveness and stress in two experiments. In Experiment 1, we examine the response of cortisol, the primary stress hormone, during both piece-rate and tournament laboratory tasks and assess subjects' willingness to compete. We find that the more competitive tournament task induces a higher cortisol response than the less competitive piece-rate task. Moreover, compared with less competitively inclined counterparts, more competitively inclined subjects exhibit higher stress responses induced by the tournament task. In Experiment 2, we exogenously manipulate stress using the Trier Social Stress Test and find that induced stress does not significantly affect subjects' willingness to compete. Taken together, our findings suggest a tendency for people who are competitively disposed to have high stress response.

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1. Introduction

Competition is ubiquitous in modern living. In school, in the workplace, and in our social networks, we compete for attention, promotion, recognition, and dominance. Tournaments, in which monetary prizes are based on performance ranking, have been widely applied in various competitive settings and extensively studied in the literature on economic incentive. The economic benefits of tournaments are commonly known to motivate workers to exert efforts and to enhance the productivity of firms (e.g., Lazear and Rosen, 1981; Bull, Schotter, and Weigelt, 1987).

This study investigates the role of stress in tournament competition, compared with a piece-rate one, in a laboratory setting. Evidence suggests that the level of perceived stress that comes with prospective employment opportunities can be a significant individual consideration often at par with financial compensations (Jex, 1998). Notably, stress in the workplace has been demonstrated to contribute substantially to healthcare cost and mortality (Goh, Pfefer, and Zenios, 2015). Notwithstanding its importance, the role of stress has been relatively neglected in economics. We address two closely related research questions. (1) Does the more competitive environment of a tournament induce higher levels of stress response than the relatively less competitive environment of a piece rate? (2) Do more competitive individuals who prefer tournament to a piece rate have greater levels of stress response than do less competitive people?

In Experiment 1, we examine the stress response during the laboratory tasks of Niederle and Vesterlund (2007). The stress response is measured by cortisol, the primary stress hormone that is secreted following exposure to both physical and psychological stressors as part of the hypothalamic–pituitary–adrenal (HPA) axis.[1] A total of 200 subjects perform two 5-minute calculation tasks of adding 5 two-digit numbers. One task is under a piece-rate compensation scheme, and the other is under a tournament compensation scheme with monetary incentive. After completing the two tasks, subjects choose whether they prefer to be compensated using the piece rate or the tournament scheme for performing a subsequent calculation task. This selection measures a key variable of interest, that is, the willingness to

[1] Stress response is often characterized by a fight-or-flight response, a physiological reaction that occurs following a perceived harmful event, attack, or threat to survival (Cannon, 1932). Stressful situations activate the two main physiological systems: the sympathetic adrenal–medullary (SAM) and the hypothalamic–pituitary–adrenal (HPA) axes. The SAM axis reflects a relatively fast actor, whereas the HPA axis reflects a relatively slow actor in response to stress. Cortisol is known as the primary stress hormone, and its secretion constitutes the main response of the HPA axis. By increasing blood pressure and blood sugar as well as suppressing the immune system, cortisol enables a steady supply of energy to meet the emergent challenge presented by the stressor.

compete or competitiveness. We measure cortisol responses in saliva samples induced by the piece rate and tournament schemes in the first two tasks.

Related to our first research question, we find increased cortisol levels following both piece-rate and tournament tasks. This finding suggests that significant stress is experienced when performing both tasks. In and of itself, this observation is notable in demonstrating that two simple laboratory tasks used in experimental economics can induce a substantial stress hormone response. We further find that cortisol response is higher in the tournament task than in the piece-rate task, thus indicating that a more competitive environment induces a greater stress response at least in the laboratory setting. In a meta-analysis of 208 laboratory studies, Dickerson and Kemeny (2004) reveal that cortisol response exhibits substantial variability across different acute situational stressors. Cortisol does not increase following emotion induction procedures (e.g., by watching emotion-eliciting films) or noise exposure tasks in which subjects experience loud noises. However, a substantial cortisol response is evident following public-speaking tasks (e.g., verbally interacting with other people) or specific cognitive tasks (e.g., performing mental arithmetic calculations). Moreover, a combination of both public-speaking and cognitive tasks elicits an even higher cortisol response. Dickerson and Kemeny argue that cortisol response is elicited only under a restricted set of conditions in which the motivated performance is either uncontrollable or characterized by social-evaluative threats, for example, poor performance that can be negatively judged by others. Our result reflects this view. As an arithmetic task with motivated performance, the piece rate task elicits a cortisol response. By contrast, the tournament task induces an even greater cortisol response because this task includes a stronger social evaluation component and a higher motivation for performance.

In relation to our second research question, we find that the more competitively inclined subjects who choose the tournament over the piece rate task for the subsequent performance exhibit greater cortisol response in the tournament task than the less competitively inclined subjects. Moreover, the observed relationship between competitiveness and cortisol response remains significant after controlling for behavioral factors that may be related to competitiveness including performance, confidence, and risk attitude. In separate analyses, we do not find cortisol response to be significantly associated with any of these behavioral factors related to competitiveness. This result implies that the observed correlation between cortisol response and competitiveness is improbable to be driven by these factors. Cortisol response is known to exhibit substantial variability across individuals. In a meta-analysis of 358 studies on individual differences in cortisol response, Campbell and Ehlert (2012) suggest that individuals with high motivational engagement exhibit a high cortisol response. For instance, subjects who attempt to preserve a positive image appear to be physiologically aroused and thus have a high cortisol response. This view of individual variability is consistent with our observation that more competitive individuals may be more motivated to compete and engage in the tournament task, thus leading to a higher cortisol response, than their less competitive counterparts.

To verify the robustness of the observed relationship between stress response and competitiveness, we also examine the response of salivary alpha-amylase, which has been proposed as another useful stress biomarker related to the sympathetic adrenal–medullary (SAM) axis (Nater and Rohleder, 2009).[2] Similar to the results obtained with cortisol, we find that more competitively inclined subjects have a higher alpha-amylase response when performing the first two tasks than the less competitively inclined ones. In addition, the association between competitiveness and response of cortisol and alpha-amylase remains significant after controlling for baseline testosterone, an additional important component of the neuroendocrine patterns in response to social stress. Overall, these analyses provide further support for the observed correlation between competitiveness and task-induced stress response that engages both the HPA and SAM axes.

To clarify the issue of causality, we conduct a second experiment to examine the effect of exogenously induced stress on competitiveness.[3] In this experiment, subjects are assigned randomly to either the control condition or the treatment condition based on the Trier Social Stress Test (TSST), which is widely regarded as the gold standard of laboratory elicitation of stress response (Kirschbaum, Pirke, and Hellhammer, 1993). Subjects in the TSST perform a public-speaking task and a cognitive task involving mental arithmetic. Subjects in the control condition perform two corresponding stress-neutral tasks. Immediately after the tasks, subjects choose whether they would prefer to be compensated using the piece rate or the tournament scheme for performing a subsequent five-minute calculation task. We find that the degree of competitiveness does not significantly differ between subjects in the TSST condition and those in the control condition. Therefore, the results from our second

[2] Alpha-amylase production in the saliva glands increases in response to psychological and physical stress through interactions with the autonomic nervous system (Nater and Rohleder, 2009).

[3] Mehta and Josephs (2006) manipulate testosterone levels using a competition game. Recently, Apicella, Dreber, and Mollerstrom (2014) examine testosterone changes following monetary wins and losses in a chance game. Buser, Dreber, and Mollerstrom (2015) scrutinize exogenously induced stress using the cold-pressor task.

experiment do not support the contention that acutely experienced stress leads to increased competitiveness. Combining both Experiments 1 and 2, our results suggest that highly competitive subjects have a trait-characteristic-heightened cortisol response.

Our study contributes to a small but growing literature that is beginning to incorporate stress into economic analysis. In an earlier study, Apicella et al. (2011) report no significant association between competitiveness and baseline cortisol level, and this finding is also reflected in the current study.[4] Schipper (2014) finds no correlation between competitive bidding in first-price auctions and baseline cortisol. Goette et al. (2015) find that cortisol response to social stress correlates with self-confidence and that the effect depends on the level of trait anxiety. Coates et al. (2009) demonstrate that the cortisol levels of financial day traders increases with both the variance of trading results and the volatility of the market. In a comprehensive review, Haushofer and Fehr (2014) interestingly suggest that poverty-induced stress may lead to poor decisions, which may in turn lead to further poverty. Chemin, de Laat, and Haushofer (2013) observe that as a negative income shock, a low level of rain in the preceding year increases cortisol levels among farmers in Kenya. In addition to these empirical studies, Klaus (2015) proposes a novel theoretical model, in which stress reduces the instantaneous utility of individuals and coping can be controlled or uncontrolled as a function of personality and enviorment. Our results reveal that simple experimental tasks such as piece-rate and tournament ones can induce significant stress response in subjects and that competitiveness is robustly linked to dynamic physiological stress responsiveness.

Using the design of Niederle and Vesterlund (2007), recent studies have been conducted to examine whether gender difference in response to stress can explain gender difference in the decision to compete. Buckert et al. (2015) find that the tournament condition induces a high heart rate and arterial blood pressure but not cortisol. They also observe that testosterone response predicts competitiveness. Buser, Dreber, and Mollerstrom (2015) discern that cortisol response correlates with competitiveness for women but not for men. They also observe that the cold-pressor task, which induces physical but not social stress, does not affect competitiveness. In addition, they find that stress cannot explain the gender gap in willingness to compete. Halko and Sääksvuori (2015) identify that basal heart rate variability predicts self-selection into competition for women but not for men. However, heart rate is not related to gender difference in competitiveness. Overall, these studies

[4] A few recent studies on competitiveness also explore the role of self-reported intake of hormone contraceptives (Buser, 2012) and self-reported menstrual cycle (Pearson and Schipper, 2013; Wozniak et al., 2014).

consistently demonstrate that gender difference in stress does not explain gender difference in competitiveness.

The potential dark side of competition and incentive, which have been extensively discussed in the literature, includes increased sabotage behavior (Charness, Masclet, and Villeval, 2013), reduced cooperative behavior (Buser and Dreber, 2015), deteriorated well-being (Brandts, Riedl, and van Winden, 2009), and diminished performance (Dohmen, 2008). Our study reveals that a more competitive incentive scheme can lead to a higher stress response than a less competitive one and that more competitively inclined individuals have a higher stress response than those who are less competitively inclined. These results suggest that stress and its accompanying potential long-term health consequences are important in considering an incentive scheme. Moreover, the ability to cope with stress is an important non-cognitive skill in affecting labor market outcomes (Heckman, Stixrud and Urzua, 2006).

The rest of the paper is organized as follows. Section 2 presents our experimental design. Section 3 discusses our findings. Section 4 presents the concluding remarks.

2. Experimental Design

2.1. Experiment 1

Behavioral tasks. We adopt the behavioral tasks in Niederle and Vesterlund (2007) designed to assess competitiveness. In Experiment 1, subjects perform calculation tasks by adding up sets of five randomly generated two-digit numbers. Subjects are allowed to use scratch papers but not calculators. Each problem is presented in the following manner, and subjects are required to indicate the sum in the blank box.

14	54	91	23	87	

Once the subject has submitted an answer, a new problem appears on the computer screen with information about whether the previous answer is correct. A record of the numbers of correct and wrong answers is retained on screen. Each subject has five minutes to solve as many problems as he/she can manage. The final score is determined by the number of correctly solved problems. Subjects are asked to complete the following four tasks.

- *Piece-rate task*. Subjects are given five minutes to calculate the sums of the sets of five randomly generated two-digit numbers. Subjects can do as many calculations as they can within five minutes and earn SG$1.50 (approximately US$1.20) per correct answer. This task provides a behavioral measure of performance under a piece-rate condition.

- *Tournament task*. Similar to the piece-rate task, subjects are given five minutes to calculate the sums of the sets of five randomly generated two-digit numbers. In each session, we have an even mix of both genders. We do not explicitly tell the subjects that subjects are randomly divided into groups of four with two men and two women because this setup can have potential priming effects of the gender role. Within each group, the subject who solves the highest number of problems receives SG$6.00 per correct answer, and the other three subjects receive no payment. Subjects only know their own performance and not the performance of the other subjects. This task provides a behavioral measure of performance under a tournament condition.
- *Tournament choice for the subsequent performance (competitiveness)*. Subjects select whether they want to be paid according to a piece-rate or a tournament compensation scheme as described above. If subjects choose the former, they receive SG$1.50 per correct answer for their score in their subsequent performance. If subjects choose the latter, they receive SG$6.00 per correct answer if the score in this task exceeds the scores of the other group members in the previous tournament task; otherwise, they receive no payment. This task provides a behavioral measure of competiveness (i.e., choosing to enter a competitive environment in the subsequent performance).
- *Tournament choice for the past performance (general factors related to competitiveness)*. Subjects' compensation depends on their performance, that is, the number of correct answers provided in the piece-rate task. Subjects choose which compensation scheme—piece rate or tournament—to apply to their performance in the piece-rate task. If subjects choose the former, they receive SG$1.50 per correct answer in the task. If subjects choose the latter, they receive SG$6.00 per correct answer if their performance in the task exceeds those of other group members regardless of their choice of compensation scheme; otherwise, they receive no payment. Niederle and Vesterlund (2007) suggest that a tournament choice for the past performance reflects general factors that may affect competitiveness, such as overconfidence, risk attitude, and feedback aversion. Thus, a tournament choice for the past performance provides an important control variable in the analysis of the relationship between competitiveness and stress.

The first two tasks are presented in a counterbalanced order followed by a tournament choice for the subsequent performance (competitiveness) and a tournament choice for the past performance (general factors related to competitiveness). Subjects are compensated on the basis of their performance in one of the four tasks randomly selected at the end of the experiment. By paying for one task, subjects have the appropriate incentive to perform well in the selected task without the possibility of hedging across tasks.

After performing the four tasks, we elicit subjects' beliefs about their relative performance in both piece-rate and tournament tasks among a group of four. Each subject guesses his/her relative performance in terms of ranking between first and fourth, and he/she is paid SG$5.00 for each correct guess. This scheme provides a measure of the subjects' confidence level in their performance in both piece-rate and tournament tasks. In addition, to test whether stress-related hormone response relates specifically to competitiveness or generally to risk attitude, we include a measure of risk attitude using a price-list design. Subjects choose between an even-chance lottery paying either SG$10 or SG$0 and 10 levels of sure amounts ranging from SG$2.50 to SG$7.00. Subjects complete a questionnaire and provide demographic information at the end of the experiment. The detailed instructions are presented in Appendix B.

Procedure. On Day 0, subjects arrived at the laboratory and were informed that the study concerned the biological basis of decision making. They were given instructions to refrain from physical activity, eating, or drinking (except water) for 90 minutes prior to their participation in the experiment on Day 1. We measured the cortisol levels from saliva samples.[5] The procedure of the experiment is summarized in Figure 1. Subjects arrived at the laboratory at 14:00 to perform the experimental tasks from 14:00 to 16:00 to minimize the effect of the circadian rhythm of cortisol. Moreover, cortisol response is usually delayed after stressor termination. From the onset of the stressor, cortisol response reaches its peak in 15 to 20 minutes and returns to the baseline level approximately 40 to 60 minutes later (Dickerson and Kemeny, 2004). Considering this temporal profile of cortisol response, seven saliva samples were collected during the 90-minute session as follows (see Figure 1). The first saliva sample was collected five minutes after arrival (indicated as the "0 minute") to assess the baseline cortisol level. Subjects were then given instructions for the first task (piece-rate or tournament depending on the assigned order). After the five-minute task, a 40-minute break was given; subjects sat by themselves and had the option to engage in light reading but not to speak with one another. In addition, three salivary samples were obtained at 0

[5] We also measure the cortisol awakening response because cortisol secretion follows a diurnal cycle with a marked increase after awakening. To focus on the cortisol response induced by the piece-rate and tournament tasks in the current study, we leave the result on cortisol awakening response to a follow-up paper.

(immediately after the task), 15, and 40 minutes post-task to document the slow activity of the cortisol. Cortisol is anticipated to begin increasing at 0 minute, peak at approximately 15 minutes, and return to its baseline at around 40 minutes. These three samples measure the cortisol response induced by the first task. Subjects were then given instructions to perform the second five-minute task followed by a second 40-minute break. Three saliva samples were collected at 0 minute (immediately after performing the second task), 15, and 40 minutes after the second task. These three samples measure the cortisol response induced by the second task. Subjects then continued with the rest of the tasks without breaks until the end of the experiment.

We recruited 200 undergraduate subjects, including 98 men (mean age: 22.75, SD = 1.31) and 99 women (mean age: 21.01, SD = 1.23).[6] Selection criteria stipulated that subjects must have no history of or current psychiatric disorder, past or present use of drugs including oral contraceptives, and not pregnant or have not given birth in the past year (compliance with these criteria was assessed with a self-report questionnaire). Informed consent was obtained for each subject using a form approved by the Internal Review Board. Subjects received SG$30 as a show-up fee and an additional payment depending on their performance during the experiment.

Sampling and biochemical analysis. Saliva samples were collected in sterile tubes by passive drool using a short plastic straw for expectorating. Immediately after performing the experimental tasks, the salivary samples (initially stored in iceboxes) were refrigerated and stored at –80 °C until assayed. Salivary cortisol concentration (nmol/ml) was determined using the SalimetricsTM salivary cortisol enzyme immunoassay kit. All samples were measured in duplicate, and we obtained the mean as the measure.

The first sample (C_0) was obtained at the beginning of the experiment, which measured the baseline cortisol. For the three samples collected at 0 (C_1), 15 (C_2), and 40 minutes (C_3) post the piece-rate task, we used the area-under-the-curve-with-respect-to-ground (AUCG) formula to compute the cortisol response for the piece-rate task (Cortisol: P) given by $\frac{15(C_1 + C_2)}{2} + \frac{25(C_2 + C_3)}{2}$. The AUCG formula is widely used in endocrinology to

[6] Originally, we had 200 subjects composed of 100 men and 100 women. We subsequently noticed that three subjects participated in the experiment a second time because of screening errors and the data from their second participation were excluded. Considering the mandatory military service for men starting at age 18, our male subjects were generally two years older than our female subjects.

integrate information contained in repeated measurements over time (Pruessner et al., 2003). In our context, AUCG provides a measure of total cortisol release induced by the task. Similarly, we had three samples collected at 0 (C_4), 15 (C_5), and 40 minutes (C_6) post the tournament task, and we computed the cortisol response (Cortisol: T) given by $\frac{15(C_4+C_5)}{2} + \frac{25(C_5+C_6)}{2}$. We further computed the differential response (Cortisol: T-P) given by the difference between the cortisol response to the tournament and piece-rate tasks. We tabulate our results using these nomenclatures.

Salivary alpha-amylase. Besides measuring cortisol response, we examined another stress biomarker, alpha-amylase, which could serve as a robustness check. Alpha-amylase response is known to peak 10–15 minutes after the onset of the stressor and return to baseline in approximately 20–30 minutes, and thus we only measured the alpha-amylase in two time points. Specifically, in our experiment, we measured alpha-amylase collected at 0 (A_1) and 15 minutes (A_2) subsequent to the piece-rate task, keeping in mind that they might not be the most accurate timing. Similarly, we measured the alpha-amylase obtained at 0 minutes (A_4), and 15 minutes (A_5) after the tournament task. The salivary alpha-amylase activity (U/ml) was determined using the salivary alpha-amylase kinetic enzyme assay kit, and all samples were measured in duplicate. We also used the AUCG formula to compute the alpha-amylase response for piece-rate (Alpha-amylase: P), given by $\frac{15(A_1+A_2)}{2}$, and the alpha-amylase response for tournament (Alpha-amylase: T), given by $\frac{15(A_4+A_5)}{2}$. We computed the differential response (Alpha-amylase: T-P) given by the difference between the alpha-amylase response for tournament and piece-rate tasks.

Testosterone. Although we did not measure testosterone response because of budget constraints and our focus on stress hormone, we measured baseline testosterone from the first saliva sample collected five minutes after arrival. Salivary testosterone concentration (pg/ml) was determined using testosterone enzyme immunoassay kit, and all samples were measured in duplicate.

2.2. Experiment 2

Trier Social Stress Test. Experiment 2 aims to investigate whether induced stress affects the willingness to compete. As demonstrated in Dickerson and Kemeny (2004), the most robust cortisol response is observed when tasks include a social-evaluative threat, in which others can negatively judge one's performance, particularly when the outcome of the performance is uncontrollable. A paradigm that incorporates these essential features of evoking a robust cortisol response is the TSST (Kirschbaum, Pirke, and Hellhammer, 1993). Briefly, the TSST comprises two tasks (i.e., free speech and mental arithmetic) that last for 10 minutes performed in front of a stone-faced panel of two committee members, a male and a female dressed in white coats, with a camera and microphone situated between the interviewers. The TSST is the gold standard of laboratory social stress tests and is widely used for almost two decades to induce stress response. The original TSST procedure requires subjects to undergo the protocol individually to reduce the possibility of obtaining a statistically reliable sample size given the limited resources (e.g., availability of laboratory). Recently, von Dawans, Kirschbaum, and Heinrichs (2011) propose a group version of the TSST, the TSST-G, which induces stress in a group of four subjects at a time without compromising the effectiveness of the protocol. In addition to the TSST, the experiments usually include a control condition, in which subjects perform two corresponding relatively stress-neutral tasks. Subjects are randomly assigned to the treatment condition of the TSST or to the control condition.

Treatment condition. For subjects in the TSST-G, a group of four subjects receives instructions with details of a mock job interview. They are informed that a video analysis of their performance will be conducted and that further questions can be asked at any point during the interview. After a five-minute preparation period, the video cameras are set to record and the four subjects are called in random order to give a two-minute speech describing why they should be selected for a job of their choice. If they finish the speech in less than two minutes, the committee member will say, "You still have some time left. Please continue." If the subject stops for a second time, the experimenter remains quiet for 20 seconds before asking a few prepared standard questions. After the speech task, subjects are called in reverse order from the speech task to perform an 80-second mental arithmetic task. In the task, subjects subtract 16 serially from a starting number ranging from 1,900 to 2,100. If they make a mistake during the recitation, they are instructed to "stop" and restart at their given number. Similar to the TSST, the committee maintains neutral facial expressions and does not give verbal or non-verbal feedback to the subjects. The combination of preparation for the public speech, the public speech task itself, and the mental arithmetic task altogether is known as the TSST, which is recognized to induce robustly stress in human subjects.

Control condition. The protocol for the control group closely parallels that of the treatment group. A group of four subjects similarly faces physical and cognitive loads. However, the sources of stress in the treatment condition, including the elements of socio-evaluative threat and uncontrollability, are removed. For the first eight minutes, instead of preparing for a speech, the control group reads an emotionally neutral popular scientific text in a low voice.[7] The subjects read the text by themselves without the audience. This activity contrasts with the public speaking task. Finally, for the next 5 minutes and 20 seconds, the subjects count upwards individually from zero in additions of five instead of individually performing the serial subtraction. This modification controls for the cognitive load of the mental arithmetic task. The control condition is known to isolate the cause of stress including uncontrollability and socio-evaluation.

Procedure. Subjects were informed that the study explored the relationship between physiological arousal and decision making. One day prior to the experiment, we sent an email to qualified subjects reminding them to have a standard breakfast and lunch on the day of the experiment. We also reminded subjects to refrain from physical activity, eating, or drinking (except water) for 90 minutes prior to their participation in the experiment and to abstain from exercising or consuming caffeine, alcohol, and any medication 24 hours before the experiment. The testing was conducted between 14:00 and 18:00 to minimize the effect of the circadian hormone rhythm.

On the day of the experiment, four subjects were led into the laboratory five minutes before the experiment. They were seated randomly at individual stalls that had barriers on three sides to discourage communication. We ensured that all sessions are conducted on groups with mixed genders. After obtaining the consent form, we randomly determined whether these four subjects would be in the treatment condition or in the control condition. We did not collect salivary samples to measure the cortisol response because the treatment

[7] We extract several articles from www.sciencedaily.com. The topics of the articles include fern hybridization, new findings in quantum steering, effects of urbanization on puma behavior, human behavior in a crowd, and a new breed of radar systems.

condition has been consistently demonstrated to induce a robust cortisol response compared with the control condition in hundreds of studies (Dickerson and Kemeny, 2004).

Immediately after performing the tasks, subjects were informed that they would be given five minutes to calculate the sums of sets of five randomly generated two-digit numbers. They were instructed to choose whether they wanted to be paid according to a piece-rate or a tournament compensation scheme. If subjects choose the piece-rate scheme, they receive SG$1.50 for each correct answer in their subsequent performance. If subjects choose the tournament scheme, they receive SG$6.00 per correct answer if their score in this task exceeds the scores of the three subjects randomly selected from 200 individuals who participated in the previous tournament task; otherwise, they receive no payment. This task provides a behavioral measure of competiveness, that is, choosing to enter a competitive environment in the subsequent performance. Demographic information such as age and gender is collected at the end of the experiment.

We recruited 84 undergraduate subjects, including 40 (18 women) in the control condition and 44 (22 women) in the treatment condition.[8] Selection criteria were identical to those of Experiment 1. Informed consent was obtained for each subject using a form approved by the Internal Review Board. Subjects received SG$10 as a show-up fee and additional payment depending on their performance and their choice in the calculation task.

3. Results

We analyze the data and report our results in several steps. We begin with a summary of the behavioral observations, including competitiveness, performance, confidence, and risk attitude, as well as the cortisol response induced by performing piece-rate and tournament tasks in Experiment 1, followed by an analysis of whether observed cortisol response predicts competitiveness. In addition, we examine if the alpha-amylase response can also predict competitiveness and consider the possible confounding factors of baseline testosterone. Subsequently, we investigate whether exogenously induced stress by TSST influences competitiveness in Experiment 2. Finally, we discuss the potential role of gender in both Experiments 1 and 2.

[8] One subject did not complete the entire experiment, and thus we exclude this subject from the subsequent analysis.

3.1. Summary statistics

Table 1 summarizes the aggregate behavioral observations. Among the subjects, 36% choose the tournament compensation scheme over the piece-rate one for the subsequent performance (i.e., Task 3), and 30.5% choose the tournament scheme over the piece rate one for the past performance (i.e., Task 4). On average, subjects solve 12.6 questions in the tournament task and 12.7 questions in the piece-rate one, and the performance is not significantly different between the tournament and the piece-rate tasks (t-test, $p > 0.914$). In the tournament task, 29.9% of the subjects speculate their performance ranking to be first, and 35% speculate it to be second. Subjects are mostly overconfident in their performance. In the piece-rate task, 22.8% of the subjects speculate their performance ranking to be first, and 37.6% speculate it to be second. No significant difference in the confidence level is evident between the tournament and piece-rate tasks (t-test, $p > 0.124$). In the risk attitude task, 18.0% of the subjects are risk seeking. Consistent with the observation of Niederle and Vesterlund (2007), the observed behaviors in the current study are generally correlated with one another using Spearman correlation tests (see Table A1 in the Appendix). As a result, we control for the related behavioral factors when we examine the relationship between competitiveness and stress in subsequent analyses.

Table 2 and Figure 2 summarize the observations regarding cortisol response. Figure 2A plots the baseline cortisol level, cortisol level induced by the piece-rate task, and that by the tournament task. In both piece-rate and tournament tasks, the measured cortisol levels at 15 minutes post-task is significantly higher than the cortisol level at 0 minute (piece-rate, $p < 0.026$; tournament, $p < 0.001$) and the 40-minute post-task cortisol level (piece-rate, $p < 0.005$; tournament, $p < 0.001$). Between tournament and piece-rate tasks, the cortisol level at 15 minutes after the tournament task is significantly higher than that at 15 minutes after the piece-rate task ($p < 0.014$). The differential cortisol response between the piece-rate and tournament tasks is marginally significant from zero ($p < 0.053$). These results suggest that subjects experience stress indexed by the cortisol response in both tasks and that more stress is experienced during the tournament task than during the piece-rate one. The cortisol response in the piece-rate task, that in the tournament one, and the baseline cortisol level are positively correlated (see Table A2 in the Appendix).

3.2. Competitiveness and stress response

3.2.1. Competitiveness and cortisol response induced by the tasks

Figure 3A plots the baseline cortisol level, the cortisol level induced by the piece-rate task, and that induced by the tournament task for subjects who select the piece-rate task and those who choose the tournament one. Figure 3A reveals a clear pattern that, despite having similar baseline cortisol levels, more competitive subjects have higher cortisol response than their less competitive counterparts in the tournament. We test the relationship between cortisol and competitiveness using Probit regression with robustness standard error (see Table 3A). The dependent variable is competitiveness, the main independent variable is cortisol response in the tournament, and the control variables are gender and order effect. Column 1 in Table 3A indicates that the cortisol response in the tournament is significantly and positively correlated with competitiveness. The marginal effect of the Probit regression is 0.0009, which implies that a one standard deviation increase in the cortisol response increases the probability of choosing tournament by 10.8%.

The observed relationship between cortisol response and competitiveness is consistent with the meta-analysis in Campbell and Ehlert (2012), which suggests that people with high motivational engagement (e.g., attempting to preserve a positive social image) have a high cortisol response. Nevertheless, other possible behavioral mechanisms are evident. In particular, a heightened cortisol response may reflect a sense of engagement, which increases the performance in the tournament and subsequently increases the probability of choosing the tournament. We examine alternative mechanisms under which cortisol response may primarily affect performance, confidence, risk attitude, or tournament choice for the past performance, leading to the observed correlation between cortisol response and competitiveness.

We control for a number of behavioral factors including performance in the tournament, performance difference between tournament and piece-rate tasks, confidence in the tournament, confidence difference between tournament and piece-rate tasks, risk attitude, and tournament choice for the past performance (see Table 3A, Columns 2 to 8). When we control for all these additional variables in the regression analysis, the relationship remains significant, with the marginal effect reduced to 0.0006. Two of these robustness checks are of particular interest. First, when either performance or performance difference between the tournament and piece-rate tasks is included as an additional independent variable, cortisol response remains significant and exhibits a nearly identical effect size (see Table 3A, Columns 2 and 3). This finding suggests that performance is unlikely to be a channel for the correlation between cortisol response and competitiveness. Second, when tournament choice for the past performance is included as a control variable, our results remain significant (see Table 3A, Column 8). This finding suggests that cortisol response is specific for competitiveness rather than other competitiveness-related factors measured in the tournament choice for the past performance. A similar pattern is observed in Niederle and Vesterlund (2007), in which a significant gender difference exists in competitiveness but not in tournament choice for the past performance. Moreover, gender difference in competitiveness remains significant after controlling for tournament choice for the past performance. The overall evidence suggests that competitiveness and tournament choice for the past performance represent distinct behaviors.

The results of our analyses support a robust link between cortisol response in the tournament and competitiveness. Nevertheless, whether this relationship is specific to cortisol response in the tournament remains unanswered. To address this question, we test if cortisol response in the piece-rate task is significantly associated with competitiveness. Using similar regression analyses, Table 3B indicates that the effect is also significant for cortisol response in the piece-rate task before controlling for tournament choice for the past performance. After we control for tournament choice for the past performance along with other variables (see Table 3B, Column 8), the coefficient for cortisol response in the piece-rate task becomes insignificant ($p > 0.150$). This finding suggests a weaker association for the cortisol response in the piece-rate task than that for the tournament task. We do not observe any significant relationship when examining if the differential cortisol response between tournament and piece-rate tasks may be correlated with competitiveness (see Table 3C).

Given the temporal profile of cortisol response, we examine the individual cortisol level at different time points by including the cortisol level for the seven time points in a single regression analysis. We determine that competitiveness is significantly correlated with cortisol level at 15 minutes after the tournament ($p < 0.015$), which represents the peak of the cortisol response induced by the tournament task, but is not significantly correlated with the baseline cortisol level along with other time points. Notably, the lack of association between the baseline cortisol level and competitiveness replicates the earlier finding of Apicella et al. (2011). This finding further supports the link between tournament-induced cortisol response and competitiveness.

3.2.2. Competitiveness and alpha-amylase response

To examine the robustness of our observation that the more competitive subjects have higher cortisol response than the less competitive subjects, we include an additional stress biomarker, namely, salivary alpha-amylase, in our analysis. Figure 2B plots the alpha-amylase responses in the piece-rate and tournament tasks. In Figure 2B, the first 0 minute and 15 minutes refer to the levels immediately and 15 minutes after the piece-rate task, respectively. Similarly, the second 0 minute and 15 minutes refer to the levels immediately and 15 minutes after the tournament task, respectively. In both piece-rate and tournament tasks, the alpha-amylase response at 15 minutes post-task is significantly higher than the alpha-amylase levels at 0 minute ($p < 0.001$ for piece-rate; $p < 0.001$ for tournament). The alpha-amylase response is not significantly different between the piece-rate and tournament tasks for both 0 minute post-task ($p > 0.178$) and 15 minutes post-task ($p > 0.200$). We suspect that this finding is due to the fast response of the SAM axis, which is not captured precisely by our designed timing. Alternatively, this finding may suggest a potentially different adaptive response (i.e., attenuation of the SAM axis) in relation to the stress experienced by the subjects. In addition, the alpha-amylase responses are not significantly correlated with the cortisol responses in the tournament and piece-rate tasks (Table A2 in Appendix A). This finding suggests that alpha-amylase and cortisol responses capture the stress systems of the SAM and HPA axes differently.

Figure 3B plots the alpha-amylase responses of subjects who select the piece-rate task and those who choose the tournament one. The more competitive subjects have higher alpha-amylase response in the tournament and piece-rate tasks than the less competitive subjects (see Figure 3B). Adopting similar regression analyses, we test for the relationship between the alpha-amylase response in the tournament and competitiveness. Column 1 in Table 4A indicates that the alpha-amylase response in the tournament is significantly and positively correlated with competitiveness. The marginal effect of Probit regression is 0.00008, which implies that a one standard deviation increase in alpha-amylase increases the probability of choosing tournament by 6.5%. We further observe that the results are robust after controlling for other behavioral factors in Columns 2–8 of Table 4A. We observe a significantly positive correlation between the alpha-amylase response and performance in the tournament, confidence in the tournament, and confidence difference between the tournament and piece-rate tasks. However, no effects are significant after we further control for competitiveness, and this finding suggests that the primary correlation is between the alpha-amylase response and competitiveness. Similarly, we observe a significant association for alpha-amylase in the piece-rate task (see Table 4B) but not for a differential alpha-amylase response between the tournament and piece-rate tasks (see Table 4C).

Finally, we include the cortisol responses and alpha-amylase responses in the tournament and piece-rate tasks as independent variables in the regression analysis. The individual responses during the tasks are not significant except for the cortisol response in the tournament ($p < 0.107$) and the alpha-amylase response in the piece-rate task ($p < 0.008$). An additional F-test reveals that the joint effect of cortisol and alpha-amylase responses on the two tasks is significant at $p < 0.021$ and $p < 0.011$, respectively. Moreover, the result of a joint F-test for all four variables is highly significant at $p < 0.002$. Overall, our results suggest a robust relationship between the stress response, as measured by cortisol and alpha-amylase, and competitiveness.

Our observation between competitiveness and stress can be subject to omitted variable bias. In particular, the cortisol response may be correlated with other hormones, especially testosterone. Testosterone has been suggested as an important part of the neuroendocrine patterns in response to aggression and competition. Although our primary interest is cortisol response, we also include a baseline measure of testosterone at the beginning of the experiment. First, we test if baseline testosterone predicts competitiveness using a similar analysis. We find that testosterone is not significantly correlated with competitiveness (see Table A3 in Appendix A). Moreover, our observed results on cortisol response and alpha-amylase remain significant after we further control for baseline testosterone (see Table A4 in Appendix A).

3.2.3. Competitiveness-related behavior and stress response

We have observed that stress responses in cortisol and alpha-amylase are correlated with competitiveness after controlling for competitiveness-related behavior such as performance and confidence. A question of interest is if stress response can also be correlated with other competitiveness-related behavior. First, we examine the role of cortisol response in the tournament. Columns 1 to 6 of Table 5A indicate that the cortisol response in the tournament is not significantly correlated with any competitiveness-related behaviors, including performance in the tournament, differential performance between the tournament and piece-rate tasks, confidence in the tournament, differential confidence between the tournament and piece-rate tasks, risk attitude, and tournament choice for the past performance.

Similarly, we examine the role of cortisol response in the piece-rate task, differential cortisol response between the tournament and piece-rate tasks, alpha-amylase response in the tournament, alpha-amylase response in the piece-rate task, and differential alpha-amylase response between the tournament and piece-rate tasks and report the results in Tables 5B, 5C, 5D, 5E, and 5F, respectively. Overall, we find no significant correlation, except that the alpha-amylase responses in the tournament and piece-rate tasks are negatively and significantly correlated with confidence in the tournament and differential confidence between the tournament and piece-rate tasks. The result suggests that subjects with a high alpha-amylase response have high confidence about their ranking and their ranking in the tournament relative to the piece-rate task.

3.3. Induced stress and competitiveness

The previous subsection demonstrates a robust correlation between stress response and competitiveness. On the one hand, more competitive individuals may be more motivated and engaged in the tasks than their less competitive counterparts, thus leading to higher stress response. On the other hand, subjects experience a higher stress response in the first two tasks, and this response may increase their willingness to compete. Experiment 2 investigates the second possibility by inducing stress using the TSST. If the second possibility is true, we expect to observe a higher percentage of subjects choosing tournament in the treatment condition compared with the control condition. By contrast, we find that the proportion of subjects choosing tournament in the treatment condition is 34.9%, and the proportion of those choosing tournament in the control condition is slightly higher at 40%. This difference is not statistically significant ($p > 0.632$). The lack of significance in the treatment effect on competitiveness is robust after further controlling for age, gender, and performance ($p > 0.370$). This finding is in accordance with that of Buser, Dreber, and Mollerstrom (2015), which reveals that stress induced by cold pressor does not affect competitiveness. The observed relationship between competitiveness and cortisol response is suggested to arise from the first possibility, that is, more competitive individuals are more engaged in the tasks and correspondingly exhibit higher stress response than less competitive people.

3.4. Gender, competitiveness, and stress

This subsection explores the possible role of gender, which is relevant for two reasons. First, as gender difference in competitiveness is the key finding in Niederle and Vesterlund (2007), verifying if we can replicate the observation in our sample is of interest. Second, men and women have been hypothesized to react differently to stressors, especially social stressors (Taylor et al., 2000). For example, men have significantly higher cortisol levels than women in response to public-speaking tasks (Shalev et al., 2009).

In Experiment 1, we observe an 8.4% gender difference in competitiveness (40.0% of men and 31.6% of women choose tournament over piece rate), although the difference is not statistically significant ($p > 0.201$). We do not find a significant gender difference in competitiveness after further controlling for performance, confidence, risk attitude, age, and order of the first two tasks (see Table A5 in Appendix A). By contrast, in Experiment 2, we observe a 23.8% gender difference in competitiveness (48.8% of men and 25% of women choose tournament over piece rate) that is statistically significant ($p < 0.026$). The observation in Experiment 2 is consistent with that of Niederle and Vesterlund (2007), which indicates that 73% of their male subjects select tournament and over 35% of the female subjects make the same choice. The inconsistency between Experiments 1 and 2 on gender difference can be attributed to the subtle differences in the experimental designs. In particular, before making the choice on competitiveness, subjects are given a 40-minute break to measure the stress response in Experiment 1, whereas they make the choice immediately after the tasks in Experiment 2 as well as in the experiment in Niederle and Vesterlund (2007). This difference in design feature may induce a “cold” decision-making state and a “hot” decision-making state in Experiments 1 and 2, respectively. We leave this question for further studies.[9]

In terms of hormonal response, no significant gender difference is evident in cortisol responses, whereas a marginally significant gender difference exists in alpha-amylase responses (see Table 2). In terms of a possible role of gender and stress in competitiveness, we find that the point estimation for the gender coefficient remains the same with respect to the inclusion or exclusion of hormone responses in Experiment 1. After adding an interaction term, including cortisol and alpha-amylase responses in the tournament and piece rate, between gender and stress responses, we do not detect significance in any of these interaction terms (see Table A6 in the Appendix). In addition, we do not find significance in the

[9] In a manuscript in preparation, Zhong (2016) randomly assigns subjects into two treatments: (1) 40-minute break before the choice on competitiveness and (2) 40-minute break after the choice on competitiveness. Gender difference in competitiveness is significantly observed when the break is after the choice on competitiveness, whereas no significant gender difference is noted when the break is before the choice on competitiveness. This result provides an explanation for the inconsistency between Experiments 1 and 2 in the current study.

interaction term between gender and treatment/control conditions in Experiment 2. Overall, these findings suggest that the gender difference in competitiveness is unlikely to be driven by stress, thus supporting the related observation in the recent study by Buser, Dreber, and Mollerstrom (2015).

4. Concluding Remarks

In Experiment 1, we adopt the simple addition tasks in Niederle and Vesterlund (2007) to induce stress, proxied by cortisol response, and examine its relationship with competitiveness. Our observation of substantial stress response in both piece-rate and tournament tasks points to the efficacy of observing stress levels in economic experiments. Moreover, subjects tend to have higher cortisol response during the tournament task than during the piece-rate one, suggesting a higher level of stress during the former. We uncover the role of task-induced cortisol response rather than baseline cortisol level in predicting competiveness. We further provide a robust check using a second biomarker—salivary alpha-amylase—for a distinct physiological stress system (i.e., SAM) and observe a similar pattern. Overall, our results suggest that more competitive individuals tend to have a higher stress response across the body's principal stress systems than less competitive people.

In Experiment 2, following the association between competitiveness and stress response, we manipulate stress through the TSST (Kirschbaum, Pirke, and Hellhammer, 1993). We demonstrate that induced stress does not affect competitiveness. In follow-up research, seeking an enhanced understanding of the causality between competitiveness and stress can be valuable. In this regard, studies may require intervention treatments to manipulate subjects' preference for competitiveness. For instance, subjects may employ emotion regulation to be less competitive, and then whether or not emotion regulation affects cortisol response can be tested. In this regard, Sokol-Hessner et al. (2009) instruct subjects to think similar to a trader and find that emotion regulation affects both loss aversion and skin conductance response to losses. Alternatively, future studies may adopt a pharmacological approach to manipulate the cortisol system and observe how it may affect competitiveness. For example, Kandasamy et al. (2014) manipulate the cortisol levels using individually tailored hydrocortisone regimens and find that cortisol shifts financial risk preferences. These implications may offer a powerful approach to demonstrate a causal role of cortisol in competitiveness.

Our study demonstrates a direct role of the within-tasks stress response in a laboratory-observed disposition to compete and contributes to the extension of the scope of research on economics to encompass stress. As the study focuses on acute stress in the laboratory, investigating if and how different incentive schemes induce chronic stress in the long term and if and how chronic stress may sequentially affect career choice in the workplace is relevant. Moreover, understanding if and how environmental factors, especially during early childhood (Heckman, 2000), affect one's ability to cope with stress and if and how the ability to cope with stress as a non-cognitive skill affects labor market outcomes can be of importance.

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Figures and Tables

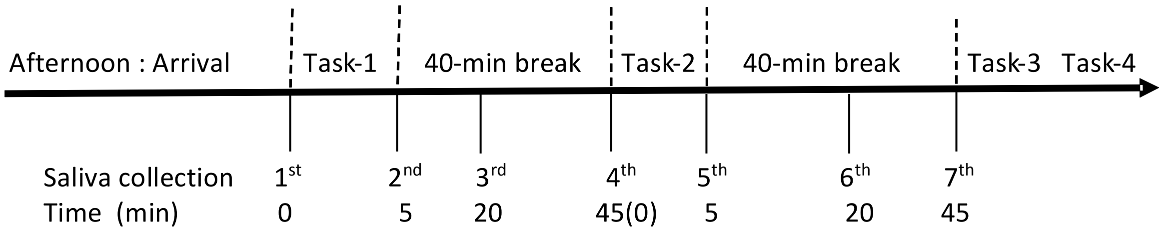

Figure 1. Experimental Timeline. Seven saliva samples were collected in the afternoon session: before Task 1; at 0, 15, and 40 minutes post-Task 1; and at 0, 15, and 40 minutes post-Task 2.

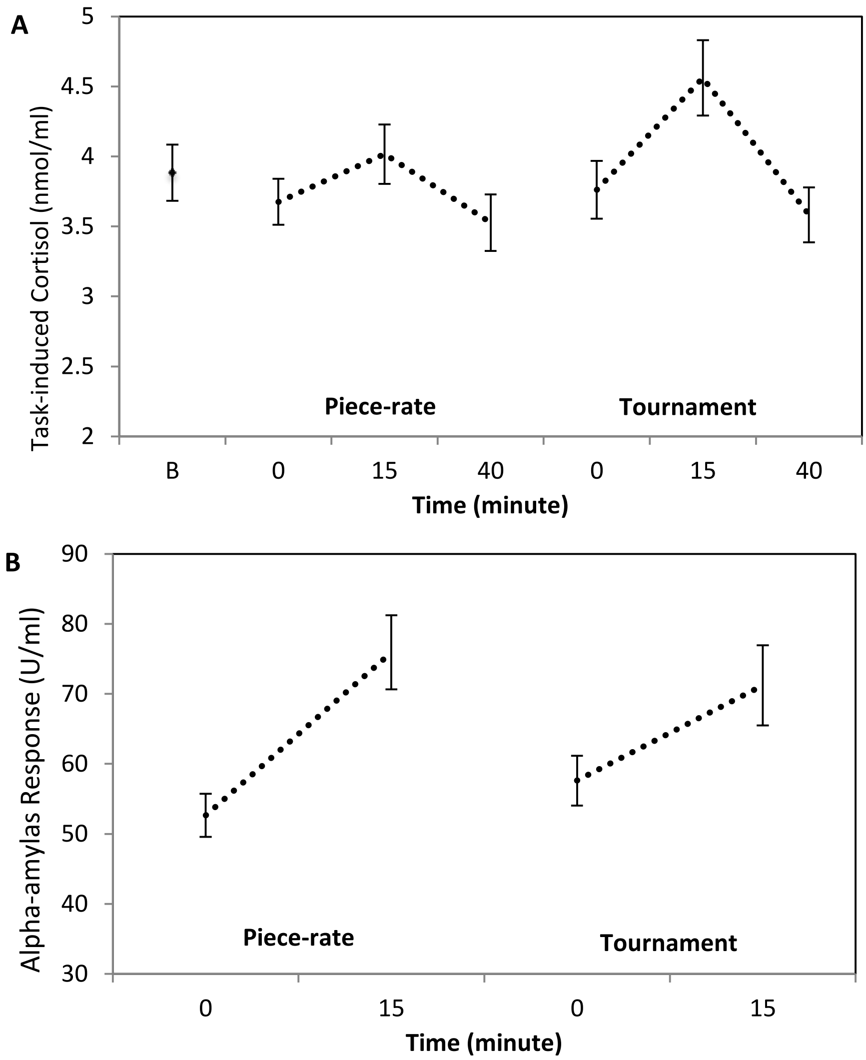

Figure 2. **Stress Response**. A. Task-induced cortisol response. X-axis is the timeline and Y-axis is the response. B. Task-induced alpha-amylase response. X-axis is the timeline and Y-axis is the response. As we counter-balanced the order of piece-rate and tournament tasks, we reorder the timeline to show the stress response induced by the piece-rate task and tournament task. The bar represents the standard error of the mean.

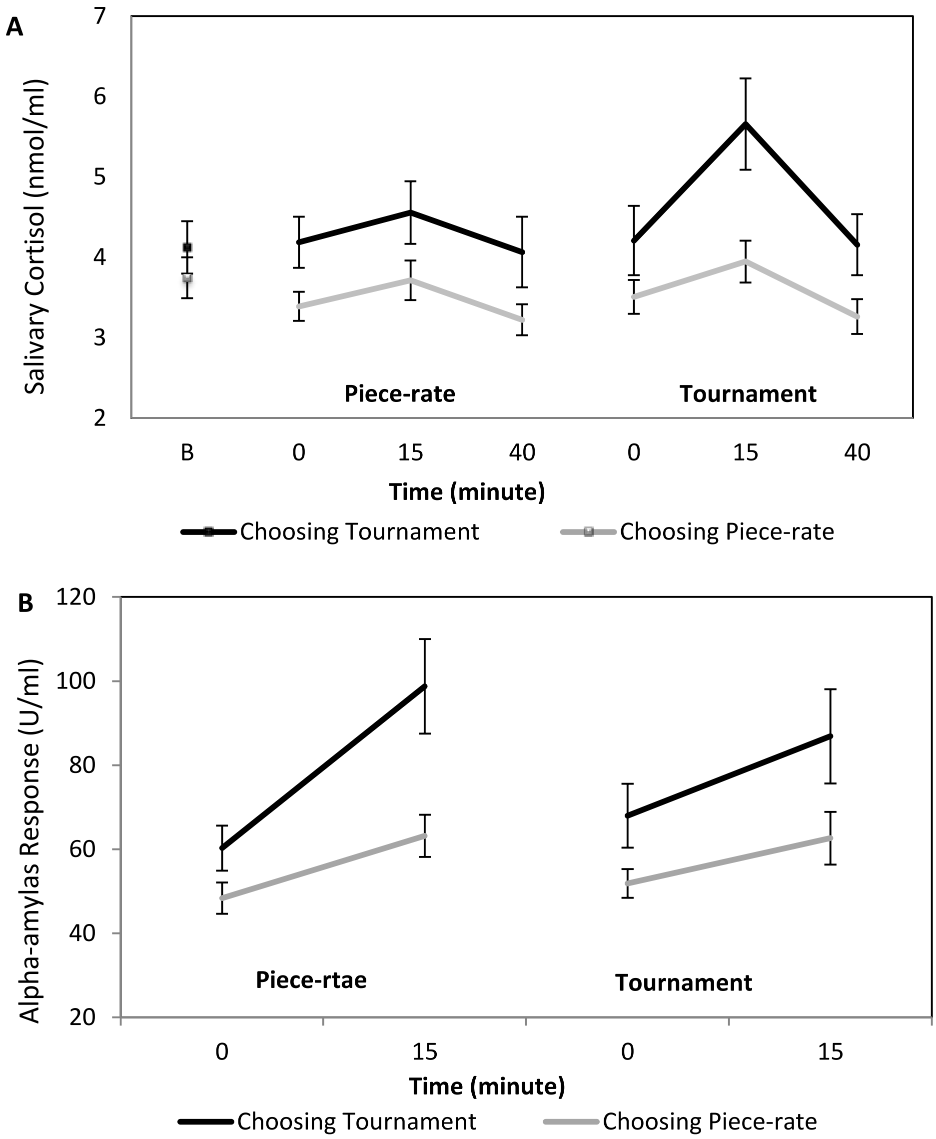

Figure 3. Stress response and competitiveness. A. Task-induced cortisol response by subjects choosing tournament and choosing piece-rate. X-axis is the timeline and Y-axis is the response. B. Task-induced alpha-amylase response by subjects choosing tournament and choosing piece-rate. X-axis is the timeline and Y-axis is the response. As we counter-balanced the order of piece-rate and tournament tasks, we reorder the timeline to show the stress response induced by the piece-rate task and tournament task. The bar represents the standard error of the mean.

Table 1. Summary Statistics for Behavior

Behavior	Pool			Men			Women			p-value
	N	Mean	SD	N	Mean	SD	N	Mean	SD	
Competitiveness	197	0.36	0.48	99	0.40	0.493	98	0.32	0.47	0.199
Task 4	197	0.30	0.46	99	0.34	0.477	98	0.27	0.44	0.190
Performance: P	197	12.69	6.26	99	13.06	6.87	98	12.32	5.58	0.283
Performance: T	197	12.73	5.73	99	13.46	5.758	98	11.98	5.63	0.083
Performance: T-P	197	0.04	4.64	99	0.40	4.467	98	-0.34	4.79	0.354
Confidence: P	197	2.33	1.00	99	2.17	0.969	98	2.49	1.02	0.016
Confidence: T	197	2.19	1.02	99	2.03	1.005	98	2.36	1.02	0.020
Confidence: T-P	197	-0.14	1.24	99	-0.14	1.04	98	-0.13	1.42	0.855
Risk attitude	188	4.28	2.09	95	4.36	2.153	93	4.20	2.03	0.688

Note. The table presents the summary statistics for behavioral variables for pool as well as for men and women separately. The first column displays the name of the variable. Columns 2 to 10 display the sample size (N), mean and standard deviation (SD) for pool, men and women, respectively. The last column reports p-value testing whether there is significant gender difference. It summarizes the percentages of choosing tournament over piece-rate in Task 3 (competitiveness), and the percentages of choosing tournament over piece-rate in Task 4, performance in piece-rate and in tournament, difference in performance between piece-rate and tournament, confidence in piece-rate and in tournament (rank between 1 and 4), difference in confidence between piece-rate and tournament, and risk attitude (between 0 and 10 with 5 indicating risk neutrality). For risk attitude, we excluded 5 men and 5 women who exhibited multiple switch points in the price-list task.

Table 2: Summary Statistics for Stress Hormone

Stress Hormone	Pool			Men			Women			p-value
	N	Mean	SD	N	Mean	SD	N	Mean	SD	
Baseline Cortisol	187	3.90	2.74	97	4.01	3.20	90	3.77	2.14	0.520
Piece-rate C1	188	3.69	2.25	97	3.57	2.01	91	3.82	2.49	0.454
Piece-rate C2	188	4.04	2.92	97	4.44	3.48	91	3.62	2.10	0.053
Piece-rate C3	187	3.54	2.74	96	3.31	2.27	91	3.78	3.16	0.239
Cortisol: P	187	153.02	96.84	96	157.51	105.04	91	148.28	87.70	0.530
Tournament C1	186	3.78	2.81	96	3.99	3.12	90	3.56	2.43	0.234
Tournament C2	188	4.60	3.71	97	5.02	4.02	91	4.15	3.31	0.081
Tournament C3	188	3.61	2.69	97	3.60	2.42	91	3.61	2.97	0.952
Cortisol: T	186	166.07	120.01	96	175.96	124.72	90	155.53	114.52	0.193
Cortisol: T-P	185	12.85	90.99	95	18.32	108.68	90	7.08	67.63	0.256
Piece-rate A1	187	53.49	43.53	96	57.71	43.30	91	49.03	43.55	0.193
Piece-rate A2	188	75.63	72.23	97	85.02	79.13	91	65.63	62.97	0.066
Alpha-amylase: P	187	968.59	813.18	96	1071.59	861.95	91	859.93	747.75	0.050
Tournament A1	188	57.44	48.47	97	64.92	53.32	91	49.46	41.53	0.028
Tournament A2	187	70.96	77.98	96	83.57	87.19	91	57.66	64.77	0.023
Alpha-amylase: T	187	962.36	907.78	96	1113.02	1008.28	91	803.42	761.72	0.009
Alpha-amylase:T-P	186	1.16	478.16	95	56.39	561.66	91	-56.50	365.93	0.217
Testosterone	187	108.03	57.48	96	147.35	51.89	91	66.56	24.47	0.001

Note. This table summarizes baseline cortisol before the task, three cortisol measure induced by piece-rate (C1-C3), overall piece-rate induced cortisol response (Cortisol: P), three cortisol measures induced by tournament (C4-C6), overall tournament induced cortisol response (Cortisol: T) and differential cortisol response between tournament and piece-rate (Cortisol: T-P). For alpha-amylase, we have two measures induced by piece-rate (A1, A2), overall piece-rate induced response (Alpha-amylase: P), two measures included by tournament (A4, A5), overall tournament induced response (Alpha-amylase: T), and differential response between tournament and piece-rate (Alpha-amylase: T-P), and baseline testosterone. In addition, there are a few missing values in some of the hormone measures. We do not measure the hormone for 9 subjects as outliers, including 5 subjects whose performance falling more than 3 standard deviations from the norm and 4 subjects who have zero performance in the tournament task. The hormone data for subjects are missing due to poor quality of the measurement.

Table 3. Competitiveness and Cortisol Response

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Cortisol Response in Tournament								
Cortisol: T	0.0009***	0.0008**	0.0009***	0.0008**	0.0009***	0.0008**	0.0007**	0.0006*
	[0.0003]	[0.0003]	[0.0003]	[0.0003]	[0.0003]	[0.0003]	[0.0003]	[0.0003]
Panel B: Cortisol Response in Piece-rate								
Cortisol: P	0.0008**	0.0007*	0.0008**	0.0007*	0.0009**	0.0009**	0.0007*	0.0006
	[0.0004]	[0.0004]	[0.0004]	[0.0004]	[0.0004]	[0.0004]	[0.0004]	[0.0004]
Panel C: Cortisol Response Difference Between Tournament and Piece-rate								
Cortisol: T-P	0.0005	0.0004	0.0005	0.0004	0.0005	0.0003	0.0001	0.0002
	[0.0004]	[0.0004]	[0.0004]	[0.0004]	[0.0004]	[0.0005]	[0.0004]	[0.0005]
Performance: T		Y					Y	Y
Performance: T-P			Y				Y	Y
Confidence: T				Y			Y	Y
Confidence: T-P					Y		Y	Y
Risk attitude						Y	Y	Y
Task 4								Y
Gender	Y	Y	Y	Y	Y	Y	Y	Y
Order effect	Y	Y	Y	Y	Y	Y	Y	Y

Note. Probit regression on the relationship between competitiveness and cortisol response in tournament, piece-rate, and difference between piece-rate and tournament. The dependent variable is competitiveness, and the independent variables include cortisol response in tournament (Panel A), piece-rate (Panel B), and difference between piece-rate and tournament (Panel C). We have a number of control variables including performance in tournament, performance difference between tournament and piece-rate, confidence in tournament, confidence difference between tournament and piece-rate, risk attitude, tournament choice without performance, gender, and order effect. The table reports the marginal effects with robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4. Competitiveness and Alpah-amylase Response

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Alpah-amylase Response in Tournament								
Alpha-amylase: T	0.00007*	0.00006	0.00008*	0.00005	0.00007*	0.00009**	0.00007*	0.00006
	[0.00004]	[0.00004]	[0.00004]	[0.00004]	[0.00004]	[0.00004]	[0.00004]	[0.00005]
Panel B: Alpah-amylase Response in Piece-rate								
Alpha-amylase: P	0.00012***	0.00011**	0.00013***	0.00009*	0.00012**	0.00014***	0.00014**	0.00013**
	[0.00005]	[0.00005]	[0.00005]	[0.00005]	[0.00005]	[0.00005]	[0.00006]	[0.00006]
Panel C: Alpah-amylase Response Difference between Tournament and Piece-rate								
Alpha-amylase: T-P	-0.00007	-0.00007	-0.00007	-0.00008	-0.00007	-0.00008	-0.00011	-0.00012
	[0.00008]	[0.00008]	[0.00008]	[0.00007]	[0.00007]	[0.00008]	[0.00009]	[0.00008]
Performance: T		Y					Y	Y
Performance: T-P			Y				Y	Y
Confidence: T				Y			Y	Y
Confidence: T-P					Y		Y	Y
Risk attitude						Y	Y	Y
Task 4								Y
Gender	Y	Y	Y	Y	Y	Y	Y	Y
Order effect	Y	Y	Y	Y	Y	Y	Y	Y

Note. Probit regression on the relationship between competitiveness and alpha-amylase response. The dependent variable is competitiveness, and the independent variables include alpha-amylase response in tournament (Panel A), alpha-amylase response in piece-rate (Panel B), and difference between tournament and piece-rate (Panel C). We include a number of control variables including performance in tournament, performance difference between tournament and piece-rate, confidence in tournament, confidence difference between tournament and piece-rate, risk attitude, tournament choice without performance, gender, and order effect. The table reports the marginal effects with robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 5. Competitiveness-related Behavior and Stress Response

(1)	(2)	(3)	(4)	(5)	(6)
Performance: T	Performance:P	Confidence:T	Confidence: T-P	Risk attitude	Tournament choice w/o performance
Panel A: Cortisol response: T					
0.0056	-0.0006	-0.0005	-0.0003	0.0009	0.0000
[0.0036]	[0.0022]	[0.0005]	[0.0007]	[0.0012]	[0.0003]
Panel B: Cortisol response: P					
0.0050	-0.0006	-0.0004	0.0004	-0.0007	0.0002
[0.0033]	[0.0030]	[0.0007]	[0.0008]	[0.0015]	[0.0004]
Panel C: Cortisol response: T-P					
0.0041	0.0001	-0.0005	-0.0012	0.0024	-0.0002
[0.0057]	[0.0034]	[0.0007]	[0.0009]	[0.0018]	[0.0004]
Panel D: Alpha-amylase: T					
0.0004	0.0003	-0.0001**	-0.0002*	-0.0002	0.0000
[0.0003]	[0.0003]	[0.0001]	[0.0001]	[0.0002]	[0.0000]
Panel E: Alpha-amylase: P					
0.0005	0.0003	-0.0002**	-0.0002**	-0.0002	0.0000
[0.0003]	[0.0003]	[0.0001]	[0.0001]	[0.0002]	[0.0000]
Panel F: Alpha-amylase: T-P					
0.0001	0.0001	-0.0001	-0.0000	-0.0000	-0.0000
[0.0009]	[0.0006]	[0.0001]	[0.0002]	[0.0003]	[0.0001]

Note. Regression on the relationship between competitiveness-related factors and stress responses. The dependent variable includes performance in tournament (Column 1), performance difference between tournament and piece-rate (Column 2), confidence in tournament (Column 3), confidence difference between tournament and piece-rate (Column 4), risk attitude (Column 5), tournament choice without performance (Column 6). The independent variables are cortisol response in tournament (Panel A), cortisol response in piece-rate (Panel B), and cortisol response difference between tournament and piece-rate (Panel C), alpha-amylase response in tournament (Panel D), alpha-amylase response in piece-rate (Panel E), alpha-amylase response difference between tournament and piece-rate (Panel F). We control for gender, order effect and competitiveness. The table reports regression coefficients with robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Online Appendix A: Appended Tables

Table A1. Correlational Analysis for Behavior

	Competitiveness	Task 4	Performance: P	Performance: T	Confidence: P	Confidence: T
Task 4	0.384***					
Performance: P	0.306***	0.292***				
Performance: T	0.245**	-0.008	0.448***			
Confidence: P	-0.329***	-0.603***	-0.567***	-0.240**		
Confidence: T	-0.368***	-0.223***	-0.282**	-0.614***	0.273**	
Risk attitude	0.273***	0.253***	0.181**	0.072	-0.247**	-0.212**

Note. This table presents the spearman correlations for behavioral variables including choosing tournament in Task 3 and Task 4, performance in piece-rate and in tournament, confidence in piece-rate and in tournament, and risk attitude. ***significant at 1% level, **5% level, *10% level.

Table A2. Correlational Analysis for Stress Hormone

	Baseline Cortisol	Cortisol: P	Cortisol: T	Alpha-amylase: P	Alpha-amylase: T
Cortisol: P	0.529***				
Cortisol: T	0.467***	0.699***			
Alpha-amylase: P	-0.073	-0.007	0.012		
Alpha-amylase: T	-0.053	0.073	0.036	0.786***	
Testosterone	0.181**	0.105	0.151**	0.012	0.039

Note. This table presents the spearman correlations for stress hormone variables including baseline cortisol, overall piece-rate induced cortisol response (Cortisol: P), overall tournament induced cortisol response (Cortisol: T), overall piece-rate induced alpha-amylase response (Alpha-amylase: P), overall tournament induced alpha-amylase response (Alpha-amylase: T) and baseline testosterone. ***significant at 1% level, **5% level, *10% level.

Table A3. Competitiveness and Baseline Testosterone

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Testosterone	0.0015	0.0016*	0.0014	0.0015*	0.0014	0.0009	0.0013	0.0009
	[0.0009]	[0.0009]	[0.0009]	[0.0009]	[0.0009]	[0.0009]	[0.0009]	[0.0009]
Performance: T		0.0271***					0.0154	0.0258**
		[0.0094]					[0.0120]	[0.0124]
Performance: T-P			-0.0089				-0.0262*	-0.0208
			[0.0123]				[0.0159]	[0.0154]
Confidence: T				-0.1709***			-0.1994***	-0.0624
				[0.0415]			[0.0625]	[0.0737]
Confidence: T-P					-0.0218		0.0709	-0.0247
					[0.0301]		[0.0483]	[0.0585]
Risk attitude						0.0734***	0.0512**	0.0503**
						[0.0196]	[0.0204]	[0.0208]
Task 4								0.3502***
								[0.1108]
Gender	0.0406	0.0773	0.0364	0.0865	0.0362	-0.0153	0.0677	0.0319
	[0.1019]	[0.1047]	[0.1016]	[0.1014]	[0.1024]	[0.1038]	[0.1106]	[0.1143]
Order effect	-0.0076	0.0581	-0.0567	0.0403	0.0079	-0.0313	-0.1162	-0.0838
	[0.0711]	[0.0762]	[0.0952]	[0.0744]	[0.0749]	[0.0733]	[0.1026]	[0.1039]
Observations	187	187	187	187	187	178	178	178
Pseudo R-squared	0.0168	0.0506	0.0193	0.102	0.0190	0.0777	0.174	0.213

Note. Probit regression on the relationship between competitiveness and testosterone. The dependent variable is competitiveness, and the independent variables include baseline testosterone, performance in tournament, performance difference between tournament and piece-rate, confidence in tournament, confidence difference between tournament and piece-rate, risk attitude, tournament choice without performance, gender, and order effect. The table reports the marginal effects with robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A4: Robustness Check after Controlling for Testosterone

(1)	(2)	(3)	(4)
Cortisol: T	Cortisol: P	Alpha-amylase: T	Alpha-amylase: P
0.0006*	0.0006	0.00007	0.00013**
[0.0003]	[0.0004]	[0.00004]	[0.0006]

Note. Robustness check after controlling for the baseline testosterone, including relationship between competitiveness and cortisol response in tournament (Column 1), cortisol response in piece-rate (Column 2), alpha-amylase response in tournament (Column 3), alpha-amylase response in piece-rate (Column 4). We include the independent variables (performance in tournament, performance difference between tournament and piece-rate, confidence in tournament, confidence difference between tournament and piece-rate, risk attitude, tournament choice without performance, gender, and order effect). The table reports the marginal effects with robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A5. Competitiveness and Gender

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Gender	-0.0883	-0.0549	-0.0910	-0.0386	-0.0890	-0.0949	-0.0363	-0.0418
	[0.0684]	[0.0715]	[0.0687]	[0.0715]	[0.0684]	[0.0706]	[0.0794]	[0.0818]
Performance: T		0.0316***					0.0227***	0.0330***
		[0.0081]					[0.0088]	[0.0116]
Performance: T - P			-0.0070				-0.0269*	-0.0242*
			[0.0104]				[0.0142]	[0.0142]
Confidence: T				-0.1852***			-0.1928***	-0.0715
				[0.0406]			[0.0622]	[0.0709]
Confidence: T - P					-0.0243		0.0687	-0.0208
					[0.0296]		[0.0475]	[0.0569]
Risk attitude						0.0643***	0.0522***	0.0496**
						[0.0186]	[0.0196]	[0.0206]
Task 4								0.3334***
								[0.1002]
Order effect	0.0122	0.0869	-0.0307	0.0618	0.0295	-0.0110	-0.1014	-0.0814
	[0.0688]	[0.0750]	[0.0925]	[0.0719]	[0.0724]	[0.0715]	[0.1025]	[0.1048]
Observations	197	197	197	197	197	188	188	188
Pseudo R-squared	0.00652	0.0737	0.00847	0.109	0.00924	0.0614	0.200	0.238

Note. Probit regression on determinants of competitiveness. The dependent variable is competitiveness, and the independent variables include performance in tournament, performance difference between tournament and piece-rate, confidence in tournament, confidence difference between tournament and piece-rate, risk attitude, tournament choice without performance, gender, and order effect. The table reports the marginal effects with robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A6: Interaction between Stress Hormone and Gender

	(1)	(2)	(3)	(4)
	Cortisol: T	Cortisol: P	Alpha-amylase: T	Alpha-amylase: P
Hormone	0.0006	0.0001	0.0001	0.0002**
	[0.0004]	[0.0006]	[0.0000]	[0.0001]
Gender	-0.0359	-0.2466*	-0.0299	0.1044
	[0.1393]	[0.1476]	[0.1186]	[0.1400]
Interaction	0.0000	0.0014	-0.0000	-0.0002
	[0.0006]	[0.0009]	[0.0001]	[0.0001]

Note. The interaction effect between hormone and gender one competitiveness are examine, including cortisol response in tournament (Column 1), cortisol response in piece-rate (Column 2), alpha-amylase response in tournament (Column 3), alpha-amylase response in piece-rate (Column 4). We include the independent variables (performance in tournament, performance difference between tournament and piece-rate, confidence in tournament, confidence difference between tournament and piece-rate, risk attitude, tournament choice without performance, gender, and order effect). The table reports the marginal effects with robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Appendix B: Experimental Instructions

Welcome to our study on decision making. The descriptions of the study contained in this experimental instrument will be implemented fully and faithfully.

Each participant will receive on average $60 for the study. The overall compensation includes a $30 show up fee in addition to earnings based on how you make decisions.

All information provided will be kept CONFIDENTIAL. Information in the study will be used for research purposes only. You are not to discuss with anyone any aspect of the specific tasks during or after the study.

1. The set of decision making tasks and the instructions for each task are the same for all subjects.
2. It is important to read the instructions CAREFULLY so that you understand the tasks and make better decisions.
3. If you have any questions, please raise your hand to ask our experimenters at ANY TIME.
4. PLEASE DO NOT communicate with others during the experiment.
5. Please take the time to go through the instructions carefully and make your decisions.
6. Cell phones and other electronic devices are not allowed.

In the experiment today you will be asked to complete four different tasks involving calculation. None of these will take more than 5 minutes. At the end of the 4 tasks, there is a decision making task involving 10 choices.

The method we use to determine your earnings varies across tasks. Before each task we will describe in detail how your payment is determined. Your total earnings from the experiment are the sum of your payment for the randomly selected task from task 1 to task 4, a randomly selected choice from the 10 choices, and a $30 for show-up fee. At the end of the experiment you will be asked to come to the side where you will be paid in private.

1. P1

For Task 1 you will be asked to calculate the sum of five randomly chosen two-digit numbers. You will be given 5 minutes to calculate the correct sum of a series of these problems. You cannot use a calculator to determine this sum, however you are welcome to write the numbers down and make use of the provided scratch paper. You submit an answer by clicking the submit button with your mouse. When you enter an answer the computer will immediately tell you whether your answer is correct or not. Your answers to the problems are anonymous.

If Task 1 is the one randomly selected for payment, then you get $1.5 per problem you solve correctly in the 5 minutes. Your payment does not decrease if you provide an incorrect answer to a problem. We refer to this payment as the piece rate payment. Please do not talk with one another for the duration of the experiment. If you have any questions, please raise your hand. ARE THERE ANY QUESTIONS BEFORE WE BEGIN?

2. P2

As in Task 1 you will be given 5 minutes to calculate the correct sum of a series of five 2-digit numbers.

However for this task your payment depends on your performance relative to that of a group of other subjects. Each group consists of four people randomly chosen in the room. If Task 2 is the one randomly selected for payment, then your earnings depend on the number of problems you solve compared to the three other people in your group. The individual who correctly solves the largest number of problems will receive $6 per correct problem, while the other subjects receive no payment. We refer to this as the tournament payment. You will not be informed of how you did in the tournament until all four tasks have been completed. If there are ties the winner will be randomly determined. Please do not talk with one another. If you have any questions, please raise your hand. ARE THERE ANY QUESTIONS BEFORE WE BEGIN?

3. P3

As in the previous two tasks you will be given 5 minutes to calculate the correct sum of a series of five 2-digit numbers. However you will now get to choose which of the two previous payment schemes you prefer to apply to your performance on the third task. If Task 3 is the one randomly selected for payment, then your earnings for this task are determined as follows. If you choose the piece rate you receive $1.5 per problem you solve correctly. If you choose the tournament your performance will be evaluated relative to the performance of the other three subjects of your group in the Task 2 -tournament. The Task 2-tournament is the one you just completed. If you correctly solve more problems than they did in Task 2, then you receive four times the payment from the piece rate, which is $6 per correct problem. You will receive no earnings for this task if you choose the tournament and do not solve more problems correctly now, than the others in your group did in the Task 2 tournament. You will not be informed of how you did in the tournament until all four tasks have been completed. If there are ties the winner will be randomly determined.

The next computer screen will ask you to choose whether you want the piece rate or the tournament applied to your performance. You will then be given 5 minutes to calculate the correct sum of a series of five randomly chosen two-digit numbers. Please do not talk with one another. If you have any questions, please raise your hand. ARE THERE ANY QUESTIONS BEFORE WE BEGIN?

4. P4

You do not have to add any numbers for the fourth and final task of the experiment. Instead you may be paid one more time for the number of problems you solved in the Task 1 – Piece Rate. However, you now have to choose which payment scheme you want applied to the number of problems you solved. You can either choose to be paid according to the piece rate, or according to the tournament.

If the fourth task is the one selected for payment, then your earnings for this task are determined as follows. If you choose the piece rate you receive $1.5 per problem you solved in Task 1. If you choose the tournament your performance will be evaluated relative to the performance of the other three subjects of your group in the Task 1-piece rate. If you correctly solved more problems in Task 1 than they did then you receive four times the earnings of the piece rate, which is equivalent to $6 per correct problem. You will receive no earnings for this task if you choose the tournament and did not solve more problems correctly in Task 1 than the other members of your group.

This is the last stage of the calculation tasks. You will now need to choose which payment schemes (piece-rate or tournament) to determine your payoff in this task. You don't have to perform calculation in this task, as we will use the number of correct answers in your Piece-Rate round (the first task) to calculate your payoff.

The next computer screen will tell you how many problems you correctly solved in Task 1, and will ask you to choose whether you want the piece rate or the tournament applied to your performance. Please do not talk with one another. If you have any questions, please raise your hand. ARE THERE ANY QUESTIONS BEFORE WE BEGIN?

Reminder: In the Piece-Rate task, the number of your correct answers is <ScoreTask1 | 1>

5. Rank Guess

We would like you to guess which was your rank compared to your group members in Tasks 1 and 2. In case of ties in the actual ranks, we counted every answer that could be correct as correct. For example, if the performance in the group was 10, 10, 11, 11, then the correct guess for score 10 is either 3rd or 4th, and the correct guess for score 11 is either 1st or 2nd.

Please enter a number between 1 (meaning that you were the best in your group of four) to 4 (meaning that you were the 4th in your group of four) for each task.

For each right guess <GuessPay | 5> will be added to your payment from this part of the experiment.

Please enter your guess for your rank in Task 1:

Please enter your guess for your rank in Task 2:

6. Risk Task

Option A: **50% chance of receiving $10 and 50% chance of receiving $0.** The Option B column lists 10 amounts (*displayed in an ascending manner*) each corresponding to what you will receive for sure if you choose this option.

DECISION: For each of the 10 rows, please indicate your decision in the final column with a tick (√).

	Option A	**Option B**	**Decision**
1	50% of $ 10, 50% of $ 0	$ 2.5	A □ B □
2	50% of $ 10, 50% of $ 0	$ 3	A □ B □
3	50% of $ 10, 50% of $ 0	$ 3.5	A □ B □
4	50% of $ 10, 50% of $ 0	$ 4	A □ B □
5	50% of $ 10, 50% of $ 0	$ 4.5	A □ B □
6	50% of $ 10, 50% of $ 0	$ 5	A □ B □
7	50% of $ 10, 50% of $ 0	$ 5.5	A □ B □
8	50% of $ 10, 50% of $ 0	$ 6	A □ B □
9	50% of $ 10, 50% of $ 0	$ 6.5	A □ B □
10	50% of $ 10, 50% of $ 0	$ 7	A □ B □