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Running title: stress and economic competition

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Abstract

Competition is ubiquitous in economic life. Yet, negative consequences of competitive environments have been reported and everyday experience suggests that competitive situations can be very stressful. It is, however, an open question whether or not economic competitions in the laboratory indeed elicit physiological stress reactions. Our study examined the subjectively perceived stress and the physiological changes induced by a well-established economic laboratory competition paradigm (first used in Niederle and Vesterlund 2007) in a mixed-gender sample of 105 healthy participants. A mental arithmetic task was performed first under a piece rate (i.e., non-competitive) payment scheme and afterwards under a tournament condition. In a third round, participants decided how to be paid (i.e., piece rate or tournament). Our results indicate that compared to a control group, which performed only the non-competitive condition, the competitive game condition indeed elicited subjective and physiological reactions that are indicative of mild stress. Furthermore, reactions that are thought to reflect an active coping style were related to the self-selection into competition in the third round of the game. We speculate that real-life economic competitions might be even stronger stressors and the way how people cope with this kind of stress might be related to competitiveness in real-life economic contexts.

Keywords:

competition, decision making, stress, heart rate, testosterone, economic tournament

Introduction

Competition is ubiquitous in economic life, be it companies that compete in markets or employees who compete for jobs, careers, or salaries. The most direct form of competition at the individual level is evoked by so-called “winner-takes-it-all” payment schemes, a form of tournaments introduced by employers to increase productivity among employees. Principal-agent theory (reviewed in Lazear and Rosen 1981; Nalebuff and Stiglitz 1983) generally states that all agents should increase their effort to win the tournament if the difference between winner- and looser price is set optimally, thereby increasing overall productivity of the company. While there is some experimental evidence for this general prediction (e.g., Cabrales et al. 2011; Eriksson et al. 2009), several negative consequences like deteriorated well-being (Brandts et al. 2009) and also decreased performance (e.g., Dohmen 2008; Ariely et al. 2009) have been observed.

Competitive situations are well known as social stressors in the psychological literature. Indeed, competitive situations often contain the core features that characterize psychosocial stressors: uncontrollability and social-evaluative threat (Dickerson and Kemeny 2004). Uncontrollability results from the uncertainty of the outcome as it depends critically on the performance of others. Social-evaluative threat is inherent in competitions as participants are compared along a common dimension that is often relevant for self-esteem. Indeed, increases in the stress hormone cortisol as well as in markers of sympathetic nervous system activity like blood pressure, heart rate, and alpha-amylase have been observed in reaction to sports competitions (e.g., Rohleder et al. 2007; Kivlighan and Granger 2006; Cooke et al. 2011), during video game playing (Harrison et al. 2001; Kivikangas et al. 2014; Veldhuijzen Van Zanten et al. 2002), and in response to motoric and cognitive tasks which were carried out in a competitive manner (Wittchen et al. 2013; Turner et al. 2012; Hatfield et al. 2013).

However, it might matter how the subject evaluates the competition, i.e., whether it is perceived as threat or as challenge. Blascovich et al. (2004), for example, found that in athletes different cardiovascular patterns were indicative of the perception of a baseball/softball game as challenging or threatening, and that these patterns were furthermore predictive of future performance. Salvador and Costa (2009) developed a model to predict the outcome of a competition, i.e., winning or losing, by the coping strategy the subject applies. Thereby the authors take into account the relevancy of cognitive variables, i.e., the perception of the situation and the perceived control that have been emphasized throughout the stress literature (e.g., Dickerson and Kemeny 2004; Biondi and Picardi 1999; Kudielka and Kirschbaum 2007; Lazarus and Folkman 1987). So, if competition is perceived as a challenge, most likely an active coping strategy is used. This is, according to Salvador and Costa's (2009) model, accompanied by an increase in positive mood as well as increased activity of the sympathetic nervous system and an increase in testosterone levels. On the other hand, if competition is perceived as threat, a passive coping strategy that is characterized by decreased mood, diminished sympathetic activity, and an increase in cortisol is applied. According to the model, an active coping style more likely leads to victory whereas a passive coping style often results in defeat. While animal studies on the rewarding properties of testosterone as well as studies on the differential physiological patterns of coping styles provided the basis for the model´s main assumptions (Salvador and Costa 2009), there is also first direct human empirical evidence supporting this "coping style" model (Salvador et al. 2003; Costa and Salvador 2012).

Aims of the present study

Whereas competition-induced stress reactions are extensively studied in the domain of sports, less is known about the potential of laboratory economic competitions to induce psychophysiological stress responses. Very recently, Adam et al. (in press) reported that the social competitive component of a laboratory auction experiment induced increases in heart rate; however, endocrine measures had not been examined in this study. The main aim of our study was to investigate if a well-established laboratory economic tournament game (Niederle and Vesterlund 2007) which has been shown to be predictive of career choices (Buser et al. 2014) may function as stressor, i.e., elicit a psychophysiological stress response. To this end, we measured changes in mood, heart rate, as well as hormone levels (cortisol and testosterone) in relation to the game. These measures were taken because acute stress mainly activates two systems: the hypothalamus-pituitary-adrenal (HPA) axis as well as the sympathico-adrenal medullary (SAM) system (e.g., Kudielka and Kirschbaum 2007). Activation of the HPA axis leads to increased levels of circulating cortisol which can be measured in saliva. Activation of the SAM system affects, amongst others, cardiovascular activity, leading to increased blood pressure and heart rate. Furthermore, testosterone changes have been reported in relation to competitions (for a recent review, see Oliveira and Oliveira 2014) and some studies also found increased testosterone levels after psychosocial stress induction (Lennartsson et al. 2012; Bedgood et al. 2014). To keep unrelated external influences on the hormonal and physiological measures minimal, a laboratory paradigm was chosen.

The tournament game consists of three rounds that differ by the respective payment schemes. Whereas the first round is non-competitive (piece rate payment), the second round is a tournament ("winner-takes-it-all" payment). In the third round, participants are free to choose their preferred payment option. By comparing those who chose piece rate with those who chose the tournament payment scheme, we also explore if the self-selection into the competitive condition is related to the physiological changes during the game.

Methods

Sample

One hundred and thirty-seven persons participated in the study. Of them, 111 were eligible for analysis as they met our inclusion criteria (no physical or mental illness, no intake of drugs or medication, age between 18 and 35, body mass index below 30, German as mother language, use of hormonal contraceptives if female). Six participants qualified as heavy smokers and were excluded, leaving a total of 105 young healthy participants for analysis (51 female, 54 male)[1]. Of them, 30 (16 females) belong to the randomly assigned control group. The remaining 75 (35 female) participants had been assigned to the experimental group. On purpose, this portion was considerably larger to ensure sampling enough data for participants that voluntarily chose competition. Mean age in the final sample was 22.2 ± 2.5 (range: 18 – 33), and experimental and control groups did not differ ($t(103) = -0.577$; $p > .56$).

General procedure

After arriving in the laboratory, participants were equipped with heart rate measurement devices and filled in questionnaires on demographic data and personality characteristics. After half an hour, the tournament game was played for about 15 minutes. Duration of experimental sessions was two hours. During the

[1] See appendix (A) for details about the exclusion criteria.

experiment, seven saliva samples were collected for analysis of hormones (cortisol and testosterone), heart rate was measured continuously, and blood pressure was measured four times (see below).

Tournament game

To investigate competitive behaviour, we used a well-established economic tournament task (Niederle and Vesterlund 2007). Participants were asked to correctly solve as many arithmetic problems (i.e., adding five two-digit numbers) as possible during a time period of four minutes. Experimental conditions differed in terms of incentives: In the piece rate condition, each correct solution paid a fixed amount (50 Eurocents). In the tournament condition, a "winner-takes-it-all" payment scheme was established. Here, each correct solution paid two Euros, but only the winner out of a group of four participants was rewarded. Each experimental session was conducted with eight participants who were randomly assigned to one of two competition groups to make sure that subjects did not know exactly against whom they were actually playing[2]. The task was played for three rounds of four minutes each. In the control group, all three rounds followed the piece rate payment scheme. In the experimental group, only the first round was piece rate while the second round was a (forced) tournament. In the third round, each participant in the experimental group could choose his/her preferred payment option. Importantly, feedback about performance in all rounds, winning or losing in competitive rounds, and money earned was provided only after the game, so that the choice of the payment option in the third round was not influenced by the outcome of the first or second round. Participants were incentivized with real money for one of the rounds that was determined randomly by

[2] No subgroups were built in control sessions. However, all but two of these sessions were also carried out with eight participants.

throwing a die at the end of the game[3]. Relevant variables are performance (as indicated by the number of correctly solved arithmetic problems) and the preferred payment option in round three (i.e., voluntary decision to compete or not).

Subjective measures

Subjective mood (MDBF). Subjective mood was assessed using the short versions A and B of the German mood questionnaire *Mehrdimensionaler Befindlichkeitsfragebogen* (MDBF; Steyer et al. 1997) in counterbalanced order. Each version consists of a list of 12 adjectives constituting the three scales mood (elevated versus depressed mood), calmness (calmness versus restlessness), and wakefulness (wakefulness versus sleepiness). Responses to the question "How [e.g. tired] do you feel at the moment?" are given on a five-point Likert scale with the poles "not at all" and "very". Scores for each scale have a possible range from 4 to 20. Cronbach´s α for these scales ranges from .73 to .89 (Steyer et al. 1997), indicating good internal consistency. Parallel test reliability can also be considered high as it ranges from .81 to .93 (Steyer et al. 1997). The questionnaire was administered before the game and once again directly after the game. Due to missing values for one participant each, sample size is N = 104 for the analysis of mood and calmness scales, respectively.

Post-competition questions. We asked the participants to rate several aspects of the game on a five-point Likert scale ranging from "not at all" to "very". Questions were formulated analogous to those used in another study to check the subjective appraisal of an external stressor (Kudielka et al. 2004). Two items are of special

[3] Note that after the third round of the game, participants in the experimental group were additionally given the choice whether or not they preferred to be paid according to the competitive payment scheme also for the first round of the game. This decision was treated as fourth round when throwing the die to determine which round should be paid out.

importance for the aims of the present study. The first one asked the participants directly about the perceived stressfulness of the competitive task, i.e. they were asked to rate the statement “The previous situation was stressful for me.” The second item was “I perceived the situation as challenge.” As the theoretical model of Salvador and Costa (2009) suggests that the appraisal of a competition as challenge versus threat is critical for physiological reactions and possibly competitive behaviour, we used this item to investigate group differences between those who chose the competitive option in the third round of the game and those who chose the non-competitive piece rate option.

Physiological and endocrine measures

Heart rate. Heart rate was measured continuously using Polar Sport Tester RS800CX (Polar Elektro GmbH, Groß-Gerau, Germany). Each participant was equipped with a breast belt at the beginning of the experimental session. The wrist watch was placed on the participant’s table so that the display was invisible and it was only handled by the experimenters. For analysis, the Polar Pro Trainer software was used. Five intervals were built for which data were aggregated: pre-game (10 min.), round 1 (2 min.), round 2 (2 min.), round 3 (2 min.), and post-game (10 min.)[4]. Due to technical problems, heart rate measurement failed in 18 participants. Therefore, sample size for analyses containing heart rate variables is N = 87. As baseline heart rate data are not available for three participants, sample size for repeated measures analyses containing the pre-stress measurement is N = 84.

[4] See appendix (B) for details.

Blood pressure. Blood pressure was measured using automatic devices (Omron O3, Omron Medizintechnik, Mannheim, Germany) once before the game, between the second and the third round of the game, after the game and once again shortly after saliva sample +45. Mean arterial pressure (MAP) was calculated according to the formula *MAP = diastolic pressure + 1/3 (systolic pressure – diastolic pressure)* (cf. Harrison et al. 2001). Due to measurement errors, data of three participants cannot be used for analysis.

Hormonal measures. Saliva samples were collected using Salivette sampling devices (Sarstedt, Nümbrecht, Germany) approximately 15 minutes before the game (S1), directly before (S2) and directly after the game (S3), as well as repeatedly afterwards, i.e., at about +10 (S4), +20 (S5), +45 (S6), and +60 (S7) minutes. Cortisol was analysed for each sample whereas testosterone was analysed for the samples S2, S3, and S5 as testosterone increases were reported several minutes post-competition in previous studies (Schultheiss et al. 2005; Mehta and Josephs 2006). Cortisol levels could not be determined for measurement points S5 and S7 of one participant; therefore this person is excluded in repeated measures analyses including these measurement points. Saliva samples were frozen and, upon completion of the study, analysed by the Psychobiological Research Laboratory of the University of Trier, Germany[5].

Statistical analysis

In initial analyses, we investigated the game behaviour using repeated measures analyses of variance (ANOVAs) and chi^2-tests. Next, to test if the economic game elicited a physiological or subjective stress response, we used repeated measures

[5] See appendix (B) for details.

ANOVAs comparing the experimental with the control group. Gender was always included as additional variable. Whenever sphericity was violated, Greenhouse-Geisser corrections were applied for repeated measures. Log-transformed data were used for analyses of endocrinological data, i.e., cortisol and testosterone. For better readability, untransformed raw data are displayed in graphs. Descriptive statistics are given as mean ± standard deviation. In graphs, means ± standard errors of the mean (SEM) are depicted. In exploratory analyses, we furthermore compared those participants within the experimental group that selected the tournament payment option with those that chose the piece rate option regarding differences in their reaction to the game as well as performance differences using univariate and repeated measures ANOVAs. For heart rate, changes from the first to the second round were analysed. For hormonal changes during the game, the measurement points immediately before and after the game were used.

Results

Game behaviour

Performance. First of all, we compared arithmetic performance under the different experimental conditions. Applying a repeated measures ANOVA with round as repeated factor (round one, two, three) and group (control, experimental) and gender as between subjects factors on performance (i.e., number of correct responses), we obtained a main effect of round ($F(2,202) = 23.672$; $p < .001$) but no significant interaction terms or group effects (all $p > .34$). Repeated contrasts indicated that performance improved significantly from round one to round two in both groups ($F(1,101) = 32.421$; $p < .001$) while it did not change significantly from round two to round three ($p > .45$). So, there is no evidence for performance enhancement by forced tournament beyond training effects (Figure 1).

Please insert Figure 1 about here

Choice of competition. Next, we checked how many persons in the experimental condition actually chose the competitive payment scheme in the third round of the game. Furthermore, gender differences were investigated using a one-sided chi^2-test. In line with the expectation (cf. Niederle and Vesterlund 2007), more men than women chose tournament (18 of 40 men [45%], and 10 of 35 women [28.6%]). This difference was marginally significant (Chi^2(1) = 2.153; p = .071). Overall, most subjects (62.7%) chose the piece rate payment scheme. Based on choice behaviour, we split the experimental group into those who chose tournament (tournament choice group; N = 28) and those who chose piece rate (piece rate choice group; N = 47) in the third round of the game for further analyses (see section: Differences between choice groups).

Subjective reactions to competition

We conducted three repeated measures ANOVAs testing for differences in the three MDBF scales using group (control, experimental) and gender as between-subjects factors to investigate group differences regarding changes in mood, calmness, and wakefulness from the pre-competition to the post-competition measure (factor time). We obtained significant main effects of time for calmness (F(1,100) = 9.555; p = .003) and wakefulness (F(1,101) = 10.101; p = .002), indicating an overall decrease of calmness and an increase in wakefulness (see Figure 2). However, the main effect of time for calmness was qualified by a significant interaction of group x time (F(1,100) = 6.166; p = .015). A significant interaction effect of group x time emerged also for mood (F(1,100) = 6.026; p = .016)[6] but not for wakefulness (p > .67). That is, good mood and calmness decreased significantly in the experimental group (mood: -1.27 ± 3.31; F(1,72) = 11.183; p = .001; calmness: -2.45 ± 4.09; F(1,73) = 26.355; p < .001) but not in the control group (mood: 0.37 ± 2.90; F(1,28) = 0.614; p = .440; calmness: -0.31 ± 3.61; F(1,27) = 0.154; p = .698). Regarding wakefulness, a marginally significant main effect of gender (F(1,101) = 2.915; p = .091) indicated that men had somewhat higher values overall. Furthermore, based on the post-experiment questions, the situation was rated as more stressful in the experimental group (3.44 ± 1.08 versus 2.97 ± 1.13; F(1,101) = 4.127; p = .045). There was no difference in how much both groups perceived the situation as a challenge (p > .84).

Please insert Figure 2 about here

Physiological and endocrine reactions to competition

Heart rate. We hypothesized that heart rate – as an indicator of sympathetic activity – would increase during round two (forced competition), relative to round one (piece rate) in the tournament group. Indeed, a repeated measures ANOVA with time (round 1, round 2) as repeated factor and group (control, experimental) and gender as between subject factors revealed a marginally significant main effect of time (F(1,83) = 3.124; p = .081) and a significant interaction of time and group (F(1,83) = 16.687; p < .001). Whereas heart rate increased in the experimental group from round one to round two (4.08 ± 6.35 bpm; F(1,59) = 24.370; p < .001), there was a slight decrease

[6] Note that feedback about game performance and money earned was provided directly after the game, i.e., before the subjective measures were taken. Therefore, we controlled for confounding influences of feedback on subjective measures using money earned as covariate. Money earned was only related with changes in the mood subscale of the MDBF (F(1,102) = 7.760; p = .006), but not with any other subjective measures. Importantly, group differences regarding mood remained significant when money earned was included as a covariate (F(1,99) = 8.682; p = .004). However, we refrain from including money earned as a general covariate in all analyses as it is not independent from game behavior.

in the control group (-1.69 ± 4.55 bpm; $F(1,24) = 3.293$; $p = .082$). This was confirmed by a repeated measures ANOVA with all measurement points (baseline, round 1, round 2, round 3, post). There was a significant main effect of time ($F(2.3,187.5) = 49.758$; $p < .001$) and a significant interaction of time x group ($F(2.3,187.5) = 4.775$; $p = .006$) (Figure 3a). Repeated contrasts indicated that groups differed significantly only regarding the change of heart rate from round one to round two ($F(1,80) = 16.022$; $p < .001$) whereas the later changes were different between groups only by trend (round two to three: $F(1,80) = 3.184$; $p = .078$; round three to post: $F(1,80) = 3.118$; $p = .081$).

Mean arterial pressure. A repeated measures ANOVA with time (baseline, during and after the game, during recovery) as repeated factor and group and gender as between subject factors revealed a main effect of time ($F(3,294) = 23.410$; $p < .001$). Repeated contrasts indicated that blood pressure significantly increased for both groups from baseline to game, and decreased thereafter (all $p < .01$) (Figure 3b). The experimental group exhibited a trend for overall higher blood pressure ($F(1,98) = 2.987$; $p = .087$). Furthermore, gender had a significant main effect ($F(1,98) = 5.373$; $p = .023$), with men showing overall higher mean arterial pressure compared to women.

Cortisol. A repeated measures ANOVA was also conducted for cortisol. The main effect of time was significant ($F(2.8,280.2) = 81.970$; $p < .001$), mapping the diurnal decrease of cortisol levels in the afternoon. Yet, there were no significant differences between groups (Figure 3c). Furthermore, a main effect of gender ($F(1,100) = 8.642$; $p = .004$) as well as a significant interaction of gender and time ($F(2.8,280.2) = 3.733$; $p = .014$) were obtained. Overall, men had higher cortisol levels with the difference being more pronounced in the first half of the experiment (i.e., S1 through S4; all $p < .007$, i.e., the Bonferroni-corrected level of significance).

Testosterone. The repeated measures ANOVA revealed a main effect of time ($F(1.8,183.0) = 16.528$; $p < .001$) (Figure 3d). Repeated contrasts indicated that this was due to a significant drop in testosterone levels from directly after the game (S3) to the later measurement (S5; $F(1,101) = 29.339$; $p < .001$). Besides a main effect of gender ($F(1,101) = 152.893$; $p < .001$), there was a marginally significant interaction of gender and group ($F(1,101) = 3.762$; $p = .055$). Men had higher overall testosterone levels compared to women in both groups and there were no group differences in the separate analyses for men and women. Therefore, the interaction seemed to be due to a different pattern. For men, those in the control group had descriptively higher testosterone levels whereas for women, those in the experimental group had higher testosterone levels, although these differences were not significant ($p > .16$).

Please insert Figure 3a-d about here

Differences between choice groups

Next, we conducted several exploratory analyses to investigate if those participants within the experimental group that selected the tournament option differed from those that chose piece rate in the third round of the game regarding their reactions to the forced tournament in round two. To this end, we conducted repeated measures ANOVAs for the physiological variables with two measurement points, i.e., the measurement directly before the game (S2) and the one directly afterwards (S3) for hormonal measures and round one and round two for heart rate, respectively.

Furthermore, we investigated differences between the choice groups regarding the subjective experience of the tournament. First of all, differences in performance were analysed with a repeated measures ANOVA for the three rounds of the game.

Performance. The 3 (time) x 2 (choice group) x 2 (gender) repeated measures ANOVA revealed significant main effects of time ($F(2,142) = 16.119$; $p < .001$) and choice group ($F(1,71) = 4.508$; $p = .037$) as well as a significant interaction of choice group and time ($F(2,142) = 3.976$; $p = .021$). Separate ANOVAs for each round indicated that those participants that chose the tournament solved a higher number of arithmetic tasks in the third round under the self-selected payment scheme ($F(1,71) = 8.378$; $p = .005$; Figure 4). There was also a tendency for better performance of these participants compared to those who chose piece rate under the forced tournament condition in round two ($F(1,71) = 3.506$; $p = .065$; note that the Bonferroni-corrected critical alpha level for three comparisons is $p = .0167$). No differences in performance were found for the first round, i.e. piece rate ($p > .34$).

Please insert Figure 4 about here

Subjective experience. Here, we used the items of our post-competition questionnaire that asked participants to rate how much they perceived the situation as a challenge and how stressful they perceived the competition. Indeed, those choosing tournament were significantly more likely to appraise the situation as a challenge compared to those choosing piece rate (4.50 ± 0.69 versus 3.96 ± 0.93; $F(1,71) = 5.132$; $p = .027$). There was no difference in how stressful they perceived the situation ($p > .18$). Significant main effects of time were obtained for all three subscales of the MDBF (mood: $F(1,70) = 12.947$; $p = .001$; calmness: $F(1,71) =$

29.608; p < .001, wakefulness: F(1,71) = 5.974; p = .017), reflecting the decrease of mood and calmness as well as the increase in wakefulness reported above (see section: Subjective reactions to competition). However, for the calmness subscale a significant interaction of choice group and time emerged (F(1,71) = 4.479; p = .038). Those who selected tournament showed a stronger decrease in calmness (-3.79 ± 4.10; F(1,26) = 20.639; p < .001) compared to those who chose the piece rate option (-1.66 ± 3.91; F(1,45) = 8.133; p = .007). Besides that, a main effect of gender for the calmness scale (F(1,71) = 7.029; p = .010) indicated that men overall were calmer than women (13.88 ± 2.15 versus 12.74 ± 2.51), although a marginally significant interaction of gender and group (F(1,71) = 3.231; p = .077) indicated that this gender difference was actually significant only in the tournament choice group (F(1,26) = 8.420; p = .007).

Heart rate. The 2 (time) x 2 (choice group) x 2 (gender) repeated measures ANOVA revealed a significant interaction of choice group and time (F(1,57) = 5.504; p = .022), reflecting different changes between the rounds as the increase in heart rate from round one to round two was higher in those selecting tournament (6.04 ± 7.89 bpm; F(1,23) = 15.738; p = .001) compared to those choosing piece rate in the third round of the game (2.72 ± 4.66 bpm; F(1,34) = 12.448; p = .001; cf. Figure 5a). Besides the interaction of choice group and time, the repeated measures ANOVA also revealed a significant main effect of time (F(1,57) = 31.779; p < .001) and an interaction of choice group and gender (F(1,57) = 8.284; p = .006). Whereas men had a higher mean heart rate during the first two rounds of the game compared to women in the group that chose piece rate (F(1,34) = 6.270; p = .017), the pattern was – descriptively – opposite in the group that selected tournament (F(1,23) = 2.816; p = .107).

Cortisol. The 2 (time) x 2 (choice group) x 2 (gender) repeated measures ANOVA revealed a significant main effect of gender (F(1,71) = 4.277; p = .042) as well as a significant interaction of gender and choice group (F(1,71) = 8.640; p = .004), but no significant interaction of choice group and time (p > .10; Figure 5b). Separate analyses showed that mean cortisol levels for the measurements before and after the game were much higher in men compared to women in the piece rate choice group (5.33 ± 1.88 nmol/l versus 3.17 ± 1.26 nmol/l; F(1,45) = 25.360; p < .001) whereas the gender differences were not significant in the tournament choice group (4.35 ± 2.52 nmol/l versus 4.33 ± 1.43 nmol/l; F(1,26) = 0.193; p = .664).

Testosterone. A 2 (time) x 2 (choice group) x 2 (gender) repeated measures ANOVA revealed a marginally significant main effect of choice group (F(1,71) = 3.840; p = .054) and a highly significant main effect of gender (F(1,71) = 66.222; p < .001). Men overall had higher testosterone levels compared to women. More importantly, the interaction of choice group and time (F(1,71) = 4.495; p = .037) qualified the main effect of choice group. Although testosterone changes themselves were not significant, this interaction indicates that the increase in testosterone was higher for those that chose tournament (3.04 ± 11.39 pg/ml; F(1,26) = 2.161; p = .154) compared to those that chose piece rate (-1.56 ± 8.17 pg/ml; F(1,45) = 2.569; p = .116; Figure 5c).

Please insert Figure 5a-c about here

We also tested the possibility that the frequency or duration of encountering a competition might have influenced hormonal changes, because those who chose the tournament option in the third round performed the competition twice, but those who chose the piece rate option only once. We reasoned that if exposure duration rather than the coping is driving the effect, the control group should display the smallest increase in testosterone and the biggest drop in cortisol, and tested this possibility by comparing the control group and the piece rate choice group regarding differences in the hormonal changes. Control participants displayed higher increases in testosterone and lower decreases in cortisol, respectively, compared to those participants in the experimental group who had selected piece rate in the third round, though these differences were not statistically significant (change in testosterone: piece rate: -1.56 ± 8.17 pg/ml, control: 1.52 ± 11.01 pg/ml; repeated measures ANOVA: $F(1,73) = 0.680$; $p = .412$; change in cortisol: piece rate: -0.43 ± 1.62 nmol/l, control: -0.29 ± 1.58 nmol/l; repeated measures ANOVA: $F(1,73) = 1.672$; $p = .200$). This result strengthens the view that the differences between choice groups are indeed rather due to different coping styles in the face of a forced competition situation.

Discussion

In the present study, we investigated if economic situations like tournaments are perceived as stressful and if they elicit a physiological stress reaction. Our results show that, indeed, the tournament condition in which participants were forced to compete was subjectively perceived as more stressful than the non-competitive control condition and also evoked physiological reactions that are associated with stress. Furthermore, we investigated if such stress reactions to forced tournament are related to the voluntary choice of competition. The observed differences between those who chose competition and those who chose piece rate are largely in line with a model proposed by Salvador and Costa (2009) that points out the importance of coping processes and associated physiological correlates. Both aspects are discussed in more detail below.

The economic tournament game as stressor

Subjectively, the experimental group perceived the tournament game as more stressful compared to the control group, and mood and calmness decreased in this group but not in the control group. Furthermore, heart rate was sensitive to game conditions. While already the piece rate condition, i.e., the first round, evoked a marked increase in heart rate from baseline for all groups, heart rate rose even further in round two under the forced tournament condition. In contrast, it declined from round one to round two in the control group, which may perhaps reflect habituation in this group. Blood pressure also increased in response to the game. Yet, the reactions were similar in the experimental and control group probably because this measure is not as sensitive to stress as heart rate. It should be noted, however, that systolic blood pressure was found to be responsive to competition in a previous laboratory study (Wittchen et al. 2013). The game-related general increase in sympathetic activity (as indicated by increases in heart rate and blood pressure) might have been due to the cognitive effort of performing mental arithmetic calculations (cf. Carroll et al. 1986) or due to general task engagement (cf. Blascovich et al. 2004).

Interestingly, in a related study, Adam et al. (in press) observed that the mean heart rate during the last 15 seconds before a bidder left an auction (relative to baseline levels) was higher in auctions which were carried out against human opponents compared to auctions which were carried out against computer opponents. Thus, social competitive aspects of economic settings seem indeed to be able to evoke stress-related physiological changes. Yet, if cortisol increase is considered as the objective defining criterion to indicate stress, clearly then the economic tournament game did not qualify as stressor because cortisol decreased for the experimental as well as the control group, reflecting normal diurnal changes. Together, these results suggest that the tournament game was effective as a mild stressor, evoking sympathetic arousal but no cortisol increase.

Several aspects of the tournament game could be responsible for the relatively low stressfulness of this paradigm. First, in line with experimental economics standards, competitions were anonymous. That is, all participating subjects in an experimental session were split into two groups whose composition was not openly communicated, so they did not know exactly with whom they were competing reducing the social evaluative threat. Second, rewards were only moderately high and made up only part of the participants' compensation. Therefore, we speculate that more severe physiological consequences are likely to occur outside the laboratory, i.e., for economic tournaments with higher stakes like bonuses or wages or more far-reaching consequences. Indeed, other studies investigating real-world contests in non-economic areas report increases in cortisol (e.g., during sports competitions: Rohleder et al. 2007) while laboratory studies often do not find cortisol reactions (e.g., Mehta and Josephs 2006; Costa and Salvador 2012).

Reaction to the game and choice of competition

We furthermore investigated if the physiological reactions to the economic tournament were related to the choice of competition. In the economic literature, several factors influencing self-selection into tournaments have been reported, including gender (e.g., Niederle and Vesterlund 2007), risk preferences (e.g., Niederle and Vesterlund 2007), personality (Müller and Schwieren 2012), and confidence in one's own performance (e.g., Niederle and Vesterlund 2007; Croson and Gneezy 2009). While some of these differences might be caused by culture (Gneezy et al. 2009), it is highly plausible to assume that competitive preferences also partly result from biological factors. Recent studies have therefore tried to explain individual differences in competitiveness in terms of differences in hormone levels (Apicella et al. 2011; Schipper 2015). Others suggest that it is not the general (baseline) hormone levels, but in fact their dynamic fluctuations, that predict competitiveness (Carré et al. 2011).

Salvador and Costa (2009) proposed a model according to which it is crucial for winning or losing how a subject copes subjectively and physiologically with the stress of competition. Specifically, this coping style model assumes that an active coping style which is characterized by the perception of the competition as challenging rather than threatening and an increase in mood as well as in heart rate and testosterone levels more likely results in victory. On the other hand, the passive coping style which is characterized by perceiving the situation as threatening and a decrease in mood as well as heart rate and testosterone levels and an increase in cortisol levels is more likely associated with defeat. This model might also be suited to explain differences in competitive preferences. Indeed, we found differences between those players choosing tournament and those shying away from competition that fit to some of the predictions of this model. Higher testosterone increase and greater reactivity of the sympathetic nervous system (i.e., heart rate increase) were observed in those selecting tournament, probably reflecting an active coping strategy. Also compatible with the coping style model, those choosing the competitive game condition were more likely to appraise the situation as a challenge. However, mood did not increase in this group as predicted by the model. Rather, calmness decreased in those who had selected the tournament payment option compared to those who chose piece rate, possibly reflecting the increased physiological arousal in this group.

The neurocognitive mechanism that links an active coping strategy to the selection of competition is not entirely clear. Several authors suggest that (pro-)active, effortful coping is associated with heightened activity of the sympathetic nervous system (Henry 1992; Koolhaas et al. 1999; Lundberg and Frankenhaeuser 1980; Salvador and Costa 2009). Also, mental effort has been related to increased physiological arousal as indicated by heart rate (Brouwer et al. 2014; Peters et al. 1998; Vogt et al. 2006). Therefore, the greater increase in heart rate in those that selected tournament could reflect greater investment of cognitive effort of these participants under the competitive payment scheme.

Regarding changes in testosterone in relation to competitive situations, several models have been proposed. The most prominent ones are the biosocial model of status (Mazur and Booth 1998) and the challenge hypothesis (Archer 2006; Wingfield et al. 1990). According to the biosocial model of status, winning a competition is supposed to result in an increase in testosterone levels which in turn is predicted to reinforce status seeking behaviour. The challenge hypothesis more broadly assumes that competitive encounters per se as well as their anticipation elicit an increase in testosterone (Archer 2006). While a range of studies investigated changes in testosterone in response to competitions and competition outcomes (reviewed in Oliveira and Oliveira 2014), only few studies investigated directly whether or not such changes in testosterone influence subsequent competitive behaviours. These studies show that – at least under certain conditions – an increase in testosterone during laboratory contests predicts the decision to compete again (Carré and McCormick 2008; Carré et al. 2010; Mehta and Josephs 2006; see Carré et al. 2011, for a recent review). Likewise, we observed a relationship between an increase in testosterone in reaction to the economic game and choosing the tournament payment scheme.

There are several potential neurobiological mechanisms how testosterone could enhance competitiveness. One potential pathway is via increased reward seeking, as testosterone seems to act on the dopaminergic reward system (Hermans et al. 2010). Alternatively, testosterone could decrease the fear of losing. This mechanism is plausible as testosterone application has been found to reduce fear reactions (Hermans et al. 2006). Also, several studies report a positive relationship between testosterone and risk taking (reviewed in Apicella et al. 2014a) and a recent study furthermore reported higher risk taking after testosterone increase which was evoked by a laboratory competition (Apicella et al. 2014b).

There is growing evidence that cultural as well as biological factors affect individual preferences regarding competitiveness (e.g., Gneezy et al. 2009; Müller and Schwieren 2012; Schipper 2015; Wozniak et al. 2014). Based on our exploratory results, we suggest that the way in which someone reacts physiologically to competition may influence his/her propensity to self-select into competitive environments such as, e.g., highly competitive jobs.

It is also interesting to note that performance was not enhanced by the forced tournament. Performance increased from round one to round two, but this was also true for the control group and might be attributable to learning effects (cf. Niederle & Vesterlund, 2007). On the other hand, performance in the third round of the game was better in those who had voluntarily chosen the competitive payment scheme compared to those who selected piece rate (cf. Eriksson et al. 2009). In line with other behavioural economic studies (e.g., Dohmen, 2006), these results indicate that competition per se does not necessarily enhance performance. Rather, it seems crucial whether the individual prefers the competitive environment. Thus, to increase productivity it seems important to design competitions in a way that makes them preferable. Our results hint at altering the appraisal of the competition (i.e., framing it as challenge) and evoking an active coping style as potential means to reach this.

Limitations

The main aim of our study was to investigate potential stress reactions in response to a well-established economic laboratory paradigm. Therefore, endocrinological measures were taken before and after the game, but not in between. Thus, the possibility exists that the differences between the choice groups were due to differences in exposure duration rather than coping styles. We tested this possibility by comparing the control group with the piece rate choice group regarding differences in the hormonal changes. Our results do not provide evidence for this alternative explanation. Another limitation of the current study is the provision of feedback before the post-game assessment of mood and hormonal levels. While it is very unlikely that the feedback affected endocrine measures in the post-game saliva sample due to the slower temporal dynamics of hormonal levels in saliva (e.g., Schlotz et al. 2008) the mood measurement might have been influenced and results regarding the mood subscale should be interpreted with caution.

Conclusion

Here, we tested if a well-established economic tournament game elicited a psychophysiological stress response. Indeed, the game condition including forced tournament was subjectively perceived as more stressful compared to the game condition with piece rate only and also elicited a stronger reaction of the sympathetic nervous system, i.e., a further increase in heart rate. Yet, it seemed not to be a strong stressor as we did not observe an increase in the stress hormone cortisol. We also explored if the subjective and physiological changes in response to the competitive stressor were related to the voluntary choice of competition. Indeed, we found differences between choice groups that largely fit to a recently proposed model (Salvador and Costa 2009) that highlights the relevancy of coping styles when confronted with competitive stress. It seems that an active coping style that comprises the appraisal of the competitive situation as a challenge as well as increases in testosterone and heart rate is related to the self-selection into competitive environments.

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Appendix

A. Details about the inclusion criteria

Participants who indicated to currently take medication were excluded with the exception of two participants taking L-Thyroxin which was allowed. Only females taking hormonal contraceptives were included in the analysis because the menstrual cycle is known to affect the cortisol response to stress (Kirschbaum et al. 1999) and may also influence competitiveness (Buser 2012 ; Wozniak et al. 2014). To avoid confounding influences we therefore decided to include only women using hormonal contraceptives. Furthermore, we classified smokers as heavy smokers if they indicated to consume more than 10 cigarettes per day. These participants were excluded as habitual smoking was shown to affect the cortisol response to stress (Rohleder and Kirschbaum 2006).

B. Details about the physiological and endocrine measurements

For analysis of heart rate, two minute intervals were taken from the middle between the markers that indicated the start and the end of each round. This procedure was chosen because the manually set start and end markers involved intervals greater than the actual round length, i.e., 4 minutes. By choosing intervals of duration 2 min., we assure that the analyzed time windows comprise only time spent on task. In case of missing markers, they were inferred from the mean length of the respective interval in the other participants.

Regarding analysis of endocrine parameters, free salivary cortisol was measured in duplicate using a time-resolved immunoassay with fluorometric detection (DELFIA, cf. Dressendörfer et al. 1992). Intra-assay variation was 4.0% - 6.7%, inter-assay variation 7.1% - 9.0%. The detection limit was 0.173 nmol/l. Salivary testosterone was measured in duplicate using commercial enzyme immunoassay kits (Salimetrics Europe Ltd., Suffolk, UK). According to Salimetrics, intra-assay variation lies between 2.5% and 6.7%, inter-assay variation lies between 5.6% and 14.05%.

Figure Legends

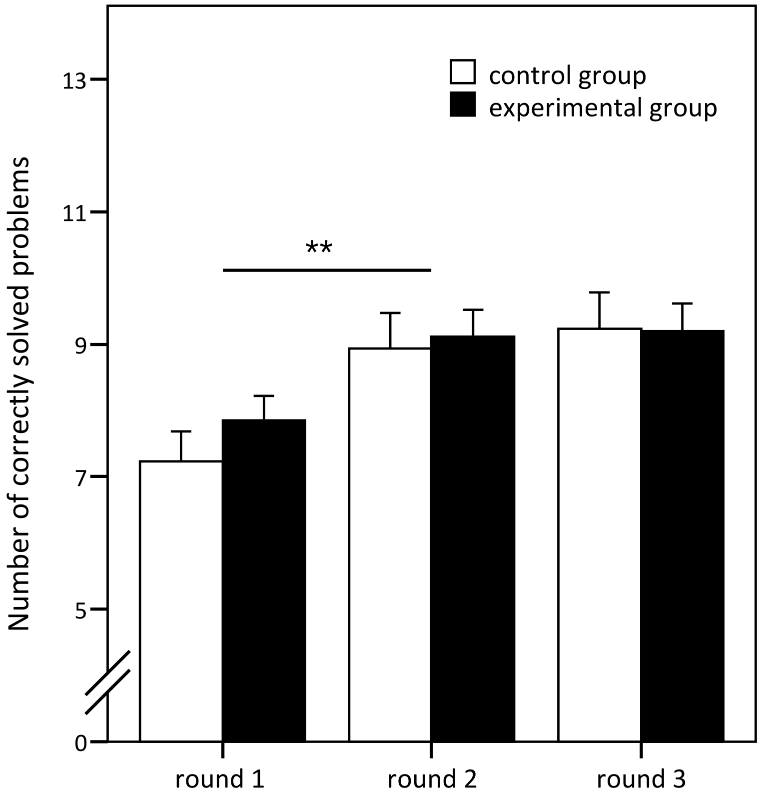

FIGURE 1: Performance. Number of correctly solved arithmetic problems (mean ± SEM) during the three rounds of the tournament game for the control (white) and the experimental group (black). Round one was piece rate for all participants, round two was forced tournament for the experimental group, round three was performed in the self-selected payment scheme by the experimental group (**p < .01).

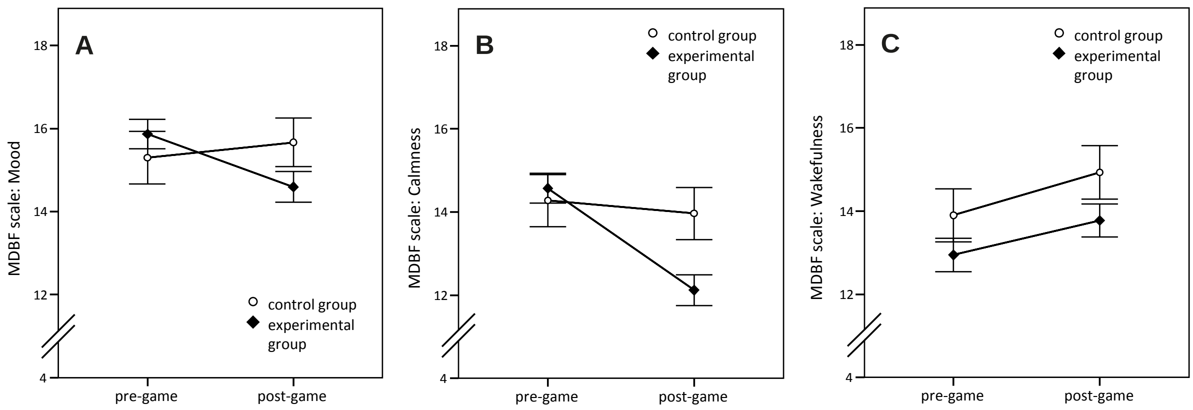

FIGURE 2: Subjective reaction to competition. Scores (mean ± SEM) of the three subscales of the MDBF (Mehrdimensionaler Befindlichkeitsfragebogen) before and after the tournament game for the control (white circles) and the experimental group (black squares).

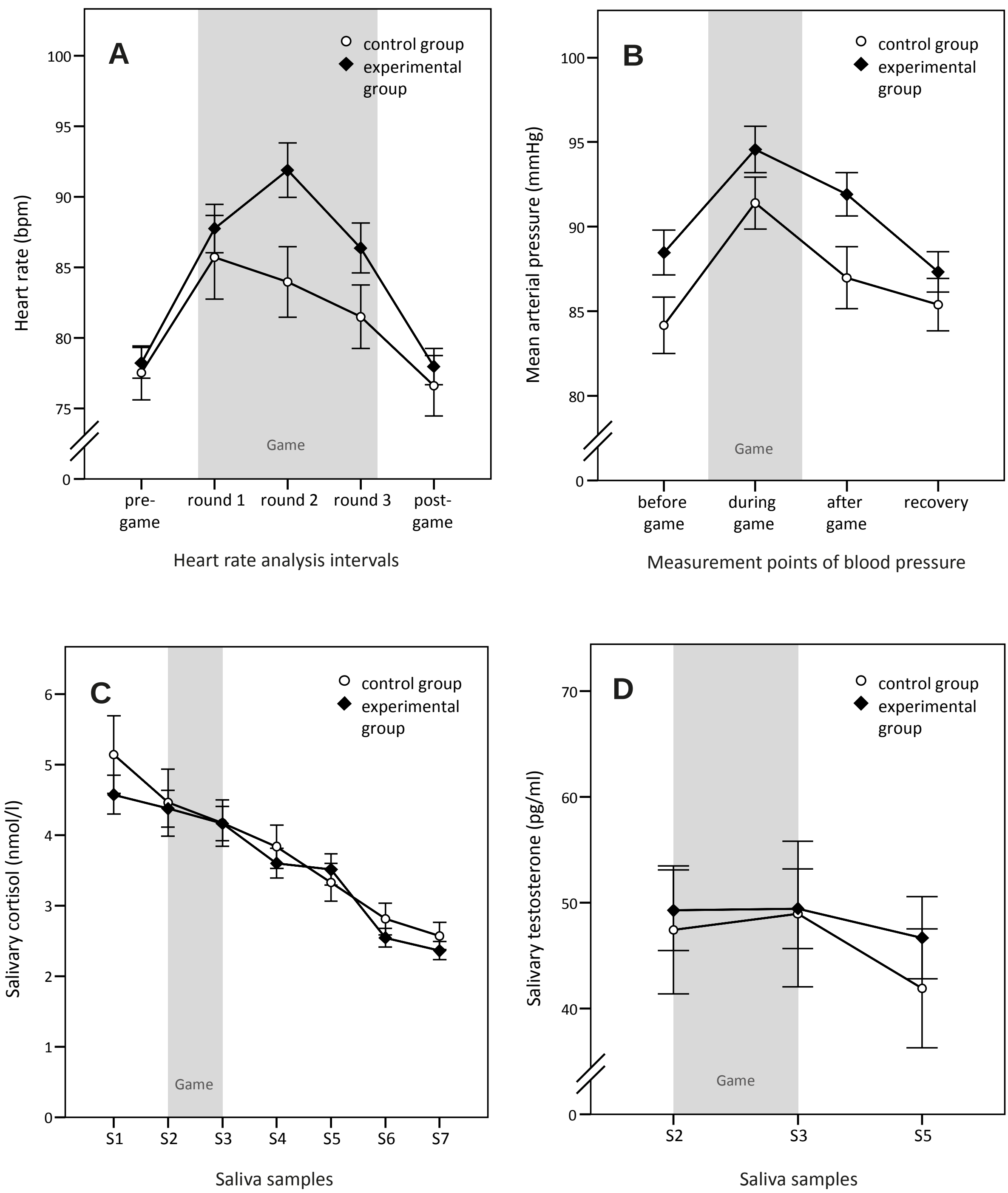

FIGURE 3: Physiological and endocrine reactions to the tournament game. Time courses of heart rate (A), mean arterial pressure (B), salivary cortisol (C), and salivary testosterone (D) for the control (white circles) and experimental group (black squares). Data are given as mean ± SEM. Grey bars indicate the timing of the tournament game. S1-S7: Saliva samples (see text for details).

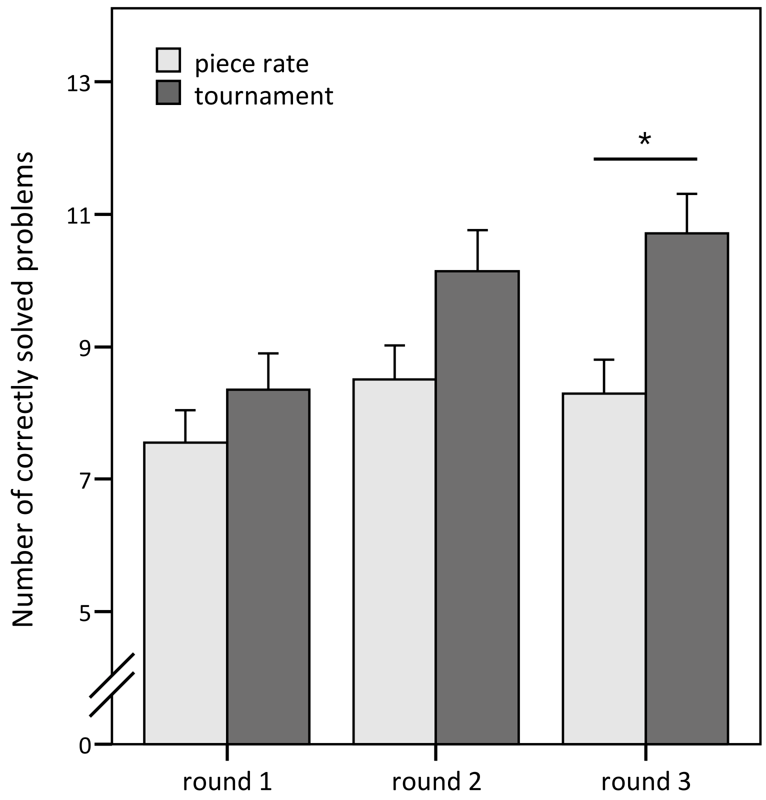

FIGURE 4: Comparison of performance between choice groups. Number of correctly solved problems (mean ± SEM) during the three rounds of the tournament game for the piece rate choice group (light grey) and the tournament choice group (dark grey) Both choice groups performed round one under piece rate and round two under forced tournament conditions. In round three, the piece rate choice group performed under piece rate conditions, the tournament choice group under tournament conditions (*p < .05).

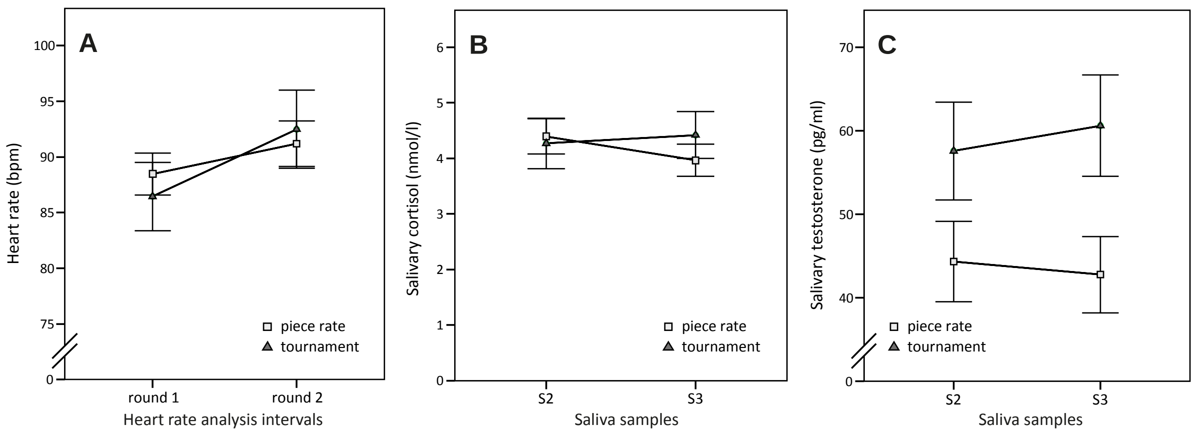

FIGURE 5: Differences between choice groups. Comparison of the changes in heart rate from round one to round two (A), and of changes in cortisol (B) and testosterone (C) from the measurement point before the tournament game (S2) to the measurement point directly after the game (S3) between the piece rate choice group (light grey squares) and the tournament choice group (dark grey rectangles). Data are given as mean ± SEM.

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