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Playing a rigged game: Inequality's effect on physiological stress responses

Martin S. Shapiro[a,*], Rhanda Rylant[a], Amanda de Lima[a], Andrea Vidaurri[a], Herman van de Werfhorst[b]

[a] Department of Psychology, California State University Fresno, 2576 E. San Ramon M/S ST11, Fresno, CA, United States
[b] Department of Sociology, University of Amsterdam, Postbus 15508, 1001 NA Amsterdam, The Netherlands

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ABSTRACT

High income and wealth inequality corresponds with high rates of various health and social problems. One possible factor that could be contributing to this correlation is stress experienced by those being treated unfairly in an unequal society. The present experiment attempted to simulate aspects of income inequality in a lab setting while recording several measures of stress. Participants ($n = 96$) were assigned to one of four groups and played a memory game against a confederate opponent to earn "money" to spend in a lab market. The four groups depended on the difficulty of the problems and the fairness of the game that they and their opponents experienced. Stress attitudes were assessed with the Short Stress State Questionnaire (SSSQ) and four physiological measures: salivary cortisol, medial frontalis and corrugator facial muscle EMG, heart rate, heart rate variability (HRV), and skin conductance levels (SCL). Cortisol levels and HRV scores were the highest in groups that competed in an unfair game regardless of the difficulty of the problem compared to the groups playing a fair game. The group playing an unfair game with hard problems (disadvantaged) also had elevated facial muscle activity indicating negative affect and reported higher distress on the stress questionnaire. The results of this experiment showed that experiencing inequality even for a short time elicited several stress responses even if the participant benefited from the inequality.

1. Introduction

Living in a country or community where there are wealth and income inequalities has been shown to correlate positively with a number of social, political, behavioral and health-related problems [50,52,58,59]. Inequality has shown positive correlations with rates of teen smoking [36], drug overdose [18], obesity [46], infant mortality and early death rates [57], depression [37], mental illness [35,56], homicide and incarceration rates [26], teen pregnancy rates [32], problems in child development [6] and lack of motivation to do well in life [45]. In a review of much of this research, Wilkinson and Pickett [58,59] show clearly that there is a strong positive correlation between a general "index of social and health problems" and the level of economic inequality found in a country—controlling for the country's average income. That is, what matters is not how wealthy or poor a country is overall but the extent to which a country's wealth and poverty are unevenly distributed across its citizens.

Although it is clear that economic inequality is associated with behavioral and health problems, scholars disagree about the explanation of these associations. The resource perspective sees inequality to be correlated to societal ills because resources are more unevenly distributed, and the marginal (health, behavioral) gains of a dollar are higher for people at the bottom relative to people at the top of the distribution [5]. The psychosocial perspective, by contrast, argues that inequality has effects that go beyond the resources available to individuals, and holds that inequality induces stress and interpersonal distrust, leading to divided societies [31,58,59]. Given the rising inequalities in many Western societies [44], it is important to know more about the psychosocial effects of inequality.

While factors that tie inequality to physical and mental health problems are certainly complex and interrelated, Wilkinson and Pickett [58,59] point out that many of these problems are related to stress [55]. It seems plausible, therefore, that inequality produces stress, which in turn has a negative effect on psychological and physical health. But how does inequality produce stress? One possibility is that when people who are relatively low in socioeconomic status interact with people who are relatively high in socioeconomic status, they experience unflattering social comparisons, perceived lack of social mobility, and shame—all of which have been shown to be elevated in societies with greater inequality [22,30]. As Paskov et al. [45] point out, this "status anxiety" is an important source of the stress experienced by people in unequal societies (see also [35]). If these interactions and social comparison are

* Corresponding author.
E-mail address: mashapiro@csufresno.edu (M.S. Shapiro).

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ever-present, then the stress responses are also persistent potentially resulting in damage to physical and mental health.

Consistent with this interpretation, there have been a number of laboratory studies investigating the effect of being in a socially threatening situation on physiological and psychological stress. In the Trier Social Stress Test or TSST [33], participants perform challenging tasks in front of critical judges. This activates the hypothalamic-pituitary-adrenal (HPA) axis, which is a hormonal system that regulates the body's reaction to stressful events by, among other actions, the synthesis and release of cortisol. Gruenewald et al. [20] used a modified version of the TSST and had college students prepare and give a speech and solve difficult math problems either alone or while being socially evaluated by a panel of judges. Participants answered pre and post questionnaires that evaluated emotions, anxiety, and shame as well as salivary cortisol levels. Those participants who were socially evaluated exhibited greater increases in shame and had lower social self-esteem and elevated salivary cortisol levels compared with those who performed the tasks alone. In addition, cortisol increases were greater in participants who reported greater shame and lower social self-esteem.

The idea that social threats are particularly stressful is also consistent with a meta-analysis conducted by Dickerson and Kemeny [12]. They summarized research on various stress-induction methods to determine which situations elicit the highest levels of physiological stress response as measured by levels of cortisol. They considered several models of stress induction including the social self-preservation theory, social-evaluative threat theory, and uncontrollability theory. Overall, they found that situations in which there was a social evaluative component were those that elicited the highest levels of cortisol. They suggest that people are inclined to preserve their "public" selves and to put that self in jeopardy through social judgment arouses the HPA axis and results in the release of cortisol (see also [10]).

It should be noted that the TSST and other laboratory stress-induction methods that have been used in previous research involve the threat of being negatively evaluated based on one's performance on a task. They do not necessarily tap into stress produced by inequality per se. The purpose of the present study, therefore, was to see whether a laboratory task that emphasizes the inequality between participants can also produce psychological and physiological stress. Such a finding would provide a more direct link between laboratory research on social threat and stress on one hand, and economic research on inequality and health on the other.

A challenge for the present research, then, was to create a laboratory task that in some small way mimics the effects of economic inequality in the world. Economic inequality is a product of many interconnected components and certainly not all of them are replicable in a laboratory setting. Frank [17] points out socioeconomic success is to a large degree a product of chance events. Having the good fortune of wealthy parents, living in a rich country, surrounding oneself with other fortunate people all play an exceedingly large role in many people's success. This is not to say that there is no role for ability and hard work, but if one starts with good fortune that gives advantages, a path to success is made much easier. Therefore, we created a competitive multi-trial game where success is based to some degree on skill and effort, while also having an extremely powerful luck component. Some participants are randomly assigned to be relatively advantaged compared to their opponent (the game is made easier for them), and others are randomly assigned to be relatively disadvantaged (the game is made more difficult). To add the social judgment component, the advantages and disadvantages afforded each player and ultimately the changing economic status is made explicit to both competitors during the competition.

The hypothesis is that threat to the "social self" of those who are disadvantaged in the game will result in an increased stress responses compared with those who are advantaged and to those who are neither disadvantaged or advantaged relative to their opponent. Stress responses were measured in several ways. Psychological stress was measured by the SSSQ administered pre and post competition and has been shown to be sensitive to different components of an experience including distress, engagement, and worry. Physiological measures including facial EMG, heart rate and skin conductance were taken on a trial-by-trial basis to measure immediate distress and arousal responses during the competition. Heart-rate variability was analyzed at the beginning, middle and end of the competition, and salivary samples to evaluate cortisol were taken at the beginning and end.

2. Methods

2.1. Participants

Ninety-six participants (48 males and 48 females) were selected from the California State University, Fresno introductory psychology subject pool, and various psychology courses. Ages ranged from 18 to 25 years and all participants received class credit for participating. The socio-economic status of each participant was not recorded for each participant, but students at Fresno state typically come from middle to lower income families, with 74% of the students receiving financial aid for economic reasons. The full experimental protocol was reviewed and approved by the three members of the Psychology Department's Internal Review Board and was classified as a minimal risk.

2.2. Experimental design

Each participant played a delayed match-to-sample task (DMTS) against a confederate (the "opponent") played by a research assistant. Having a confederate created a sense of competition and social judgment, but also allowed for greater control of the competition. There were an equal number of male and female opponents, and the pairing was balanced across groups (i.e., equal number of male/male, female/female, male/female and female/male pairings). Saliva samples for cortisol analysis were taken before and after the competition, electrocardiogram (ECG) for heart rate (HR) and heart-rate variability (HRV) analysis, skin conductance level (SCL), and facial electromyography (EMG) were recorded during gameplay. The study used a between-subjects 2 × 2 design with participants randomly assigned to either a fair version of the task with either low or high difficulty or an unfair version with low or high difficulty. The participant and the opponent each took turns solving a DMTS problem with each being able to see the other's problems as well as their respective feedback. Participants were assigned to one of the following groups:

Unfair-Hard: The participant was given difficult problems to solve while the confederate opponent received easy problems.
Unfair-Easy: The participant was given easy problems to solve while the confederate opponent received difficult problems.
Fair-Hard: The participant and the confederate opponent were given equally difficult problems to solve. The participant in the *Fair-Hard* condition received the same problem set in the same order as the participant in the *Unfair-Hard* condition.
Fair-Easy: The participant and the confederate opponent were given equally easy problems to solve. The participant in the *Fair-Easy* group received the same problem set in the same order as the participant in the *Unfair-Easy* group.

Table 1 shows information about each group. To ensure there was not an order effect of running groups, a participant running sequence was created in advance. Each of the four possible sex-pairing combinations within each group was assigned a randomly generated number between 0 and 1 and the order of running was arranged from the lowest to the highest random number. If, however, a female signed up for a time slot where a male was needed, then that female participant was run in the next available female time slot and vice versa.

The DMTS game was programmed using the stimulus software by *E-*

Table 1
For each group this table shows the total number of each sex, the ethnic demographics (A = Asian American, B/AA = Black/African American, H = Hispanic, NA = Native American, PI = Pacific Islander, W = White, OU = Other or Undeclared), and the difficulty of the problems solved by the participants and the confederate opponent.

Groups	Sex	Age range	Ethnic demographics	DMTS difficulty (participants)	DMTS difficulty (opponent)
Unfair-Hard (n = 24)	Male (n = 12) Female (n = 12)	18–24	A (8.3%), B/AA (0%) H (50%), NA (4.2%) PI (0%), W (25%) OU (12.5%)	Difficult	Easy
Unfair-Easy (n = 24)	Male (n = 12) Female (n = 12)	18–23	A (16.7%), B/AA (0%) H (58.3%), NA (0%) PI (0%), W (16.7%) OU (8.3%)	Easy	Difficult
Fair-Hard (n = 24)	Male (n = 12) Female (n = 12)	18–25	A (16.7%), B/AA (4.17%) H (45.8%), NA (0%) PI (0%), W (25%) OU (8.3%)	Difficult	Difficult
Fair-Easy (n = 24)	Male (n = 12) Female (n = 12)	18–25	A (12.5%), B/AA (4.17%) H (50%), NA (0%) PI (4.2%), W (12.5%) OU (4.2%)	Easy	Easy

Prime. Although the "opponent" appeared to be doing their best on the DMTS task, the task was programmed to determine whether the opponent was correct or incorrect on each trial and was influenced by how well the participant performed. This programming ensured the final overall relative standing of each player. In group *Unfair-Hard*, the game concluded with an overall score ratio of 40:60 in favor of the opponent; in group *Unfair-Easy*, the overall score ratio was 60:40 in favor of the participant, and in *Fair-Hard* and *Fair-Easy* the overall score ratio was 50:50 (a tie).

The Short Stress State Questionnaire (SSSQ) was administered at the beginning and end of the competition [23]. Appendix A describes the questions used in the pre-survey, with the post-survey asking the same questions in past tense (for the full survey see [23]). The SSSQ is a shortened version of the Dundee Stress State Questionnaire (DDSQ; [38]), and has proven to be sensitive to three dimensions of stress state: task engagement, distress, and worry [24]. In addition to the SSSQ, an additional question was asked at the end of the competition: "The game you just played was a fair competition between you and your opponent." As with the SSSQ, participants answered the final question on a 1–7 (agree to disagree) scale.

2.3. Procedure

Fig. 1 shows the sequence of events from the time the participant entered the lab until leaving. The participants were asked to refrain from ingesting caffeine or eating for one hour before the study. All participants were run between the hours of 12:00 p.m. and 5:00 p.m. due to diurnal fluctuations in cortisol [34]. The participant entered the lab and was asked to take a small sip of water 10 min before giving the first saliva sample. During this time both the participant and the opponent read and signed the informed consent form and completed the SSSQ pre-survey. Once the required 10 min had elapsed, the researcher instructed the participant to hold a small sterilized cotton swab (provided by the commercial laboratory, Salimetrics) under his or her tongue for 2.5 min to collect the first salivary cortisol sample. The sample was then frozen and sent to Salimetrics SalivaLab (Carlsbad, CA) for analysis after the study was completed. Samples were assayed in duplicate at Salimetrics using the Salimetrics High Sensitivity Cortisol Enzyme Immunoassay Kit, without modifications to the manufacturers' protocol. The average coefficient of variation for all samples tested was < 3%, which meets the manufacturers' criteria for accuracy and repeatability in Salivary Bioscience, and exceeds the applicable NIH guidelines for Enhancing Reproducibility through Rigor and Transparency. Sample test volume was 25 μL of saliva per determination. The assay has a lower limit of sensitivity of 0.007 μg/dL and a standard curve range from 0.012 μg/dL to 3.0 μg/dL.

Following the collection of the sample, the researcher attached the BIOPAC® electrodes to the participant. The EMG electrodes were attached to the participant's right medial frontalis after the area had been cleansed with an alcohol pad and slightly abraded with a sponge. One electrode was placed 2 cm superior to the pupil and the other placed laterally from the first electrode 1 cm at a 45° angle. These two electrodes were directly over the medial frontalis, but also record activity of the corrugator supercilii. Activation of these muscle groups has been typically associated negative emotions such as anger [13] anger and fear [41], surprise [54], and sadness (for review see [7]). Impedance was checked on the EMG electrodes and if above 25 kΩ, the area was cleaned again and the electrodes were reattached. The ECG electrodes were placed under the right clavicle and inside of the left. The SCL electrodes were placed on the palmar side of the middle and index fingers on the left. After these steps were concluded the researcher explained the steps of the game.

The researcher informed the participant and confederate opponent that each problem they answered correctly would earn them ten dollars

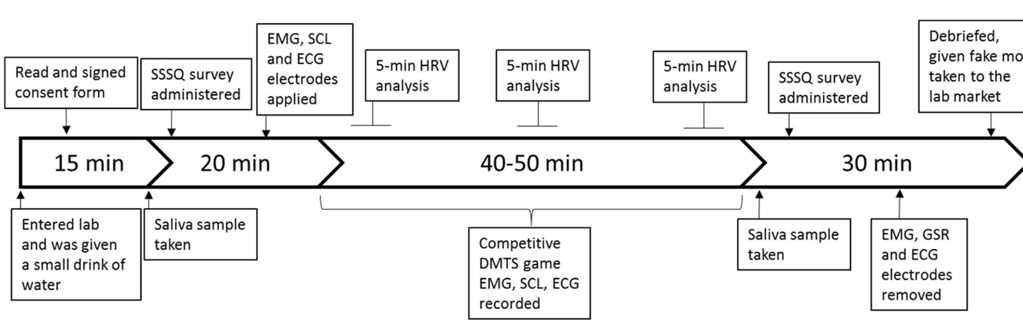

Fig. 1. This is a timeline of events during the experiment.

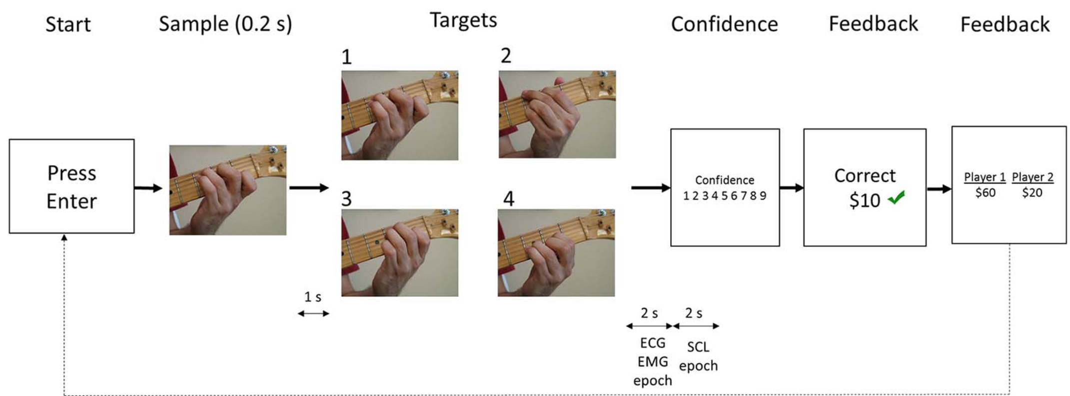

Fig. 2. Step-by-step events of a trial. This figure shows the events of each trial the participant played. It began with the sample flashing once on the screen and was then replaced by the four targets to which the participant must have matched the sample. The participant makes his or her choice and was then asked to rate how confident he or she was in the choice on a scale from 1 to 9 with 1 indicating no confidence in the choice to 9 indicating full confidence in the choice. This screen was followed by a feedback screen that told the participant if they got the problem right or wrong. This feedback screen was immediately followed by a screen that showed the players' standings relative to each other.

of "fake" money that they can use in the lab market. A trial was run explaining each slide. Fig. 2 shows a diagram of a single trial in the game. The researcher then instructed the participant and opponent to begin the game.

The participant and opponent sat opposite each other facing their computer screens. The participant played the first trial, the opponent played the next trial, and so on, with each player able to see their opponent's trial and feedback on their screen. Each trial was a delayed-match-to-sample task and consisted of a problem, a confidence rating, feedback, and a comparison of the players' performances relative to each other. At the beginning of the trial, a picture flashed quickly on the screen (0.20 s in the easy condition and 0.10 s in the hard condition). This was followed by a 1-s blank screen, and then four target pictures of varying similarity were displayed. The object was for the player to match which picture was the one that originally flashed on the screen (the "sample"). In addition to the sample latency, the difficulty of the problem was also determined by the similarity of the targets. A set of hard and easy image sets were created by using data from another experiment that used the same DMTS task to investigate risky decision making. In this experiment, 900 participants attempted to solve 100 DMTS problems and were asked to risk or play-it-safe to earn points based on how well they thought they did on solving the problem. This experiment investigated the effect of gaining or losing points on risk taking [49]. The 900 participants did provide good information on the level of difficulty of each picture set, and we used this accuracy information to create DMTS problems of different difficulty for the present experiment.

In the present experiment, after the player attempted to match the sample to the target, he or she was asked to rate his or her confidence for that trial. The confidence rating was a 1–9 scale with a score of 1 indicating certainty that the choice was incorrect and a 9 indicating certainty that the choice was correct. The player then received feedback of success (+$10) or failure (+$0). After this feedback, the game displayed the players' relative scores followed by the beginning of the next trial. There were 160 of these trials (each participant solved 80) with a 30-s break occurring every 40 trials. The entire match took between 40 and 50 min.

After the game had ended, the participant was asked to give another salivary cortisol sample using the same procedure as with the first sample while the confederate filled out the SSSQ post-survey. The opponent was given the "money" he or she earned during the game and was escorted to the "market" that was in another room where he or she pretended to spend the money while the participant filled out the post-surveys. After the participant had finished the surveys, the researcher removed the BIOPAC electrodes and gave the participant their money earned and escorted him or her to the "market." The market was stocked with snacks, pens, pencils, and a raffle for gift cards. The actual value of the merchandise ranged between four and six dollars.

2.4. Analysis of BIOPAC® physiological responses

For EMG and heart rate, we epoched the recording 0–2 s from the point the participant viewed the four target images from which to choose the sample – this is a point where they realized the difficulty of their problem (i.e., the participant's targets). We also recorded 0–2 s from the point where the participant could view the four target images that their opponent had to choose from (i.e., opponent's target).

Skin conductance levels (SCL) were analyzed 2–4 s after the participants viewed the target stimuli (participant's targets) and when the participant viewed the opponent's targets (opponent's targets). SCL peaks 2–4 s after an emotional event [8].

For this study, an analysis of HRV took place during three 5-min sections while playing the game at the beginning, the middle, and the end. In the automated analysis available in the AcqKnowledge program through Biopac, three scores are provided: sympathetic, vagal and sympathetic/vagal. The sympathetic score represents the activity of the sympathetic nervous system and high stress while the vagal component represents parasympathetic activity and lower stress; therefore, the higher the sympathetic/vagal (S/V) score the greater the theoretical stress levels of the individual. Heart rate variability (HRV) has been used to reflect physiological arousal linked to stress [25]. HRV generally refers to the difference in time between heart beats as controlled by two branches of the autonomic nervous system (ANS) [3]. The sympathetic branch is linked to elevated physiological arousal with the vagal (parasympathetic) branch indicating lower arousal [48]. Research suggests that these systems work to maintain cardiovascular homeostasis and reflect HRV control in the short term [48]. The vagal component of variability is thought to represent parasympathetic activity that is linked to low arousal and low stress, and the sympathetic component is linked to high arousal and high stress. Hjortskov et al. [25], for example, found higher sympathetic/vagal scores in individuals solving a difficult rather than an easy computer problem.

2.5. Statistical analysis

The statistical package SPSS was used in the analysis. All results are considered significant at an alpha level of $p = 0.05$. Repeated measures and univariate ANOVAs were used, which are typically robust to violations of statistical assumptions [19]. That said, to correct for possible violations of the sphericity assumption in repeated measures designs, we employed the Geisser-Greenhouse correction when Mauchly's test of sphericity was significant. To test for normal distributions, we used the

Shapiro-Wilk's test as well as visually inspecting the Q-Q plots. In the present experiment, the cortisol results were the only data that showed a significant violation of normality, so analysis was performed on a log transformation of these data that corrected for this violation. Homogeneity of variance was evaluated for independent data using the Levene's test, and in no comparisons did we find a significant violation. In the repeated measures analysis, the effect size is given by providing a partial eta squared (η_p^2) ($\eta_p^2 \sim 0.02$ = small, ~ 0.13 = medium, and ~ 0.26 = large effect sizes) and in *t*-test, effect size is reported using a Cohen's d value. A Tukey HSD post hoc procedure was employed to adjust the alpha level for significance when making comparisons.

3. Results

This study examined task performance and stress responses when competing in an unfair and fair economic competition against an opponent. Several physiological responses were measured as well as attitudes about stress through the SSSQ. Each of these will be discussed starting with task performance followed by trial-by-trial within-game physiological measures (EMG and SCL), the two cortisol samples taken at the beginning and end of the competition, and 5-min blocks of heart rate variability (HRV) analysis taken towards the beginning, middle and end of the game, and finally, the results of the SSSQ survey results.

3.1. Accuracy and confidence

First, we assessed the participant's behaviors in the DMTS task. Fig. 3 shows the accuracy on the DMTS task for the four groups. For each participant, accuracy was averaged in 20-trial blocks and a repeated measures ANOVA was conducted with groups as the between-subject factor and blocks as the within-subject factor. There was an overall group effect, $F(3, 92) = 92.52$, $p < 0.001$, $\eta_p^2 = 0.75$, a block effect, $F(3, 276) = 6.00$, $p = 0.001$, $\eta_p^2 = 0.06$, and a group × block interaction, $F(9, 276) = 3.88$, $p < 0.001$, $\eta_p^2 = 0.11$. This was followed by separate analysis comparing groups that solved the same problems in the same order. Comparing groups *Unfair-Hard* and *Fair-Hard*, we found no group effect ($F < 1$) nor a group × block interaction, $F(1, 46) = 1.27$, $p = 0.29$, $\eta_p^2 = 0.03$, but there was an overall block effect, $F(1, 46) = 10.44$, $p < 0.001$, $\eta_p^2 = 0.19$. However, comparing groups *Unfair-Easy* and *Fair-Easy*, we find a group effect, $F(1, 56) = 13.29$, $p = 0.001$, $\eta_p^2 = 0.23$, an overall block effect, $F(3, 138) = 2.63$, $p = 0.05$, $\eta_p^2 = 0.05$ and group × block interaction, $F(3, 138) = 2.72$, $p = 0.047$, $\eta_p^2 = 0.56$. This indicates that while these two groups solved the same problems, the *Unfair-Easy* group was less accurate and their performance declined over the course of the match compared with the *Fair-Easy* group.

In a similar analysis of confidence, we found an overall group effect, $F(3, 91) = 8.57$, $p < 0.001$, $\eta_p^2 = 0.22$, with this confidence

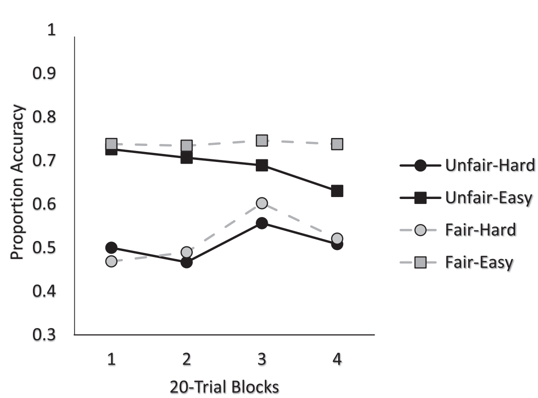

Fig. 3. This figure shows the accuracy on solving the DMTS problems averaged over four 20-trial blocks for all four groups.

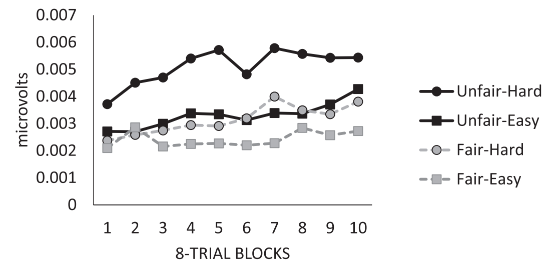

Fig. 4. The EMG activity was recorded 0–2 s after the target stimuli was presented showing the difficulty of the DMTS problem. EMG activity was averaged over 10, 8-trial blocks for each participant in each group. The lines with solid circles (gray and black) indicate a hard set of problems for the participant while the solid squares (gray and black) indicate an easy set of problems. Black solid lines indicate an unfair game while gray dotted lines indicate a fair game.

difference attributed to the difference in difficulty of the problems between groups. A Tukey HSD post hoc pairwise comparison found that the *Unfair-Hard* group differed only from the *Fair-Easy* group ($p = 0.002$), the *Unfair-Easy* group only differed from the *Fair-Hard* group ($p = 0.032$), and the *Fair-Hard* group also differed from the *Fair-Easy* group ($p < 0.001$). Even though the *Unfair-Hard* and *Unfair-Easy* had different difficulty in problems, their confidence measures did not differ from each other ($p = 0.30$).

3.2. Facial EMG

Fig. 4 shows the EMG activity averaged over 8-trial blocks when participants viewed all the target sets whether it was theirs or their opponents' to solve. For the analysis, 10, 8-trial blocks were averaged for the participant's targets and opponent's targets followed by a repeated measures ANOVA. The target type (participants or opponents) and the 10, 8-trial blocks were the within-subject factors and the groups were the between-subject factor. We found no overall difference in EMG activity when the participant viewed the participant's targets or opponent's targets ($F < 1$). We did find an overall block effect, $F(3.77, 339.66) = 13.71$, $p < 0.001$, $\eta_p^2 = 0.13$, an overall group effect $F(3, 90) = 5.48$, $p = 0.002$, $\eta_p^2 = 0.15$, and a group × block interaction, $F(11.32, 339.64) = 2.46$, $p = 0.005$, $\eta_p^2 = 0.08$. As can be seen in Fig. 3, the *Unfair-Hard* group had greater EMG activity than the other three groups; this was supported by a post hoc Tukey HSD pairwise comparison that found group *Unfair-Hard* differed from *Unfair-Easy* ($p = 0.05$), *Fair-Hard* ($p = 0.026$) and *Fair-Easy* ($p = 0.001$). The other three groups did not differ from each other. The *Unfair-Hard* group had greater EMG activity while seeing the difficulty of their problems and the ease of their opponent's problems, and therefore expressed more negative emotion than the other groups.

3.3. Skin conductance levels

As with EMG, the SCL was evaluated after the participant viewed the targets on their trials or other opponent trials and then averaged in 10, 8-trial blocks. A repeated measures ANOVA was conducted with trial type (participant or opponent) and 10, 8-trial blocks as the within-subject factor and groups as the between-subjects factor. The ANOVA found no overall group effect ($F < 1$). There was an overall increase in SCL over the course of the match as indicated by a block effect, $F(1.77, 158.08) = 22.10$, $p < 0.001$, $\eta_p^2 = 0.19$, but there was no block by group interaction, $F(5.27, 158.08) = 1.57$, $p = 0.16$, $\eta_p^2 = 0.05$. There was, however, a trial-type effect in that there was greater SCL when participants viewed their targets compared to viewing their opponent's targets, $F(1, 90) = 24.139$, $p < 0.001$, $\eta_p^2 = 0.21$.

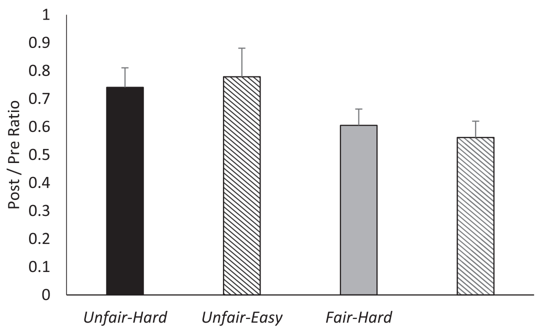

Fig. 5. In this figure, the solid bars represent a difficult game while striped bars represent an easy game. Black indicates an unfair game while gray indicates a fair game. Salivary cortisol samples were taken 10 min after the participant arrived in the lab and directly after the participant finished playing the game. Each participant's post score was divided by their pre- score. A higher ratio indicates more stress brought on by the game. Error bars were calculated as one standard error.

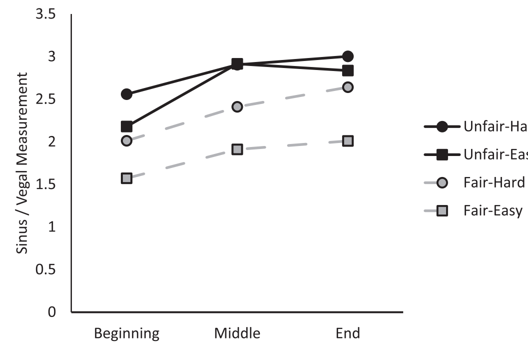

Fig. 6. The lines with solid circles indicate a hard game while lines with solid squares indicate an easy game. Black solid lines indicate an unfair game while gray dotted lines indicate a fair game. An analysis of HRV took place during three 5-min sections while playing the game at the beginning, the middle, and the end. The sympathetic score represents the activity of the sympathetic nervous system and high stress while the vagal component represents parasympathetic activity and lower stress; therefore, the higher the sympathetic/vagal (S/V) score the greater the theoretical stress levels of the individual.

3.4. Heart rate

As with SCL and EMG, heart rate was evaluated after the participant viewed the targets on their or their opponent's trials and averaged over 10, 8-trial blocks. A repeated measures ANOVA was conducted with target type (viewed by participant or opponent) and the 10, 8-trial blocks as the within-subject factor and groups as the within subject factor. There was an overall block effect, F(4.96, 445.92) = 3.26, $p = 0.001$, $\eta_p^2 = 0.04$, no overall group effect F(3, 90) = 1.57, $p = 0.20$, $\eta_p^2 = 0.05$, no group × block interaction, F(14.86, 445.92) = 1.04, $p = 0.41$, $\eta_p^2 = 0.04$, and no group × trial-type interaction ($F < 1$). As in the SCL analysis, there was an overall trial-type effect F (1, 90) = 13.93, $p < 0.001$, $\eta_p^2 = 0.14$, but unlike the SCL measurement, heart-rates increased when the participant viewed the target stimuli of their opponent.

3.5. Cortisol

Fig. 5 shows the ratio of the second sample divided by the first sample averaged across participants for each group. We use this ratio because we are not necessarily interested in raw cortisol levels but in relative change. What can be seen from Fig. 5 is that all groups showed a decrease in cortisol levels from the first to second sample meaning that either the task itself was not incredibly stressful, or the first sample represented a heightened stress level just prior to arriving at the lab. Because the raw cortisol data violated the assumption of a normal distribution, a log transformation of the raw data was used in the analysis. A univariate ANOVA was conducted with the ratios as the dependent factor and the groups as the fixed factor, and we found no overall difference between groups, F(3, 91) = 1.98, $p = 0.12$, $\eta_p^2 = 0.06$. We were, however, particularly interested in the effect of being exposed to a fair or unfair competition, so we ran an independent sample *t*-test of the cortisol ratios comparing those playing an unfair game (groups *Unfair-Hard* and *Unfair-Easy*) against those playing a fair game (groups *Fair-Hard* and *Fair-Easy*) and found that the cortisol ratio in the unfair conditions was significantly higher than the fair conditions, $t(93) = 2.34$, $p = 0.02$, d = 0.47. Although we considered this an apriori comparison, these findings were still significant with an adjusted alpha level to 0.05/2 = 0.025.

3.6. Heart rate variability

Fig. 6 shows the S/V scores averaged across participants within each group for the beginning, middle and end 5-min block. A repeated measures ANOVA was run with groups as the between-subjects factor and the time of the measurement as the within-subjects factor. There was an over-time effect, $F(2, 146.52) = 6.70$, $p = 0.002$, $\eta_p^2 = 0.07$ indicating that S/V increased in score as they played, but there was not an overall group effect, $F(3, 89) = 2.14$, $p = 0.10$, $\eta_p^2 = 0.06$ and no group × time interaction ($F < 1$). This increased S/V scores does give some support that the task itself was somewhat stressful. Because we found an effect of fairness with cortisol, a similar analysis was conducted with HRV combining groups that experienced an unfair game and those that experienced a fair game. A repeated-measures ANOVA was conducted with fairness as the between-subjects factor and time of measurement as the within-subjects factor. As with cortisol, there was an overall fairness effect, $F(1, 91) = 0.27$, $p = 0.02$, $\eta_p^2 = 0.06$, and this too was significant with an adjusted alpha level with a post hoc comparison.

3.7. Short Stress State Questionnaire

The factor analysis of the SSSQ by Helton and Näswall [24] provided strong evidence that the SSSQ was sensitive to three dimensions of stress related to a task with items 2, 5, 11, 12, 13, 17, 21, and 22 measuring *task engagement*, items 1, 3, 4, 6, 7, 8, 9,and 10 measuring *distress*, and items 14, 15, 16, 18, 19, 20, 23, and 24 measuring *worry*. To determine if there was a difference in dimension items, we first averaged responses across the items for the three dimensions for each participant and then calculated the post/pre ratios. We then ran a repeated measures ANOVA with the post/pre ratios for each dimension as the within-subject factor, and found a strong difference between dimensions, F(2, 180) = 139.73, $p < 0.001$, $\eta_p^2 = 0.62$. To use this survey in a meaningful way, we analyzed each SSSQ dimension separately when looking at differences between groups. Fig. 7 shows the

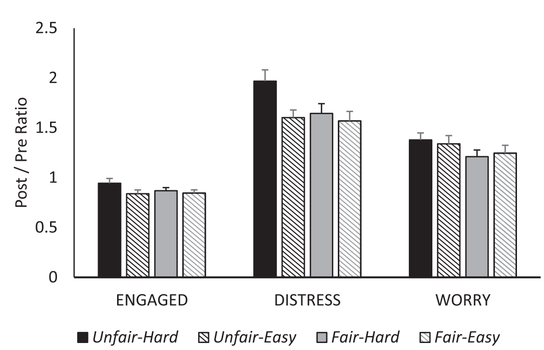

Fig. 7. This figure shows the post/pre scores averaged for the items on the SSSQ that assess engagement, distress and worry separated into the four groups. Solid shades represent hard problems, and stripes represent easy problems. Black represents unfair and gray represents fair competition. The error bars are one standard error.

post/pre ratio scores for each group separated for each dimensions. Scores above 1 indicate an increase and below 1 indicates a decrease in each state. A univariate ANOVA was run for each dimensions separately, with groups as the fixed factor and post/pre ratio as the dependent variable. There was no difference between groups for engagement, $F(3, 91) = 1.93$, $p = 0.13$, $\eta_p^2 = 0.06$. There was a difference in distress between groups $F(3, 91) = 3.79$, $p = 0.01$, $\eta_p^2 = 0.11$. Post hoc comparisons using the Tukey HSD test indicated that group *Unfair-Hard* had a higher post/pre ratio than group *Unfair-Easy* ($p = 0.04$), *Fair-Hard* ($p = 0.05$) and *Fair-Easy* ($p = 0.01$). The latter three groups did not differ from each other. There was no overall group effect when analyzing the dimension of worry, $F(3, 93) = 1.20$, $p = 0.32$, $\eta_p^2 = 0.04$. As with the cortisol and HRV results, the scores on the dimension of worry appeared to show a pattern of the two unfair groups elevated over the two fair groups. We ran an independent *t*-test comparing the post/pre ratios of the unfair groups against the fair groups in just the worry dimension, and it approached significance, $t(93) = 1.92$, $p = 0.06$, $d = 0.22$.

3.8. Fairness ratings

At the end of the competition, participants were asked to rate the fairness of the game. A rating of "1" indicated that the game was completely unfair and a rating of "7" indicated that the game was completely fair. Fig. 8 shows these scores averaged across groups. Group *Unfair-Hard* rated the game as less fair than the other groups. A Univariate ANOVA determined that there was an overall group effect, $F(3, 86) = 4.03$, $p = 0.01$, $\eta_p^2 = 0.12$. A Tukey HSD post hoc analysis found that the *Unfair-Hard* group did not differ from *Unfair-Easy* group though it approached significance ($p = 0.11$), but the *Unfair-Hard* group did differ from the *Fair-Hard* group ($p = 0.01$) and *Fair-Easy* group ($p < 0.001$). The *Unfair-Hard*, *Fair-Hard* and *Fair-Easy* group did not differ from each other. This suggests that, as expected, the *Unfair-Hard* group noticed the game was unfair and rated it accordingly, but it is difficult to determine the degree to which the *Unfair-Easy* group viewed the game they played as unfair. As can be seen in Fig. 8, the *Unfair-Easy* group appears to rate the game as less fair than the *Fair-Hard* and *Fair-Easy* group though not significantly, and appears to rate the game fairer than *Unfair-Hard* group but not significantly.

3.9. Sex difference

Because we balanced the sex of the participant and opponent across groups, this afforded us the ability to investigate any sex difference in performance or physiological responses. Overall, we found very few differences between the sexes. When conducting an independent *t*-test,

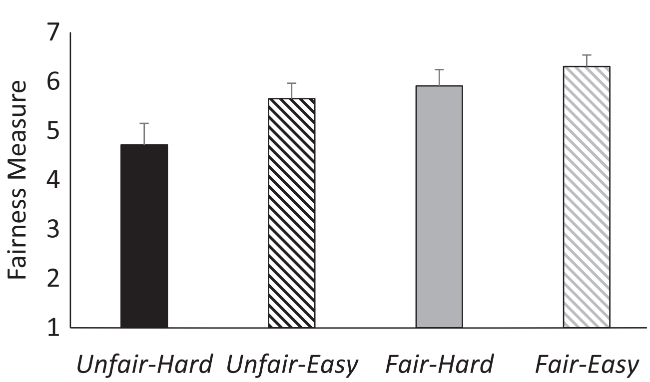

Fig. 8. The solid bars represent a difficult game while striped bars represent an easy game. Black indicates an unfair game while gray indicates a fair game. After the game, each participant was asked to rate on a 1–7 scale how fair they believed the game to be, with higher numbers indicating that the game was fairer. Error bars were calculated as one standard error.

we found no effect of sex of the participant on accuracy ($t < 1$) nor confidence ($t < 1$). When looking at EMG, a repeated measures ANOVA with blocks as the within-subject factor and sex of the participant and sex of the opponent as the between subject factors, we found no sex-of-the-participant effect ($F < 1$), nor a sex-of-the-opponent effect ($F < 1$) and no interaction in either case with blocks ($F < 1$). Similar results were found with SCL. When analyzing sex differences in cortisol, we ran a repeated measures ANOVA with pre and post raw cortisol values as the within-subject factor and sex and group as the within-subject factors. We did find an overall higher raw cortisol levels in males $F(1, 93) = 7.88$, $p = 0.006$, $\eta_p^2 = 0.08$, but not a sex by post/pre ratio effect ($F < 1$) nor an effect of sex by group interaction ($F < 1$). There was a similar higher HRV S/V levels for males $F(1, 90) = 8.22$, $p = 0.005$, $\eta_p^2 = 0.08$, but no sex by time of measurement interaction ($F < 1$) nor a sex by group interaction ($F < 1$).

4. Discussion

The present experiment tested the effect of experiencing inequality brought on by unfairness on several measures of stress. It was clear that the *Unfair-Hard* group found the experience somewhat stressful compared to the *Fair-Hard* group that had to solve the same problems but had a fair competition as indicated by higher facial EMG, higher cortisol, higher heart-rate variability and increased distressed scores on the SSSQ. The measures that did not show differences were heart rate and skin-conductance levels, which could be due to the fact the HR and SCL are often more associated with general arousal but not necessarily distress [1,29]. These results support the original notion that recognizing that one has disadvantages can be stressful even for a short period in a controlled environment.

One could conclude that these elevated stress markers in the *Unfair-Hard* group were merely due to losing and that certainly could be a contributing factor. But similar stress responses (cortisol and HRV) were found in the *Unfair-Easy* group that experienced the same inequality conditions but won the competition. The elevated cortisol and HRV in the *Unfair-Easy* group could have been a result of the arousal of winning the game and not the experience of inequality. It was unclear whether the *Unfair-Easy* group consciously recognized that the game was an unfair competition rigged in their favor (Fig. 8), so winning could certainly be a contributing factor. There are some reasons, however, that the arousal from winning might not be the primary cause for the elevated stress responses. First, the measures of general arousal, heart rate and SCL, did not show differences between groups. Second, HRV is not just an arousal response associated with the sympathetic nervous system activity but is the interplay between the parasympathetic and sympathetic in dealing with emotional regulation and expression brought on by social interactions. HRV has been associated with individual differences in coping with negative emotions and experiences such as dealing with phobias, bereavement, and social anxiety (for review see [2]). In addition, HRV scores have been affected by increased cognitive demands [25,53], by playing violent but not non-violent video games [28] and by variations of the TSST [15,27,42]. The increased HRV scores in the *Unfair-Easy* group, therefore, was not likely just associated with the positive affect or arousal of winning.

Experimental evidence of the influence of winning and losing on cortisol levels is mixed. Steiner found heart rate and alpha-amylase increased in fans watching their favorite soccer team win or lose matches but HRV, cortisol, and testosterone were unaffected. Booth et al. [61] found testosterone increased in winning tennis players but cortisol levels were unaffected. In competitive female rugby players, Bateup et al. [4] found that cortisol was increased during the game for two reasons: (1) the opponent was harder than expected and (2) if the player's team lost the match. Elias [14] however, found male wrestlers showed an increase in cortisol in winners compared with losers. In the experiment reported here, cortisol increased in both winners and losers compared with the groups that tied. But cortisol was not affected by whether the competition was hard or easy or by the difficulty of the problems that had to be solved. The present experiment also did not find a male-female by group interaction as might have been expected if winning and losing were the primary cause of the increase in cortisol in the *Unfair-Hard* and *Unfair-Easy* groups.

If both the *Unfair-Hard* and *Unfair-Easy* group were stressed by their experiences, it could be for different reasons. The Social Self Preservation Theory [12,20] might predict that the *Unfair-Hard* group felt a threat to their "social self," lowering their social esteem and social status as well as feeling a negative judgment by others. The Social Self Preservation Theory is most associated with the TSST that certainly produces more stress than our protocol, but the underlying principles may still apply to unfairness and economic inequality. One would expect that The *Unfair-Easy* group that won their competition solved easier problems and gained more reward did not experience negative self-judgment, lower social esteem, nor shame. This group did not show an elevated activity of the frontalis and corrugator muscles, which is a representation of distress and negative affect [7]. In addition, they did not show particularly high scores on the SSSQ questions dealing with distress, though they did show the same slightly higher level of worry.

One possibility is that the *Unfair-Easy* group experienced stress induced by empathy for an opponent who they could see was being disadvantaged or was at least losing. Empathetic stress has shown to increase levels of cortisol. Engert, et al. [15] had participants observe through a one-way mirror another individual that had to undergo the TSST, and found that 26% of the observers showed an increase in HRV and salivary cortisol levels, with these percentages decreased to 10% if observing a stranger and increasing to 40% if observing an intimate partner. Zilioli et al. [60] found that self-reported empathy was high in males with high cortisol levels as long as their testosterone levels were low. This speaks more to individual differences as opposed to behavior-induced changes in stress hormones, but it does indicate a relationship between empathy and cortisol. Some support for the idea of empathy comes from the fact that the *Unfair-Easy* group showed a decline in accuracy in the second half of the experiment while the *Fair-Easy* group did not. Whether done at a conscious or unconscious level, the decline in accuracy may indicate an attempt to reduce the negative experience of their opponent. Independent of empathy, Wilkinson and Pickett [58,59] assert that inequality affects everybody, not just the poor.

A concern one may have with the present research is whether we study the stress effects of inequality or unfairness. The rigged, unfair nature of the experiment may be unconnected to real life inequality that may (partly) result from fair distributional principles (e.g. intelligence or ability). The increased stress experienced by the *Unfair-Hard* and *Unfair-Easy* groups could in part be simply a result of having an experience that is unfair. Starmans et al. [51] argue that inequality in and of itself is not troubling to people but rather it is economic unfairness that causes distress, though the two are often confounded. Their argument comes from research with children and adults looking at the fair and unfair distribution of money or goods. When adults were asked about what they considered ideal distribution of wealth in a society, they prefer inequality; though the ideal inequality is far less than the inequality that actually exists [43]. However, when people (adults and children) are asked to distribute resources in a small group, they prefer to divide resources equally, will show negative emotions at unequal distribution, and will even give up their own resources to punish others that are unwilling to distribute equally [11,16,21]. Unlike other rigged competition [39] that have measured physiological responses, the present experiment attempted to make the fairness or unfairness explicit by allowing both players to see the experience of their opponent. Therefore, the stress responses could be a reaction to the witnessed unfairness of the competition and less about inequality, which in our experiment was conflated. Nevertheless, while on some response variables we found that all the unfairly treated respondents showed higher stress (independent of whether they received hard or easy assignments), some results pointed to stronger effects on the 'disadvantaged' than for the 'advantaged' among the unfairly treated. The *Hard-Unfair* group (the 'disadvantaged' in terms of the inequality) were more negative about the fairness of the game than the *Easy-Unfair* group, implying that fairness concerns are inextricably linked to whether one benefits or suffers from the unfairness. Similarly, the disadvantaged displayed higher levels of distress and more negative emotion than the advantaged among the unfairly treated.

This research also contributes to the literature of those attempting to investigate larger social class and social status issues in laboratory settings. Cardel et al. [9] had students play a rigged game of monopoly giving some an advantage thereby putting them into a "high" social status while others were in a "low" social status position. Compared to the "high" status group, the "low" social status group had higher heart rates and reported a decreased feeling of pride and powerfulness after playing the game. The "low" status group then went on to consume more calories at a buffet lunch served after the game. Piff [47] and his colleges also used a rigged monopoly game and reported those with advantages showed body expressions of power, displayed rude behavior, expressed greater ability in the game and consumed more snacks available during the game.

4.1. Limitations and future directions

Economic inequality is an incredibly complex social construct and understandably difficult to represent in a meaningful way in a short laboratory experiment, so the current experimental protocol does lack some ecological validity. This design focused on income inequality and unfair conditions, but there are several forms of inequality that likely contribute to social, psychological and health problems such as gender, social, health, judicial, and environmental inequality. Future experimental designs might incorporate some of these components into the participants' experiences.

While this experiment's main focus was on stress responses to inequality, other questionnaires beyond the SSSQ could have been employed to better tease out the cause of the stress responses. For example, Gruenewald et al. [20] used the Affects Balance Scale on emotions and added questions about shame, self-esteem, and guilt in their experiment with the modified TSST. In addition, a similar design to the present research could also ask questions related other factors of experiencing inequality such as trust, prosocial behavior, and meritocracy.

The present experiment controlled well for any stress responses related to the difficulty of the problem but did not control for the effects of winning and losing. An ideal experimental design would be a $2 \times 2 \times 2$ design (fair, unfair; difficult, easy; win or lose), with the outcome in each group manipulated by the confederate opponent as in the present experiment. This design would be difficult for many practical reasons including the large sample size needed and the fact that one group would have easy problems compared to their opponent and would still lose and one would have difficult problems compared to their opponent and still win.

Future research in this area could more systematically investigate different demographics. The county of Fresno, California has a high concentrated poverty level, and most of the students come from the Central Valley of California. While we did not measure socio-economic status specifically, 74% of full-time undergraduates receive some need-based financial aid. Because inequality effects specifically people with different accumulated wealth or incomes, future studies could seek out participants from different socioeconomic status or racial background as a controlled variable.

While the present experiment did find support that competing in an unfair environment produces several stress responses, there are a number of ways that research on the physiological responses to inequality could go forward. First, more saliva samples should be taken and for a longer period to track the course of stress responses. Since the second saliva sample was taken at the end of the game, it actually represented stress levels approximately 20 min before the end. This was a time at the height of the game when we felt the participants would be most engaged in the game but also with sufficient experience as to the fairness of the competition. That said, the peak cortisol activity could have been missed. Second, testosterone could be evaluated in addition to cortisol. There is good evidence that there is an interaction between cortisol and testosterone in relationship to dominance, social status, economic decision making and aggression (for review see [40]). This might be particularly relevant if one tests individuals that come from different socio-economic statuses. There are also findings that individual differences in perceptions and attitudes affect and are affected by levels of testosterone and cortisol differently [39].

The delayed-matching-to-sample task in this experiment was used to ensure a better control over participant's experience and create a sense of working for reinforcement and to time-lock reactions to certain events. However, creating a task or game that simulates economic and social status (e.g., variation on Monopoly™ or Life™) maybe be more immersive into the experience, promote greater competition and provide greater external validity to the complex issue of economic inequality.

5. Conclusion

Issues as broad as income and wealth inequality are extremely complex social phenomena that involve inter-related factors that deal with class, race, location and social mobility. The correlation to high inequality and social and behavioral problems are similarly complex. The research linking economic inequality to stress-related problems can, however, benefit from an investigation of physiological and behavioral measures of stress in more controlled environments manipulating certain aspects of inequality like unfair conditions and social judgment. In the social sciences and epidemiology, a theoretical debate is centered around the question of whether inequality affects various outcomes simply because relevant resources are distributed more unequally (i.e. money, infrastructural support), or whether psychosocial processes are set in motion that create stress in unequal settings, implying that there is more to inequality than simply a distribution of resources. Our study has contributed to that debate by showing that inequality, and particularly unfair inequality, is related to stress, supporting the psychosocial theory of inequality effects. By imposing exogenous differences in advantage and disadvantage, our experiments point to causal effects of inequality on stress. While we did not find evidence of stress effects in all the stress measurements, the number of supports of the stress effects of inequality is larger than would have been expected on the capitalization of chance.

The current research could lead to more studies investigating aspects of race and socio-economic status on physiological and attitudinal changes when experiencing inequality in a lab setting. Perhaps experimental designs that more closely mirror more economically realistic scenarios could create greater external validity but also make the experiment more sensitive to stress measures. The finding that the *Unfair-Easy* group also experienced elevated stress in both cortisol and HRV scores may also suggest further research into the possibility that anyone, regardless of socioeconomic status, living in a society with greater economic inequality may be experiencing higher levels of stress – especially in those individuals that score higher on measures of empathy.

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Appendix A. Short Stress State Questionnaire

Please indicate how well each word describes how you feel at the moment.

Not at all = 1, A little bit = 2, Somewhat = 3, Very much = 4, Extremely = 5

1. Dissatisfied
2. Alert
3. Depressed
4. Sad
5. Active
6. Impatient
7. Annoyed
8. Angry
9. Irritated
10. Grouchy

Please indicate how true each statement is of your thoughts during the past ten minutes.

Not at all = 1, A little bit = 2, Somewhat = 3, Very much = 4, Extremely = 5

11. I am committed to attaining my performance goals.
12. I want to succeed on the task.
13. I am motivated to do the task.
14. I'm trying to figure myself out.
15. I'm reflecting about myself.
16. I'm daydreaming about myself.
17. I feel confident about my abilities.
18. I feel self-conscious.
19. I am worried about what other people will think of me.
20. I feel concerned about the impression I am making.
21. I expect to perform proficiently on this task.
22. Generally, I feel in control of things.
23. I thought about how others have done on this task.
24. I thought about how I would feel if I were told how I performed.

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