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Cortisol Meets GARP: The Effect of Stress on Economic Rationality[ζ]

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Abstract: Rationality is a fundamental pillar of Economics. It is however unclear if this assumption holds when decisions are made under stress. To answer this question, we design a laboratory experiment where we exogenously induce physiological stress in participants and test the consistency of their choices with economic rationality. We induce stress with the Cold Pressor test and measure it by assessing individuals' cortisol levels in saliva. Economic rationality is measured by the consistency of participants' choices with the Generalized Axiom of Revealed Preference (GARP). We find that participants exposed to the stress manipulation experience a significant increase in cortisol levels compared to those in the placebo group. However, differences in cortisol levels do not affect the consistency of choices with GARP. Our findings provide strong empirical support for the robustness of the economic rationality assumption.

Keywords: Economic Rationality; GARP; Physiological Stress; Cortisol.
JEL code: C90; C91; D01; D91

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1. Introduction

The concept of rationality holds a central role in modern economic theory (Sugden, 1991). Both in individual decision making and in strategic interactions, choices are considered rational when they maximize the decision maker's expected utility. Individuals' preferences and utility functions are, however, not directly observable. The Generalized Axiom of Revealed Preferences (GARP) sets conditions such that rationality can be judged by observing choices and choice sets. In particular, if choices satisfy the GARP, they can be explained as the outcome of the maximization of a well behaved utility function (Afriat, 1967).[3]

In this paper we test whether people are capable of making rational economic choices, i.e. choices consistent with GARP, when deciding under stress. Exposure to stress is a prominent feature of everyday life and it has been shown that stressors have a major influence upon mood, subjective well being, behavior, and health (Schneiderman et al., 2005). Stressful conditions interfere with deliberative processes and induce decision-makers to fall back on intuitive responses that require few cognitive resources (see Yu, 2016, and references therein). The use of such of intuitive thinking modes, as opposed to deliberative ones, increases cognitive biases (Kahneman and Egan, 2011) and reduces people's patience (Haushofer and Fehr, 2014). In this paper we investigate whether there is a causal effect of exogenously induced physiological stress on economic rationality.

There is a limited empirical literature testing the consistency of individuals' choices with GARP. Studies conducted with student samples from different universities (Cappelen et al., 2014; Choi et al., 2007a), among primary school kids (Harbaugh et al., 2001) and with a representative sample of the Dutch population (Choi et al., 2014), show that economic rationality varies markedly across different socio-demographic groups. Only a few studies have focused, however, on the vulnerability of GARP to contextual factors. Burghart et al. (2013) find that individuals with a high concentration of alcohol in blood are no less rational than sober individuals, but this evidence is purely correlational as the intake of alcoholic drinks was not randomized in this study. Castillo, Dickinson, and Petrie (2017) observe that consistency with GARP is not affected by whether individuals make decisions at a time that fits their (self-reported) circadian rhythm. The paper by Drichoutis and Nayga (2017) comes probably closest to ours. The authors study whether individuals' consistency with GARP is affected by the cognitive load induced by a memorizing task. They find that cognitive load has adverse effects on performance in reasoning tasks, but observe no effect of cognitive load on consistency with GARP. To the best of our knowledge, our study is the first providing a direct test of the causal effect of stress on economic rationality.

We conduct a laboratory experiment where participants are randomly assigned to two stress-related treatments: Stress and No Stress. In the Stress treatment, participants are administered the Cold Pressor Test (CPT), which requires to immerse ones' dominant hand into a bucket of ice-cold water (approximately 4 °C) for 90 seconds. The CPT is an effective way to induce stress, as the pain of enduring a physically unpleasant situation typically produces a sharp increase in participants' subjective stress as well as levels of cortisol, the human body's stress hormone (see, e.g., Porcelli and Delgado, 2009; Delaney et al., 2013; Schoofs et al., 2009). Participants in the No Stress treatment are asked to put their dominant hand in a bucket of lukewarm water (30 °C - 35 °C) for 90 seconds. Throughout the experiment, we measure

[3] A well behaved utility function is a continuous, concave and monotone function.

participants' stress levels by assessing the concentration of cortisol in saliva (e.g., Vining et al., 1983; Kirschbaum and Hellhammer, 1989). Cortisol reacts to both physical and psychological stressors through the autonomic nervous system and the hypothalamic–pituitary–adrenal axis (Dickerson and Kemeny, 2004) and it can be accurately measured in saliva.

After the experimental manipulation, in both treatments we measure the extent to which participants make choices consistent with GARP. Participants face fifty independent economic decision problems that involved allocating money between two accounts, knowing that the amount of money in each account is paid out with probability 50% (Choi et al. 2007a, 2007b, 2014). The decision problems thus require to make tradeoffs between risk and returns, a feature which is common to many decisions outside the laboratory. Each of the fifty decision problems differ in the rate at which participants could transfer money from one account to the other and in the total amount of money to allocate. These variations generate a rich dataset that we use to assess how consistent individuals' choices are with GARP (Choi et al. 2007a, 2007b, 2014).

We find that participants' choices in the experiment are largely consistent with economic rationality, and that this holds even when they are exposed to an exogenous stressor. The results are unchanged when accounting for the natural decline of cortisol over time. Furthermore, simulated choice behavior shows that our results cannot be attributed to participants choosing randomly. All the results are robust to different ways of quantifying violations of GARP.

The reminder of this paper is organized as follows. Section 2 describes the experimental design and section 3 describes how economic rationality is measured. Results are provided in section 4. Section 5 discusses the results and concludes.

2. Experimental Design

Within each experimental session, participants are randomly assigned either to the Stress treatment or to the No Stress treatment. The experiment includes two main parts: in the first part, we manipulate participants' stress levels, in the second part we measure whether participant's choices in an economic task are consistent with GARP.[4] Saliva samples are collected at different points in time to monitor how stress levels change during the experiment. In what follows we describe the experiment in detail.

Once participants arrived at the laboratory, they are asked to read and sign an informed consent form[5]. In order to avoid revealing the purpose of the experiment, participants receive information only about the condition to which they are assigned. Participants are allowed to stop participating in the experiment at any time, without providing any explanation to the experimenter.[6]

At the beginning of the experiment, participants provide the first saliva sample by spitting in a small tube. The concentration of cortisol in this sample provides a baseline value to later evaluate the effectiveness of our treatment manipulation.

[4] The experimental instructions are available in Appendix C.
[5] Our experimental protocol was approved by the Ethics Review Board of the School of Social and Behavioral Sciences of Tilburg University.
[6] Only one student did not sign the consent form and quitted the experiment.

Thereafter, participants are instructed to immerse their dominant hand, including the wrists, into a bucket of water for 90 seconds or, otherwise, until they could no longer tolerate it. Those in the Stress treatment, did so in a bucket with ice-cold water (4 °C – 6 °C). Participants in the No Stress treatment use a bucket with pleasantly warm water (30 °C - 35 °C). The difference between the Stress treatment and No Stress treatment solely lies in the temperature of the water. This procedure, called Cold Pressor Test, is a well-established way to increase cortisol levels without putting the respondent at risk. The physiological response to stress is not immediate and cortisol typically peaks 20 to 30 minutes after the cessation of the stressor (Weitzman et al., 1971; Pruessner et al., 1997; Selmaoui and Touitou, 2003; Debono et al., 2009). Therefore, we collect two saliva samples after the stress manipulation: one immediately after participants take the hand out of the bucket and one after 20 minutes, which is shortly before the start of the second part of the experiment. In order to avoid downtime until the start of second part of the experiment, participants answer a questionnaire on demographics, health habits, risk attitudes, personality traits and their general feelings. The only purpose of this questionnaire was to keep participants busy while waiting for the second part of the experiment. [7]

The second part of the experiment starts 20 minutes after the stress manipulation. First, we collect the third saliva sample of the experiment. Thereafter, we ask participants to make fifty choices involving economic trade-offs. In Section 3 we explain how these fifty choices are used to measure participants' degree of economic rationality defined by choice consistency with GARP. The economic decision problems are presented using the computerized graphic design developed by Choi et al. (2007a, 2007b, 2014). For each decision problem, participants have to allocate money between two accounts (labeled BLUE and RED respectively), knowing that the amount of money in each account is paid out with probability 50%. The experimental currency unit is points which are converted to Euro at the exchange rate of 8 points = 1 Euro.

Figure 1 provides an example of a typical decision problem. Participants have to choose a point (x, y) on the A-B budget line by clicking with the mouse on it. In this example, the expected payoff of choices decreases from A to B and hence choosing point A, i.e. allocating all the money into the RED account, yields the maximum expected payoff. However, since each account is paid out with probability 50%, participants who are risk averse may choose to allocate some money to the BLUE account to ensure themselves a minimum payoff. The slope of the A-B budget line determines how much money in the RED account a participant must give up to allocate one additional monetary unit to the BLUE account. Equal allocation to the two accounts, represented by point C on the 45-degree line, eliminates risk completely.[8] Furthermore, for any degree of risk aversion, all allocations on the C-B line are dominated by allocations on the A-C line.

[7] Except for self-reported pain, which was significantly higher in the Stress condition, we find no difference in the other answers between treatment groups.

[8] The 45-degree dashed line is not shown to participants during the experiment.

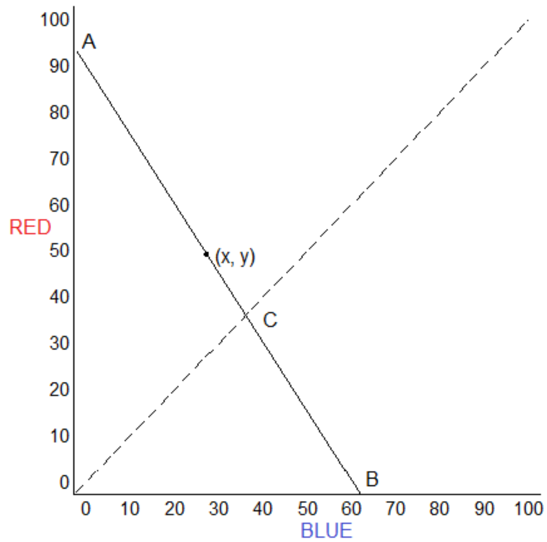

Figure 1. Example of a decision problem

Participants face fifty independent decision problems similar to that shown in Figure 1. Each decision problem differs in the slope of the A-B line and/or its intercepts. Specifically, each problem starts with the computer randomly selecting a budget line from the set of lines that intersect at least one of the axes at 50 or more points, and with no intercept exceeding 100 points. The budget lines selected for each subject in different decision problems are independent of each other and of the sets selected for any other subject in the experiment. At the end of the experiment, the computer program randomly selects one of the fifty choices for payment. Once all fifty choices are made, participants provide the last saliva sample and answer a short questionnaire. Saliva samples are frozen at -80° C after collection and subsequently sent to the laboratory of the Faculty of Social and Behavioral Sciences of the University of Amsterdam for cortisol measurement.

A total of 100 participants are recruited through an online system to participate in the experiment, 56 are assigned to the Stress treatment and 44 to the No Stress treatment. During the recruitment, participants are informed that they would not be allowed to do sports, smoke and take food and beverages at least an hour before the experiment, because such activities are known to potentially influence cortisol levels. Participants are also reminded about this before the experiment. The experiment is programmed in z-Tree (Fischbacher, 2007) and conducted in June 2017 at the CentERlab of Tilburg University, in the Netherlands. We conduct six experimental sessions, between twelve and twenty participants take part in each session.[9] Each session lasts approximately 90 minutes and the average earnings are 9.4 Euro. Participants receive their earnings via bank transfer at the end of the experiment.

3. Consistency of choices with GARP

In this section, we explain how individuals' degree of economic rationality is inferred from choice data. We first introduce the Critical Cost Efficiency Index, which provides a measure of the consistency of choices with GARP. We then describe the Unified Critical Cost Efficiency Index, which additionally requires that choices do not violate first order stochastic dominance.

[9] The sessions took place between 2:00 pm and 5:30 pm to reduce the impact of the diurnal cycle of cortisol (Weitzman et al., 1971; Pruessner et al., 1997; Selmaoui and Touitou, 2003; Debono et al., 2009).

3.1 The Critical Cost Efficiency Index

GARP demands that an individual's choices display a certain degree of consistency. For instance, when an individual chooses option x when faced with a choice between options x and y, it would be surprising if y is chosen when the set of alternatives includes x. The idea is that the initial choice of x reveals a predisposition to choose x over y that should be robust to the inclusion of different alternatives in the choice set (Mas-Colell et al., 1995). Stated more formally: *Let X, Y be distinct bundles of alternatives, each lying on a linear budget constraint. GARP requires that if X is (indirectly) revealed preferred to Y, then Y is not strictly directly revealed preferred to X, that is, X is not strictly within the budget set when Y is chosen.* (Varian, 1982)

GARP is of fundamental importance for economic theory because if, and only if, choices satisfy GARP they can be rationalized as the outcome of the maximization of a "well-behaved" utility function (Afriat, 1967). Empirically, it is likely that choice data violate GARP to some extent and it is thus necessary to have a criteria that evaluates to which degree the data are consistent with the axiom. The Critical Cost Efficiency Index (from now on CCEI) provides such a summary statistic, as it reflects the minimum adjustments required to eliminate all violations of GARP associated with the choice data (Afriat, 1972). The CCEI is defined between 0 and 1, where 1 corresponds to a fully rational set of choices. A CCEI of, for example, 0.80 indicates that on average budget sets need to be shifted by 20% to reconcile all choices with GARP.

The construction of the CCEI for a violation of GARP is illustrated in Figure 2. The figure shows a pair of choices, $\mathbf{x}^i$ and $\mathbf{x}^j$, in which $\mathbf{x}^i$ is directly revealed preferred to $\mathbf{x}^j$ and vice versa, so that GARP is violated. The choice inconsistency can be removed in two ways: the line going through bundle $\mathbf{x}^i$ is shifted from B to A, such that $\mathbf{x}^j$ is *directly revealed preferred* to $\mathbf{x}^i$. Alternatively, the line going through $\mathbf{x}^j$ is moved from D to C, in a way that $\mathbf{x}^i$ is *directly revealed preferred* to $\mathbf{x}^j$. The shift from D to C is the smallest perturbation necessary to restore consistency with GARP, and the CCEI for this choice is thus defined as C/D.

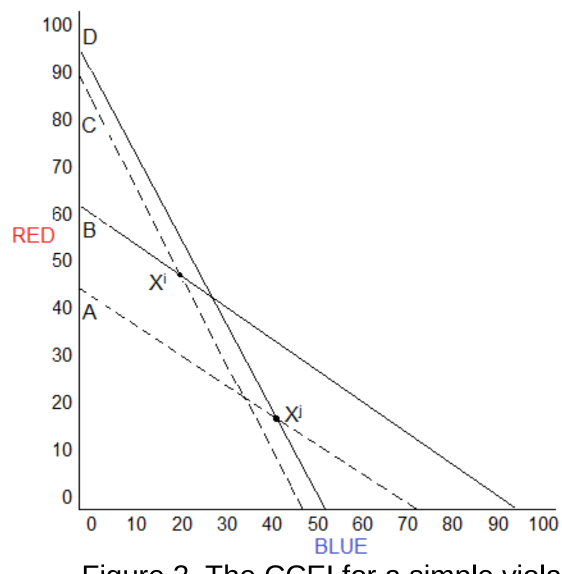

Figure 2. The CCEI for a simple violation of GARP

3.2 Unified Critical Cost Efficiency Index

Using CCEI as a measure of economic rationality has some limitations. Choices that violate first order stochastic dominance, and that hence do not maximize payoff in the experiment, may nevertheless be consistent with GARP. For instance, an individual who allocates all the money to the BLUE account in all the decision problems, is consistent with GARP although she is not maximizing her payoff when the BLUE account is more expensive than the RED. Since the CCEI score does not capture to which extent choices violate stochastic dominance, we also analyze choice data using the Unified Critical Cost Efficiency Index (UCCEI), which captures both violations of GARP and of stochastic dominance (Choi et al., 2014).

The UCCEI is constructed by adding all mirror image allocations to the dataset. These are created by reversing the BLUE and RED prices and the associated allocation in each decision problem, while the payoff from the actual and mirror image allocations is the same. In this augmented dataset, stochastically dominated choices in combination with their mirror image violate GARP. Differently, choices that do not violate stochastic dominance do not violate GARP when compared to their mirror image. The UCCEI is thus equivalent to the CCEI calculated on an enlarged database, and by construction it is at most as large as the CCEI associated to the actual data.

Figure 3 illustrates how the UCCEI is constructed. In the figure, line AB represents a decision problem where the RED account is cheaper than the BLUE. Any decision to allocate fewer points to the cheaper account, that is a choice on the B-C line, violates stochastic dominance. Assuming that allocation D (x_1, x_2) is observed, we can construct the mirror image allocation D' (x_2, x_1). The pair of choices D and D' violate GARP, and thus decrease the CCEI score. Any choice along A-C does not violate stochastic dominance, and hence any pair of choices on A-C and their mirror image does not violate GARP.

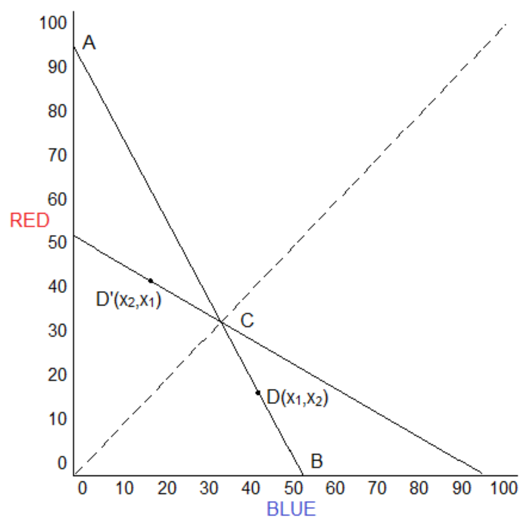

Figure 3. A violation of stochastic dominance

4. Results

4.1 Cortisol Response to Stress

Figure 4 shows average cortisol levels standardized by individual baseline values. Since baseline cortisol levels typically vary substantially across individuals, standardization helps visualizing the effectiveness of the stress manipulation. Recall that sample 1 is collected at the beginning of the experiment, sample 2 is taken right after the stress manipulation, sample 3 is taken 20 minutes after it and sample 4 is collected after participants finished making all economic choices.

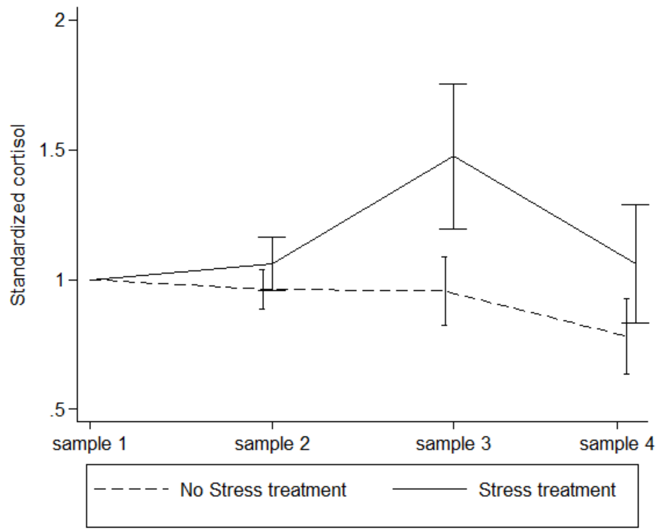

Figure 4: Standardized cortisol levels with 95% confidence intervals.

Figure 4 shows that our treatment manipulation is effective: cortisol increases on average by 50% in sample 3 compared to sample 1 in the Stress treatment. In contrast, participants in No Stress experience a slight decrease in cortisol during the experiment.

We test whether cortisol levels change significantly *within* treatments using the Wilcoxon matched-pairs signed-rank test. In the Stress treatment, the cortisol level in sample 3 is significantly higher than in all the other samples (p = 0.00 in pair-wise comparisons). In particular, 20 minutes after the stressor, cortisol increases by 47 percent compared to the standardized baseline[10]. This is similar to the percentage increase observed in other studies (e.g. 50 percent in Schwabe and Wolf, 2009, 43 percent in Sharpley et al., 2009 and 44 percent in Buser et al., 2017). There are no significant differences in cortisol levels between sample 1 and sample 2 (p = 0.68), sample 1 and sample 4 (p = 0.24), sample 2 and sample 4 (p = 0.43). In the No Stress treatment, cortisol levels show a decreasing trend: from sample 1 to sample 2 (p = 0.05), from sample 2 to sample 3 (p =0.26), from sample 3 to sample 4 (p = 0.00).

In order to test whether cortisol concentrations differ *between* the Stress and the No-Stress treatment, we use the two-sample Wilcoxon rank-sum test. Cortisol concentration in sample 2 is similar in the two treatments (p = 0.12). In contrast, cortisol levels measured 20 minutes after the stress manipulation are significantly higher in the Stress than in the No Stress treatment (p = 0.00). The difference in cortisol levels between treatments persisted after subjects completed the economic decision problems (p = 0.09).

4.2 Economic Rationality

Figure 5 shows the average CCEI and 95 percent confidence intervals in the two treatments. The mean CCEI of participants in the No Stress treatment is 0.94, which is in line with the CCEI estimated for other university students samples.[11] The average CCEI in the Stress treatment is

[10] A percentage baseline-to-peak increase of 15.5% is able to effectively distinguish between cortisol responders and non-responders to stressor (Miller et al., 2013).

[11] The average CCEI score of students at UC Berkeley is 0.95 (Cappelen et al., 2014) and it is 0.93 among students at the Agricultural University of Athens, Greece (Drichoutis and Nayga, 2017).

0.95, which is not statistically different from the average CCEI in the No Stress treatment (Wilcoxon rank-sum test p = 0.64).

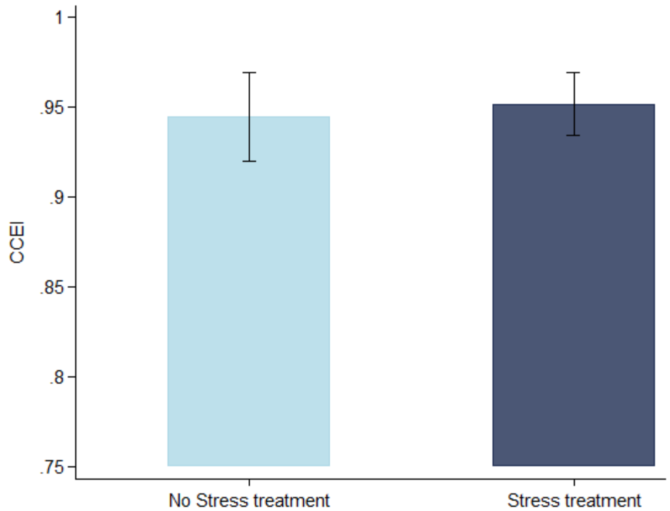

Figure 5. CCEI scores and 95% C.I. by treatment

Figure 6 shows the distribution of the CCEI by treatment. The figure shows that although most participants in our experiment are not fully rational, their choice behavior is very close to satisfying GARP even under stressful conditions. A Kolmogorov-Smirnov test confirms that the CCEI is similarly distributed in the two treatments (p = 0.98). Taken together, these results thus show that stressful conditions do not have an impact on participants' ability to make rational economic choices.[12]

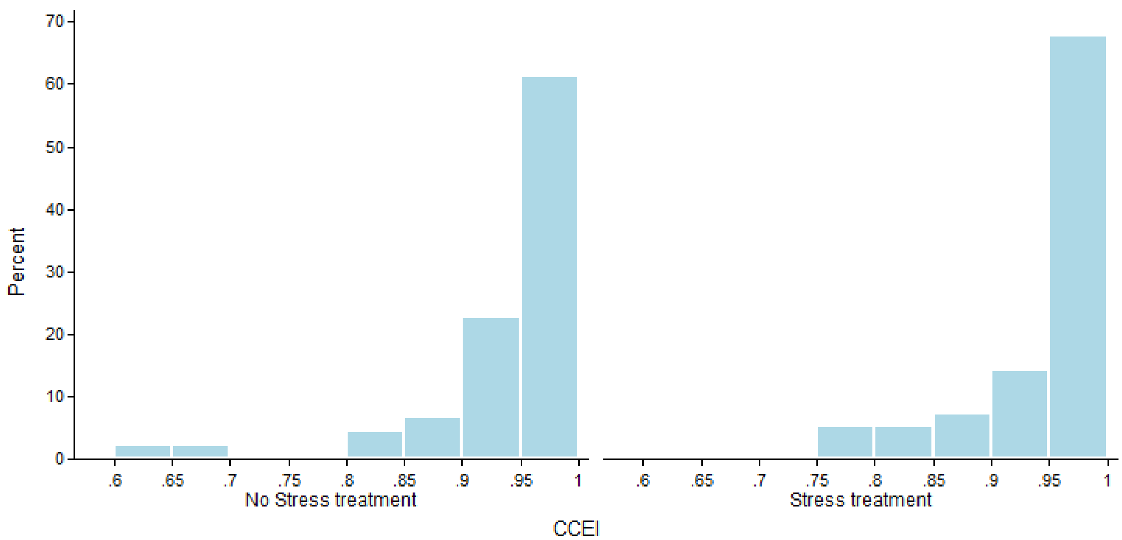

Figure 6. Distribution of CCEI scores by treatment

The high observed consistency of choices raises the question of whether satisfying GARP is a rather undemanding requirement. To put this conjecture to test, we generate two samples of

[12] All our results are robust to controlling for self-reported chronic stress measured at baseline (Perceived Stress Scale, Cohen et al., 1994). Results are available upon request.

respectively 100 and 25.000 simulated individuals that choose randomly in 50 decision problems of the type implemented in the experiment. Figure 7 shows the distribution of the CCEI scores in our experiment and in the two simulated samples. Clearly, economic rationality is much higher among participants in our experiment than in the simulated samples. In both simulated samples, the average CCEI is 0.60 and no subjects have a CCEI above 0.95. It is therefore very unlikely that the degree of economic rationality observed in our experiment is attributable to random choice behavior.

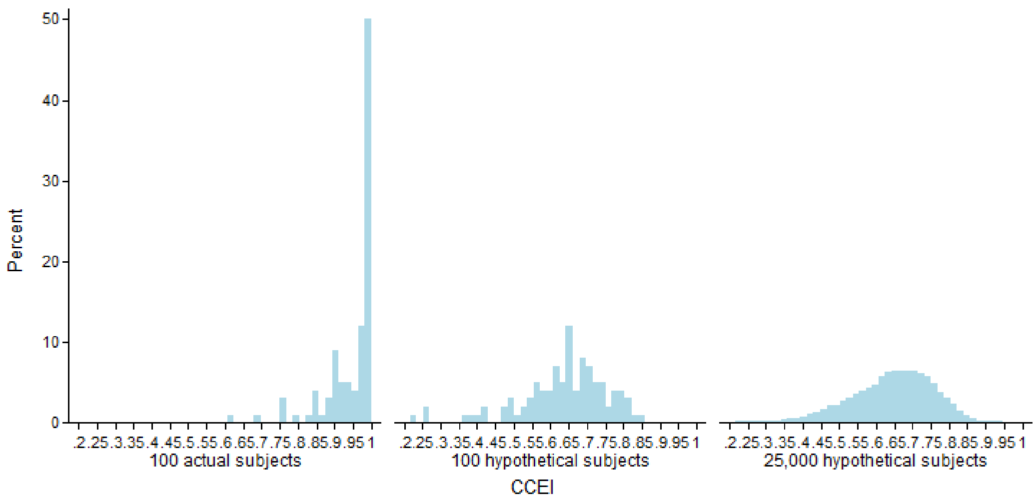

Figure 7. The distribution of CCEI of actual data and hypothetical subjects

Note that the conclusion that stress does not reduce economic rationality is most likely not due to lack of statistical power. Our data show that if anything, stress slightly increases consistency with rationality (CCEI = 0.94 in No Stress treatment, CCEI = 0.95 in Stress treatment) rather than reducing it. Hence, even if we were to enlarge the sample size there would be no a-priori reason to expect that the direction of the result would change.[13]

Next, we consider whether stress affects economic rationality when the latter takes also violations of first order stochastic dominance into account. Figure 8 shows the average UCCEI and CCEI score in both treatments. As expected, the UCCEI is lower than the CCEI, and it is 0.88 in the No Stress treatment, and it is 0.90 in the Stress treatment. The indexes are not significantly different in the two treatments (Wilcoxon rank-sum test $p = 0.32$). In Appendix B we show that our results are also robust to several alternative indexes of economic rationality.

[13] A power analysis shows that if the effect size is above 0.6, our sample size is able to detect the association of the stress levels with the consistency of the economic choices (see Appendix A, Table A).

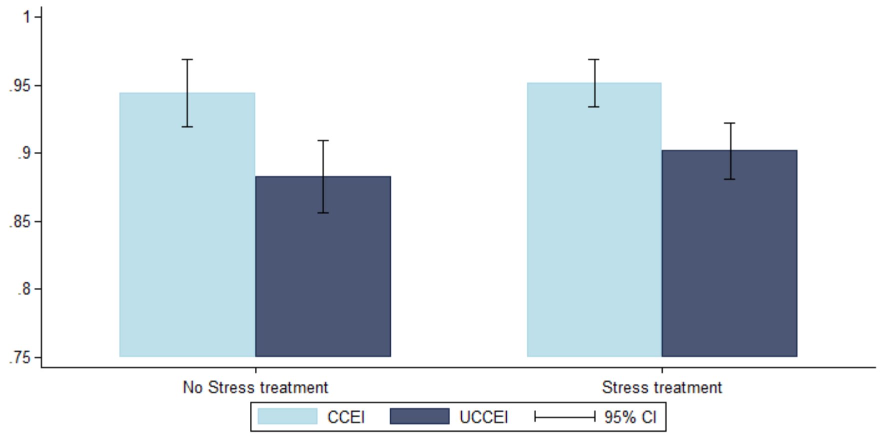

Figure 8. Average CCEI and UCCEI scores

At last, we analyze whether economic rationality responded to the gradual decrease of cortisol over the time during which economic decisions were taken. Does rationality increase with the reduction of cortisol in the body over time? To answer this question, we divide the 50 economic choices into 5 groups of 10 choices and compute the CCEI score for each group separately. As Fig. 9 shows, we do not find statistically significant differences between treatments in any of the groups (Wilcoxon rank-sum test p = 0.75, 0.62, 0.78 and 0.46 respectively). We also do not observe any significant difference between treatments when dividing the economic choices in two groups of 25 choices each (Wilcoxon rank-sum test p = 0.27, 0.84 respectively). We thus conclude that economic rationality is quite stable with respect to the different levels of cortisol experienced during the experiment.

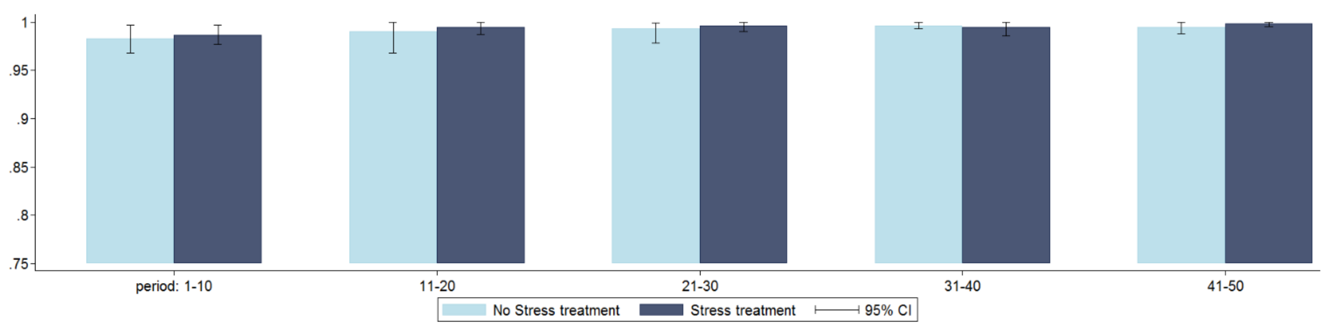

Figure 9. CCEI scores calculated over 10 decisions by treatment

5. Discussion and Conclusions

Over the past four decades, individual rationality has been criticized for being a rather unrealistic assumption in economics. This criticism, when borne out by scientific evidence, precludes most economic models from making valid predictions. More importantly, this criticism constitutes a challenge for welfare and policy analysis, as policy makers cannot base their decisions on models whose assumptions are systematically violated by decision makers. In light of this, scholars have proposed alternative positive and normative frameworks that encompass non-standard models of choice (e.g. Bernheim, 2009; Manzini and Mariotti, 2014) or have advocated to completely dismiss welfare analysis based on observed choice behavior (Sen, 1985; Sugden, 2004; Layard, 2005).

This paper takes a step back on this debate and experimentally tests whether the rationality assumption indeed breaks down in a context in which individuals make economic decisions under physiological stress. This context is especially relevant because it has been shown that when making decisions in stressful situations, which are ubiquitous in everyday life, fast and effortless heuristics may dominate over demanding deliberation (Yu, 2016). We show that the main rationality axiom used in economics survives well under stress. The choices of participants who are stressed out are highly consistent with the main rationality axiom used in economics, and are not significantly different from the choices of participants in a control group. These results are robust to several alternative measures of economic rationality.

Before discussing the implications of our results, some considerations on our identification strategy are due. First, we note that GARP is not a trivial axiom to satisfy. Studies on GARP, including ours, test the pair-wise consistency of choices in a large number of decision problems, and we show that random behavior would dramatically decrease consistency. The heterogeneity in consistency observed across countries and socio-economic conditions (see, e.g., Choi et al., 2014 and Choi et al., 2007a) further indicates that GARP is not a trivial axiom to satisfy. Second, the decision problems participants face in the laboratory resemble typical trade-offs between risk and expected returns that people face in many economic decisions in real life. Third, while the population of university students is not representative of the general population, there is no a priory reason to think that stress would affect students rationality in a different way than non-students. Moreover, in the OECD countries, 43% of the population has some type of tertiary education and hence our results speak about a non-negligible group of people.[14]

The results reported in this paper have important general implications. This paper sheds light on the discussion of the concept of rationality and its robustness (Sugden, 1991; Manzini and Mariotti, 2014). In line with other existing studies (e.g. Drichoutis and Nayga, 2017), we show that rationality defined as consistency of choices is a robust assumption. This however, does not imply that people always maximize their payoff. The observed difference between the CCEI and UCCEI scores shows that some participants, although consistent, violated first order stochastic dominance and hence did not maximize their earnings in the experiment. More generally, a decision maker who systematically fails to fully internalize the consequences of his choices may nevertheless satisfy GARP. This discrepancy between consistency of choices and utility maximization is taken up for example, in models of addiction, projection bias, cognitive biases and overconfidence (see Dalton and Ghosal, 2018).

Overall, we see this paper as an initial step into a broader research agenda that tests the assumption of economic rationality under different conditions and with different type of decision making problems. For example, we have induced temporary, physiological stress in participants, but it would also be interesting to test whether chronic stress has different effects (Riis-Vestergaard et al., 2017). Chronic stress is especially common among people with low socio-economic conditions, and a growing literature shows that decision making in such groups is often short-sighted and more prone to biases (Haushofer and Fehr, 2014). In this study we focus on decision making under risk, but it is not clear whether consistency with GARP would also

[14] Source: OECD (2018), Population with tertiary education (indicator). doi: 10.1787/0b8f90e9-en (Accessed on 03 June 2018). https://data.oecd.org/eduatt/population-with-tertiary-education.htm

hold when decisions involve ambiguous prospects. There is ample evidence that phenomena like probability distortions and ambiguity aversion are common in decisions problems under uncertainty (Wakker, 2010); studying consistency with GARP in these environments is an interesting avenue for future research.

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