Charles University in Prague

Faculty of Social Sciences
Institute of Economic Studies

DISSERTATION

Essays on Decision Making under Stress

Author: **PhDr. Lubomír Cingl**

Advisor: **PhDr. Michal Bauer, Ph.D.**

Academic Year: **2015/2016**

Acknowledgments

I am very grateful to all colleagues and friends who helped me during my long studies so that this PhD thesis could become reality. I would especially like to express thanks to my supervisor Michal Bauer for all his time and valuable pieces of advice that allowed me to proceed to this final stage and his support of me in my rather unorthodox experimental methodology. Apart from my colleagues at IES I would also like to thank to CERGE-EI students, especially my co-author Jana Cahlíková, and their faculty members Peter Katuščák, Fabio Miccheluci, Filip Pertold and others for frequent discussions and consultations; Joseph Henrich, Ara Norenzayan and many others for making it possible to spend unforgettable four months as a visiting researcher at the University of British Columbia. Concerning Chapter 3, I want express my thanks to Mathias Wibral, Frances Chen, Bertil Tungodden, Peter Martinsson, the editor David Cooper and two anonymous referees of the journal Experimental Economics where the article was published, and the audience at the 2013 Florence Workshop on Behavioral and Experimental Economics for their valuable comments; Bernadette von Dawans and Clemens Kirschbaum for providing all materials and helpful advice for the execution of the TSST-G procedure. Research presented in Chapter 4 greatly benefited from consultations with Steffen Huck, Andrew Schotter, Arno Riedl, Matthias Sutter, prof. Clemens Kirschbaum, John List, Bertil Tungodden, Debrah Meloso, Peter Katuščák, Tereza Nekovářová, Barbara Pertold-Gebicka, Jozef Baruník and the audience at the Norwegian School of Economics.

Last but not least, I would like to gratefully acknowledge financial support. The funds for the experiment in Chapter 2 were provided by Charles University under GAUK grant No. 59110 and by J&T Bank, a.s., while the research in the remaining two chapters was supported by GAUK grant No. 4046/11. The whole research was also considerably supported by the chance to use the heart-rate monitors of the Faculty of Physical Education and Sports, allowed by Dr. Josef Horčic. The chance to use the Laboratory of Experimental Economics in Prague is gratefully acknowledged. I also thank Miroslav Zajíček, Klára Kalíšková, Lukáš Rečka, Tomáš Miklánek, Ján Pálguta, Michala Týčová, Ian Levely, Dagmar Straková, Václav Korbel, Jane Simpson and Zuzana Cahlíková for their valuable assistance during data collection. All errors remaining in this text are the responsibility of the author.

Bibliographic record

Cingl, Lubomír: *Essays on Decision Making under Stress*. Dissertation thesis. Charles University in Prague, Faculty of Social Sciences, Institute of Economic Studies. January 2016, pages 150. Advisor: PhDr. Michal Bauer, Ph.D.

Contents

Abstract

This dissertation comprises three thematically connected experimental studies of human behavior under non-standard conditions: time-pressure and stress. In the Introduction section I present the argument for why it is important for economists to recognize stress research as a valid part of the research in economics and how it can contribute to the growing knowledge of human behavior in general, including several examples from the literature. The first paper presented in Chapter 2 examines the effect of time pressure on the individual propensity to herd, while the remaining two papers examine the effect of acute stress on risk-preferences and herding behavior, respectively. Herding behavior is a very important phenomenon in human decision making since social influence is very frequent in our lives and economic decisions: consider traders in financial markets, wait-and-see investors, but also purchase behavior due to fads, fashion and top-ten lists. Risk preferences are another essential factor which determines many important economic outcomes, and the assumption of their stability is a building block of many economic theories.

The first article investigates the effect of time pressure on herding behavior. To do so, an experiment was run where subjects solved a cognitively simple task under three levels of time pressure in a within-subject design. After having performed first alone, they were then allowed to look at the decisions of others and according to that, change their own decision, which was taken as an indicator of herding behavior. The main finding is that people did frequently change their original decisions, but the rate of doing so was not different under the different levels of time pressure. Nevertheless, other variables implicitly associated with time pressure were significant as predictors of herding behavior, such as the time spent on the screen showing the decisions of others, reported subjective levels of stress and the increase in heart rate during the solution of the task. The fact that the increased heart-rate during the solution of the task correlated with the subjective levels of stress suggests time pressure can be used as a mild stressor. However heart rate is a rather crude measure of physiological stress as it can rise due to other factors, such as effort or simple movement, and not stress, and as a single measure of stress is not satisfactory. We also observe an interesting correlation between heart-rate increases and risk-preferences of men which suggests that there may be a relationship between physiological stress and risk-taking behavior.

In the second article we report on an experiment where we exposed 151 subjects to an efficient laboratory stress-inducing or a control procedure - the Trier Social Stress Test for Groups - in order to find the causal effect of stress on individual risk-attitudes. As a risk measure we used a standard externally validated multiple-price list method. Using three different measures, we first show that the subjects in the treatment-stressed group were both physiologically and psychologically stressed: their heart-rate and cortisol levels increased while they felt worse and more nervous compared to the baseline and to the control group. Our main result is that for men, the exposure to a stressor (intention-to-treat effect, ITT) and the exogenously induced psychosocial stress (the average treatment effect on the treated, ATT) significantly increase risk aversion when controlling for their personal characteristics. The estimated treatment difference in certainty equivalents is equivalent to 69% (ITT) and 89% (ATT) of the gender-difference in the control group. The effect on women goes in the same direction, but is weaker and insignificant.

The third article examines whether stress causes differences in individual herding behavior. To impose stress we employ the same methodology as in the second article, the Trier Social Stress Test for Groups, on a sample of 140 subjects and show using the same three measures as in the previous chapter (heart-rate, cortisol and mood questionnaire) that subjects were indeed stressed. Herding behavior was measured in a Bayesian updating task that allowed for full control over the information provided to subjects either from private or public sources. The main result is that herding behavior as a relative weight of public signals in individual decision making does not change under stress. Apart from that, the weight of private signals and the precision of the stated probabilities were also not different between the treatment and control groups, even after controlling for personality characteristics and the subjects' psychological measure of conformity. On the other hand, we observe updating behavior comparable with other studies, including clusters of stated probabilities on multiples of five and conservatism.

List of Tables

List of Figures

1 Chapter One: Introduction

The three research papers presented in the remaining chapters examine individual economic behavior under stress and time pressure. At the onset of my dissertation research I was concerned about the effect of time pressure on individual propensity to conform to the opinion of others as this can be observed in the real world e.g. during panics, bank-runs and crashes in the stock and financial markets. To examine whether people really do conform and copy the behavior of others under stress, I carried out the first experiment where subjects could change their mind after observing the choices of others and revise their original decisions, and they were supposed to be stressed using different levels of time pressure. Subjects however did not change their decisions more frequently under increased time pressure, but subjective stress and heart-rate increase were positively associated with the probability of the revision of their decisions. The link between time pressure and stress was found to be rather weak and heart-rate was found to be, according to the literature, insufficient as the only measure of physiological stress. Therefore, the findings could not be interpreted as the causal effects of stress but left this question open. Apart from that, an interesting correlation between risk-preferences and increases in heart-rate was found, suggesting a relationship between physiological stress and risk-preferences. The results of this research were published in 2013 in the journal Prague Economic Papers.

The results of the first experiment inspired me to conduct another experiment, the results of which are presented in the remaining two articles that investigate the causal effect of stress on risk-preferences (Chapter 3) and herding behavior (Chapter 4). I then spent a long time preparing an improved experimental design that was almost sure to introduce an acute stress reaction in the majority of subjects and I explored ways to most effectively measure it. The procedure finally applied is well known in the psychology literature and has been in use since 1993: the Trier Social Stress Test. It was found to be the most efficient laboratory stressor in terms of the increases in cortisol it elicits and in 2011 a modification was introduced that allowed its application in groups, which is an essential feature for the possibility of its use in the design of economic experiments (Dickerson & Kemeny, 2004; Kirschbaum, Pirke, & Hellhammer, 1993; von Dawans, Kirschbaum, & Heinrichs, 2011). The authors of this procedure Clemens Kirschbaum and Bernadette von Dawans were very helpful in advising me how to properly use it and how to avoid common mistakes in measuring the common indicators of stress.

I was aware that this methodology is new in economics and it would be risky conducting experiments in a less explored area and publishing the results in economic journals, because no experimental work on stress effects on economic behavior had been published in an economic journal to date. Nevertheless, I decided to take that risk and proceed. The experiment gave rise to two papers, one has been published in the journal Experimental Economics (Chapter 3) and the other (Chapter 4) is awaiting submission. After its presentation at various conferences, we generally received very good feedback on this methodology and thus felt encouraged to proceed with the work. Therefore we conducted also other experiments that are not reported in this dissertation, but also received good feedback at prestigious economic conferences, like American Economic Association and Economic Science Association meetings. Overall, stress research is now coming on the radar of economists, also thanks to the contributions that are presented in this dissertation. However, most economists are not well informed about what stress actually is, what impacts it has and, most of all, why is it actually important to study it. In the next pages I therefore first argue why economists should care about stress, and summarize the most important aspects of stress with focus on published research on economic behavior under stress.

Why is it important for economists to study stress?

In contemporary society, stress is present in many aspects of human life, including economic choices. It is ubiquitous – people of almost all professions have to deal with more or less severe stress that stems from their jobs and family environment; and almost all people have to face difficult and potentially stressful decisions that imply serious consequences for their future lives, like asking for promotions and attending job-interviews. Just consider stress that is documented to arise from everyday time constraints (Buckert, Oechssler, & Schwieren, 2014; Lundberg, 1993) work conditions including being under constant pressure, lack of health-insurance, shift-work, job insecurity, unemployment, long working hours, low job control (Goh, Pfeffer, & Zenios, 2015) unequal gender composition (Elwér, Harryson, Bolin, & Hammarström, 2013) unfair treatment (Feige, 2005), competitive environment (Fletcher, Major, & Davis, 2008), and poverty (Haushofer & Fehr, 2014; Haushofer & Shapiro, 2013; Chemin, Laat, & Haushofer, 2013).

The adverse health-effects and associated costs of stress have already been subjected to a substantial amount of research (Ganster & Rosen, 2013); they are significant: let us mention alone that the disability caused by stress is estimated to be as great as the disability caused by workplace accidents or common diseases like hypertension and diabetes (Kalia, 2002). Stress currently ranks the second most commonly reported work-related health problem in Europe while it causes almost a half of all working days lost in Europe (Eurofound & EU-OSHA, 2014). In the USA, the 10 most common workplace stressors are responsible for 120,000 deaths p.a. and approximately 5-8% of annual health-care costs could be saved by proper management of the workforce (Goh et al., 2015). Moreover, since stress is often accompanied by negative emotions, many people try to avoid stressful situations completely. Unfortunately, stressful situations are also often situations involving high stakes, and their abandonment thus reduces the future prospects of an individual (e.g. women may shy away from competitive environments as in Niederle & Vesterlund, 2007).

The stress-generated health inequalities imply also socio-economic outcomes; stress can thus operate as a major source of social inequalities (Aizer & Currie, 2014; Currie, 2011). Social inequality and everyday lack of resources for survival, poverty, act as a persistent chronic stressor that may bias the decision making of the poor toward the short-sighted, less efficient decisions that make it harder to escape their poverty (Haushofer & Fehr, 2014). Moreover, children raised in a stressful environment have worse cognitive abilities than children from a more normal environment (Blair et al., 2011), which further strengthens the vicious circle of poverty. Apart from that, acute stress increases the probability of the relapse of risky behavior, such as smoking, drug abuse or alcoholism which generate further costs for society (Arnsten, 2009; Sinha, 2001, 2008).

Stress is a complex individual physiological, psychological and usually also a behavioral response that evolved in order to help animals minimize the dangerous effects of an uncontrollable perceived threat (a stressor) to their major goals (Dickerson & Kemeny, 2004). The acute stress reaction stimulates the body, including the responses of the nervous, hormonal and metabolic systems. The long-term processes that are not immediately necessary, like digestion, growth and immunity, are temporarily suppressed in favor of an immediate inflow of energy and enhancement of short-term coping strategies. This is certainly not sustainable in the long term: The body sooner or later depletes its energy reserves and the stimulating effects thus cease, but the important long-term functions remain disrupted which may eventually result in health problems (McEwen, 2012). The behavioral effects of short-term and long-term stress may thus seriously differ. Generally speaking, the individual stress response is a complicated process and it is hard to generalize whether the behavioral effects are helpful or harmful for the decision-maker.

The effects of stress may differ with respect to the type of stressor. Stress typically arises when an organism is threatened on life and its body is exposed to non-standard conditions. Such stress may thus be termed the *physical stress* with stressors being all sorts of life-threatening circumstances, including blood-loss, electric shocks, infection, pain, food and sleep deprivation, dental procedures, hyper or hypothermia and drug withdrawal states. *Psychological (mental) stressors* do not threaten the physical survival, but are connected with important goal in one's social, emotional or personal life. *Emotional* stressors then include interpersonal conflict, loss of relationship, death in family and loss of a child, while personal psychological stressors can be daily hassle, meeting deadlines, traffic jams or interpersonal conflicts (Sapolsky, Romero, & Munck, 2000; Sinha, 2008). A prominent type of a psychological stressor is the *psycho-social stressor*. Since human is a social animal, it possesses also a "social-self", which reflects one's social value, esteem, status and is mostly based on individual perception of self-worth. Threat to preserving such social self has been shown to induce similar stress reaction as a threat to physical survival. Generally, the aforementioned types of stress differ in terms of physiological and psychological response. (Dickerson & Kemeny, 2004). Behaviorally, the effects may also differ: as noted below, Haushofer & Jang (2015) compare the effects of three different types of stressors on temporal discounting: social, physical and an economic game. They find opposing effects of the social stressor and the economic game, while the physical stressor has no effect.

Based on a meta-study of 208 laboratory studies, the Trier Social Stress Test (TSST; Kirschbaum et al., 1993; von Dawans et al., 2011) used in Chapter 2 and Chapter 3 has been considered the most efficient laboratory stressor in terms of the magnitude of cortisol increase it stimulates (Dickerson & Kemeny, 2004). Moreover, the type of stress it induces in subjects, the acute psycho-social stress, is the most common type of stress experienced by the general public in the workplace (Ganster & Rosen, 2013; Goh et al., 2015) compared to other types of stressors. A different typical laboratory stressor that induces physical stress is the Cold Pressor Test: the procedure consists of putting the non-dominant hand or one foot into ice-cold water (0-4ˇC) for a period of 5 minutes (Blandini, Martignoni, Sances, Bono, & Nappi, 1995; Hines & Brown, 1936; Schwabe, Dalm, Schächinger, & Oitzl, 2008). However, e.g. the result of Lighthall et al. (2009) show this procedure may be problematic: the male treated subjects did not have the cortisol change significantly different to the control group and the female subjects showed only a mild increase. Apart from the mentioned procedures, commonly used are also time pressure (Buckert, Oechssler, et al., 2014), information about future performing in TSST protocol (Engert et al., 2013), and mere watching other participant undergoing TSST (Engert, Plessow, Miller, Kirschbaum, & Singer, 2014). Also combinations of psychological and physical stressors have been used, e.g. Cold Pressor Test in combination with mental arithmetic task and social evaluation (Dickerson & Kemeny, 2004).

The current frontier in the stress research is to use one type of a stressor and study its effects on one type of behavior. The next steps will be to focus on the robustness of the behavioral results with respect to various changes in the protocol, such as the change of the type of stressor, the timing of the intervention and behavioral task, the age of the subjects, culturally specific reaction to stressors etc. In particular, the robustness of the behavioral results with respect to the type of stressor has been studied consistently only once, particularly in the domain of time-preferences (Haushofer & Jang 2015). Thus, investigating the effects of a wider variety of stressors on risk-preferences and herding behavior would certainly increase the scientific value and the external validity of this thesis, but it is not within its scope and rather suggested for future research.

Another issue worth discussing is the relative importance of the monetary stakes that subjects disposed with during the experiments in this thesis: the amounts were typical for the experiments in the area and not too much smaller than the stakes used in comparable experiment in other countries, when adjusted for the purchasing power parity. However, the intrinsic hardship of the situation created by the stress procedure may have prevailed over the extrinsic concern over money (Skořepa, 2010) and the subjects may have not cared about their decisions enough. Thus what we observe is probably only a lower bound of the effects of stress on the particular type of behavior, and it is an interesting area for a future research to assess the effects of stake size, as has been the case with other phenomena in behavioral economics (e.g. Ultimatum game; Andersen, Ertaç, Gneezy, Hoffman, & List, 2011), since in many "choking-under-pressure" situations people get stressed because they deal with big amounts of money (Dohmen, 2008).

The line of stress research has implications also for economic theory: consider that most of the theories in economics and finance assume that preferences are quite stable over time, and take this assumption as one of the building blocks that ultimately generate elegant economic models. Several studies have shown that this is not the case (Guiso, Sapienza, & Zingales, 2013; Kandasamy et al., 2014) and stress is one of the circumstances when individual preferences temporarily or permanently shift. Let us highlight the role of risk-preferences that are one of the most studied behaviors under acute stress: in Chapter 3 we show that risk-preferences do change due to exposure to acute stress, in particular people (mostly men) become more risk-averse. This finding draws important implications: since most of the traders of various boards of exchange are men and they react to the major events in their markets with moderate stress, the higher risk-aversion generated by stress may exaggerate their defensive trading behavior during market crises thus deepening the bottom of economic cycles (Coates & Herbert, 2008). Similar evidence is provided by priming of a bust scenario, which may be indirectly connected with stress (Cohn, Engelmann, Fehr, & Maréchal, 2015).

The behavioral effects of stress

To illustrate that the area of research in this dissertation is already advancing, I would like to mention a few studies on the effects of stress on economic behavior. Generally speaking, the early (Hartley & Adams, 1974; Hockey, 1970) as well as recent studies (Leder, Häusser, & Mojzisch, 2013, 2015; Schwabe & Wolf, 2009) of human behavior under stress reveal that acute stress is detrimental to performance in tasks that are demanding on complex, strategic and flexible thinking, but enhances performance in simple or well-practiced tasks since people stick to habitual responses and well-known practices. The neurological evidence shows that this behavioral change stems from the effects of stress on the prefrontal cortex, which is the part of the brain responsible for long-term oriented, rational behavior (McEwen, 2012). Let us highlight three areas of economic decision making investigated under acute stress: risk-, time- and social preferences.

The area of *risk-preferences* has been quite extensively investigated but overall there have not been any conclusive results, which may be due to the fact that the methodology was very heterogeneous. There have been a variety of methods used to elicit risk-preferences, a variety of stress-inducing procedures, and other methodological factors that may have caused the different results. Some studies point to increased risk-taking under stress (Putman, Antypa, & Crysovergi, 2010 for high rewards; Starcke, Wolf, Markowitsch, & Brand, 2008), others find decisions to be more risky under stress for men, but less risky for women (Lighthall, Mather, & Gorlick, 2009; van den Bos, Harteveld, & Stoop, 2009), or conclude on no change in risk preferences under stress (von Dawans et al., 2012). Porcelli and Delgado (2009) obtain increased risk-aversion for gain domains, but increased risk-seeking for loss domains; Pabst, Brand, & Wolf (2013b) find less risky behavior of stressed groups for loss domains but not gain domains; Buckert, Schwieren, Kudielka, & Fiebach (2014) observe more risk-seeking in gain domains and no difference in loss domains (refer to Table 1-1 for an overview).

The mentioned studies have to be treated with care. Some of the existing studies on risk attitudes under stress focus rather on the correlations of stress and risk preferences and not on the causal effect of stress (Buckert, Schwieren, et al., 2014; van den Bos et al., 2009). In these studies the results from behavioral tasks are not analyzed according to the random assignment to treatment, but rather by division of the treatment group according to the cortisol reaction into high-cortisol and low-cortisol responders. Showing a difference between high-cortisol and low-cortisol responders in the treatment group is potentially an important correlation, but it does not show a causal effect of stress – it may just capture differences in underlying preferences among people who become stressed easily and those who do not (Trautmann, 2014). Apart from that, the tasks applied to elicit risk preferences were quite different.[1] The observed change in behavior under stress can be attributed to multiple driving mechanisms, not just to a change in risk preferences. In the Iowa Gambling Task (Bechara, Damasio, Damasio, & Anderson, 1994), Cambridge Gambling Task (Rogers et al., 1999), Baloon Analogue Risk Task (Lejuez et al., 2002) and in the Game of Dice Task (Brand et al., 2005), feedback is given throughout the task and the performance therefore greatly depends

[1] For standard economic measures of risk-preferences, see a summary of Harrison and Rutström (2008)

on feedback processing, which is itself affected by stress (Starcke and Brand, 2012). This situation in the literature was an opportunity to report on my experiment (Chapter 3) that clearly identifies the causal effects of stress on risk preferences and overcomes the limitations of the previous contributions.

Even though the commonly known effect of stress is both psychologically and physiologically a suppression of a long-term oriented behavior in favor of the short-term behavior, research on *time-preferences* using an efficient stressor in a laboratory has brought so far robust null results (Haushofer et al., 2013). To follow-up on this, Haushofer & Jang (2015) exposed subjects in Nairobi to three different types of stressors: social, physical and an economic game. They find that the social stressor decreases temporal discounting (i.e. makes subjects more patient), the physical stressor has no effect and the economic stressor increases discounting. This further supports the idea of the differential effects of different types of stress stemming from different types of stressors.

Also the dimension of *social preferences* has come under scrutiny. One study exposed a sample of 72 men to a social stressor and let them play a set of simple binary games, right in the middle of the stress protocol. Subjects have been found to be more trusting, trustworthy and sharing, while they did not show a change in the non-social risk and "punishment" dimensions, compared to the control group (von Dawans, Fischbacher, Kirschbaum, Fehr, & Heinrichs, 2012). In another study, male participants went also through TSST-G protocol and then were tested in pro-social decision making either directly after or 75 minutes later to reveal time-dependent effects of stress on behavior. The games applied were the Ultimatum game (UG) and a one-shot Dictator game (DG) where subjects could donate to charity. The stressed participants acted as responders in UG while the hypothetical identity of proposers and the proposed division of the pie was varied. The stressed participants in the late condition showed significantly smaller rejection rates in UG than the early condition and also than both late and early conditions in the control group. In the DG the stressed participants donated significantly less than the control group, while there were no differences in these groups with respect to the timing of the game (Vinkers et al., 2013).

The above mentioned studies demonstrate the need for economists to take the stress research into account and show that some promising research is already taking place. Due to its complicated nature and serious effects on human decision making I believe that it is of great importance to uncover and understand also the direct behavioral changes due to stress so that we can prevent the adverse effects and promote the stimulating effects that this reaction may bring. The generated insights may be beneficial in many economic fields, e.g. implementing incentive structures in labor markets in order to encourage the efficiency-enhancing and avoid the cost-imposing effects of stress. Theories dealing with efficient matching, risk-management and financial decision-making in general should be prepared for periods of stress since these are usually of a crucial practical importance. The research presented in this dissertation aims to contribute to building knowledge in this emerging area of literature.

Table 1-1: Summary of previous literature on the effect of stress on social preferences (based on Starcke and Brand (2012), extended)

Study	**Results – Risk preferences under stress**	**Participants**	**Stressor**	**Stress measurement**	**Task**	**Task measures**	**Other limitations**
Buckert, Schwieren, et al.,(2014)	More risky behavior of cortisol-responders	Students, 89, 14 excluded 39f, 36m	TSST-G	Cortisol, heart-rate, MDMQ	Taylor-made	Risk-preferences	A third of subjectsnot stressed, not causal analysis
Pabst, Brand, & Wolf (2013b)	Less risky behavior of stressed in losses, no effect in gains	Students 40m / 40f	TSST, placebo TSST	Cortisol, alpha-amylase, PANAS	GDT	framing with unequal distributed EVs across alternatives	Testing between 10AM and 12AM, subjects informed of stress
von Dawans et al. (2012)	Men: No difference in the number of risky choices between treatment and control	Students 67 m	TSST-G	Cortisol, heart rate, subjective stress	Risk game: choices between low-risk and high-risk lotteries	Risk preferences	Subjects knew effects of stress were sutdied (risk of self-selection correlated with risk aversion)
van den Bos et al. (2009)	High-cortisol responders chose the disadvantageous (riskier) deck less often; U-shaped relation	Students & university staff 30 m/34 f	TSST	Cortisol	IGT	Risk preferences, feedback processing (reward sensitivity, learning)	Not a full control procedure in TSST; Analysis: not a causal effect of stress,
Lighthall et al. (2009)	Men: higher average number of balloon pumps in treatment Women: lower average number of balloon pumps in treatment	22 m/23 f	CPT	Cortisol	BART	Risk preferences, feedback processing (reward sensitivity, learning)	No cortisol increase for men, mild for women; Task: in the analysis only observations where the balloon did not explode were used
Starcke et al. (2008)	Stress led to more disadvantageous choices. Cortisol reactions and risky decisions are correlated.	Students 18 m/22 f	Anticipated Speech	Cortisol, alpha-amylase, STAI	GDT	Risk preferences, strategy application, feedback processing	
Porcelli and Delgado (2009)	On gain domain trials, stress led to more conservative choices, on loss domain trials, stress led to more risky choices	Students 14 m/13 f	CPT	Skin conductance	Modified CGT	Risk preferences, feedback processing (reward sensitivity)	Within-subject treatment – control, then stress condition (order effects?)
Preston et al. (2007)	Men: Acutely-stressed men are risk-taking, acutely-stressed women are risk averse	Students & university staff 20 m/20 f	Anticipated speech	Heart rate	IGT	Risk preferences, feedback processing (reward sensitivity, learning)	Stressor less effective, no cortisol measure
Putman et al. (2010)	Stress led to more risky decisions when the potential reward was high	Students 29m	Application of cortisol	Cortisol, STAI	Modified CGT	Risk preferences, feedback processing (reward sensitivity)	

Notes: f=female, m=male; TSST=Trier Social Stress Test, TSST-G =Trier Social Stress Test for Groups, CPT=Cold Pressor Task; STAI=State Trait Anxiety Inventory; IGT=Iowa Gambling Task, BART=Baloon Analogue Risk Task. GDP=Game of Dice Task, CGT=Cambridge Gambling Task

2 Chapter Two: Herding under Time Pressure[2]

Abstract

In this paper we explain individual propensity to herding behavior and its relationship to time-pressure by conducting a laboratory experiment. We let subjects perform a simple cognitive task with the possibility to herd, which was implemented as an explicit change in subject's decision only due to the observation of the decisions of some other subjects, under three levels of time pressure in a within-subject design. The main finding is that the propensity to herd was not significantly influenced by different levels of time pressure, even after the addition of many control variables. However, there could be an indirect effect through other variables, such as the time subjects spent revising the decision and levels of stress which have been significantly associated with the tendency to herd. Apart from that we show that heart-rate significantly increased over the baseline during the performance of a task and its correlation to the subjectively stated level of stress was positive but weak, which suggests that time pressure may be used as a mild stressor. Our results suggest that under time pressure, people are not more likely to copy the behavior of others, provided the time pressure does not cause stress.

[2] This chapter has been published in a slightly different form as Cingl, L. (2013). Does Herd Behavior Arise Easier Under Time Pressure? Experimental Approach. *Prague Economic Papers*, 22(4), 558–582.

2.1 Introduction

In the current constantly accelerating world and with the ever increasing value of our time, many decisions are made under severe time pressure. Moreover, we are under the influence of the decisions of others in almost every activity, including investments and financial transactions. For example, the news that Warren Buffet buys a stock quickly influences its price which may on the one hand be completely rational, but on the other hand it may only be the result of investors and managers blindly following the crowd, engaging in herding behavior (Hirshleifer & Hong Teoh, 2003). Despite its importance, the effects of time-pressure on decision making have however been largely omitted in research (Kocher & Sutter, 2006). If we focus on the impact of time pressure on herding behavior, it may be of high importance e.g. in stock and financial markets where the participants have to almost instantly react to the arrival of new information and the subsequent development of the markets. If time pressure changes the individual propensity to engage in herding behavior, e.g. if it increases that propensity, traders knowing that may earn more money if they rely less on the development of the market and more on objective sources of information. Furthermore, a commonly neglected fact in the economic literature is that human behavior heavily depends on the physiological state of the body which is hard to consciously control, such as the stress reaction. Time pressure has been shown to cause a mild stress reaction (Lundberg, 1993) which we hypothesize can reinforce the urge to engage in herding behavior. This paper is thus the first to experimentally investigate the effects of time pressure on individual willingness to engage in herding behavior.

As to the underlying mechanism of herding, there are many reasons for taking into account the decisions of other people, but generally two main approaches have been proposed so far: bounded-rationality and the behavioral approach. The behavioral approach proposes that some personal characteristics predispose certain individuals to be more conforming than others, while the bounded-rationality approach disregards personality and focuses only on the information conveyed in the decisions of other people. Ignoring one’s own signals when the behavior of others contains more information has been labeled in the literature as an information cascade (Anderson & Holt, 1997; Banerjee, 1992; Bikhchandani, Hirshleifer, & Welch, 1992; Welch, 1992). A theoretical synthesis of these two approaches has already been made (Cao & Hirshleifer, 2000) and this experiment does not try to resolve the duality between them (Baddeley, Pillas, Christopoulos, Schultz, & Tobler, 2007), but it rather focuses on the relationship between time pressure and herding, which has so far been omitted in the literature.

Generally, the effects of time-pressure on decision making are not straightforward. Maule & Edland (2000) provide a useful review of the effects of time-pressure on individual decision making: it can reduce the quality of the activities, change risk preferences, increase the importance of internal sources of information at the expense of the external ones, increase the relative importance of different information sources, and many others. However, these effects do not always appear. The main effect of time-constraint on information-processing can be characterized as that participants process information faster and with a higher selectivity of important facts (Payne, Bettman, & Luce, 1996; Rieskamp & Hoffrage, 2008). Kocher & Sutter (2006) in the framework of an experimental beauty-contest game found that the convergence to equilibrium is faster and the payoffs are higher in the low pressure treatment than in the high time pressure treatment; however during a period of high pressure the quality of decision making does not decrease.

In this paper we present an experiment where subjects were supposed to count the number of zeros in a table of 400 symbols with only ones and zeros (Abeler, Falk, Goette, & Huffman, 2011; Falk, Menrath, Kupio, & Siegrist, 2006) under varying levels of time pressure. Their performance was rewarded by a fixed-portion of payment for the accuracy of their guesses and by a decreasing time-dependent portion which was the means of inducing time pressure. After setting the first guess of the correct number of zeros in the table, subjects had an opportunity to observe the first guesses that had already been entered by other subjects, and subsequently change the first guess. If a subject had looked at information about other players' results and as a result changed his/her guess, it is used as 0/1 proxy for the occurrence of herding behavior. Subjects performed the task under three different levels of time-pressure in a within-subject design. Since the propensity to herd may be influenced by both the personality and the information contained in the decisions of others, we control for both. Personal characteristics are tracked and controlled for by using the standardized psychometric protocols IPIP-NEO (Goldberg, 2010) that measures the "Big-Five" personality dimensions. Tracking of personal characteristics is important also for other reasons, as stress can have a different impact on the performance of people with different attitudes to risk (Cadsby, Song, & Tapon, 2009). Since Baddeley, Burke, Schultz, Tobler, & Tobler (2010) found a positive association of herding with personality traits associated with risk-taking, namely impulsivity and venturesomeness, we also elicit the risk-preferences using an incentivized protocol (Dohmen et al., 2011; Dohmen, Falk, Huffman, & Sunde, 2010).

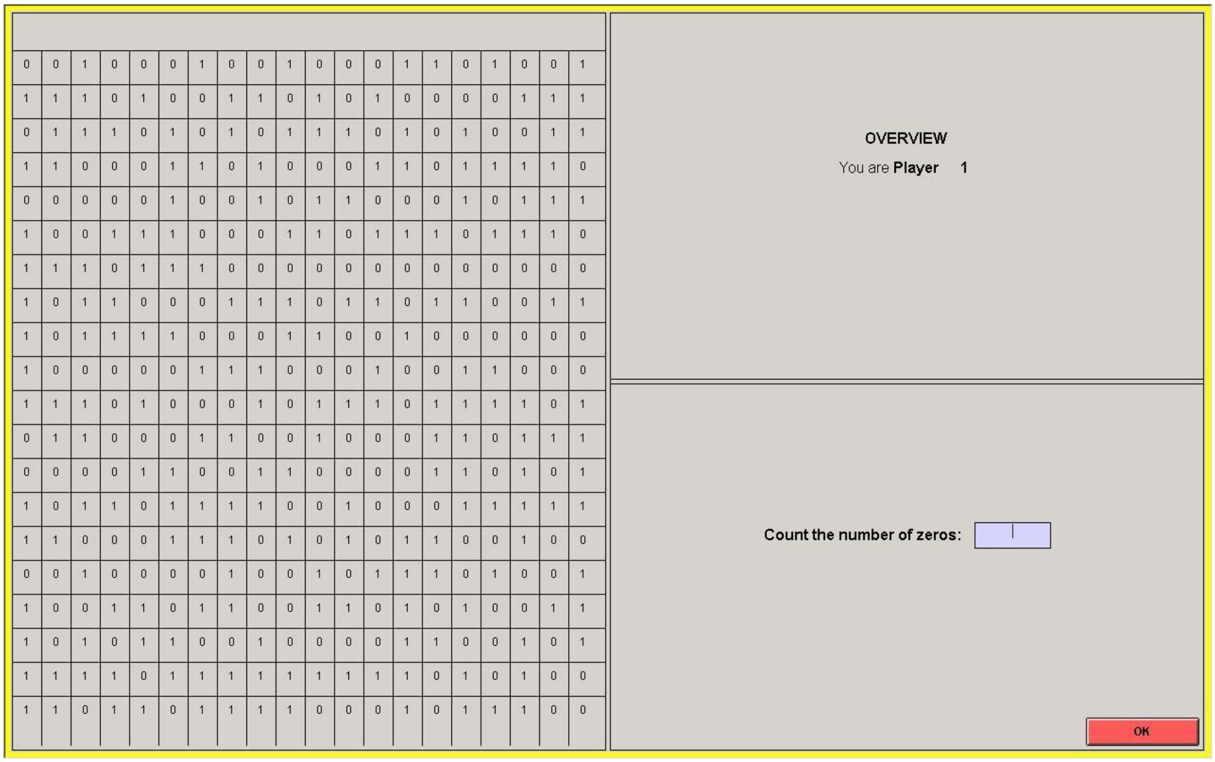
The main investigated hypothesis is whether the occurrence of herding is not more frequent under more severe time pressure, conditional on the decision to see the publicly available information. Our results show that indeed, this hypothesis cannot be rejected in various specifications which implies that there is no level relationship between time pressure and herding behavior. On the other hand, variables implicitly associated with time pressure, such as time spent examining the publicly available information, reported subjective level of stress, and heart-rate are significant predictors of the tendency to herd which suggests that there may be a more complicated relationship. Apart from that, we show a small but significant correlation between subjective levels of stress and heart-rate increases during the task solution, mainly driven by women under high time pressure, which suggests that time pressure can act as a stressor. The fact that we see no effect of time pressure per se but a significant effect of stress variables suggests that stress is the channel through which time pressure may actually operate in increasing the probability of herding behavior.

2.2 Methodology

A laboratory experiment was executed using Z-TREE (Fischbacher, 2007) and ORSEE (Greiner, 2004) in April 2010 and was attended by 90 participants. There were six experimental sessions in two days plus one pilot session that was used for parameter calibration. The majority of participants were undergraduate students – mostly Czechs (77.8%) followed by Slovaks (12.2%) and other nationalities (10%). The participants were 62.2% males, the most common field of study was economics and business (75%) and the median age was 22. Participants were paid privately at the end of the experiment; the average payment was 350 CZK (app. 13.5 €) including a guaranteed show-up fee of 150 CZK (app. 6 €). In total, the experiment lasted less than 2 hours.

The participants performed a simple cognitive effort task (Abeler et al., 2011; Falk et al., 2006), which was supposed (i) not to require previously earned skills or any innate cognitive abilities, (ii) not to induce any emotions, (iii) not to induce a learning effect and (iv) only positive payoffs were allowed in order to eliminate the loss-aversion effect (see Figure 2-1 for a screenshot of the task). The participants were required to count the correct number of zeros from a table of 400 symbols (zeros and ones only) that appeared on the screen. The numbers were randomly generated from a uniform distribution with a variability large enough so that accurate random guessing without counting was highly improbable. Each participant was supposed to solve eleven tasks in total, including the practice session. After counting the number of zeros, participants were supposed to enter their estimated number (guess) into a field on the screen.

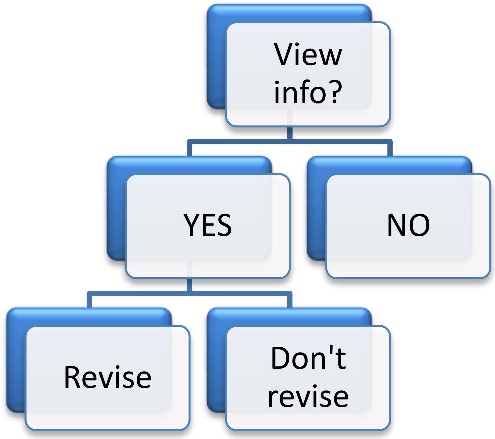
Figure 2-1: Task screenshot.



There were three different within-subject treatments: first the subjects were not restricted by time and had two tasks only to practice. Second, three levels of time pressure were introduced, which was represented by a strict time constraint, and three types of time-dependent parts of payment. Third, in the last rounds subjects had an opportunity to look at the first guesses of others who were faster than the subject and then to revise the original guess. In this context the occurrence of herding is defined as a situation when a participant used information from observing the guesses of the other participants. This 0/1 variable is meant to be the observable outcome of an unobservable tendency to herd, which is the main variable of interest. The subjects could choose whether or not to see the publicly available information (see Figure 2-2).

In the revision part of the task each subject could observe only the first guesses of the other subjects who had submitted them before him/her. This was supposed to correspond to the real world, when people observe only actions that have been made before their decisions.

Figure 2-2: Scheme of decision-making process after setting the first guess.



Time pressure was imposed both on the counting part as well as on the revision part of the task: i.e. time was running out during both parts of the task. Time pressure in the counting part served as a generator of uncertainty about one's private signal and time pressure in the revision part was expected to influence the individual propensity to herd. Had there been no time pressure in the counting part of the task, everybody would have reached very precise private information and thus would have had no incentive to revise it by taking inspiration from others.

The pay-off function consisted of two components: a fixed part and a time-dependent part. Similarly as in Falk et al. (2006), participants were paid a fixed amount of 100 ECU (2€) per task if they answered exactly the number of zeros in the sheet, 80 ECU if their answer was in the range of +/- 1, or 40 ECU if it was in the range +/- 2. The size of the time-dependent part was different with each level of time pressure (see Table 2-1) and was calibrated so that participants would receive a similar number of ECU across the different levels of time pressure. The time limit was binding in the sense that if the task was not completed in the given time, the participant got zero ECU in total for the given task. Also the precision of the guess was binding such that if a participant missed the correct number of zeros by more than two, he/she received zero from both fixed amount as well as from the time dependent bonus. The fixed part of the payment per task served as the motivation to count accurately while the time-dependent part motivated subjects to count as quickly as possible. All subjects are under the same level of time pressure at the time, so the individual performance relative to others should stay the same and the beliefs about other subjects and the probability of their success should not change with different levels of time pressure.

Table 2-1: Payoff function parameters

Level of time pressure	Time limit	Time-dependent part (start value)	Factor of decreasing (per second)
Low	150s	400 ECU	-3 ECU
Medium	130s	500 ECU	-4 ECU
High	100s	600 ECU	-5 ECU

Heart rate is the frequency of the contractions of the heart muscle and its unit of measurement is frequency per minute. Changes in heart rate refer to higher levels of arousal, which are often somatically mediated, which suggests that when heart-rate increases, the body is in a state of increased awareness, such as stress (Lo & Repin, 2002). Heart-rate increase measured as the individual difference of the average heart-rate during the performance of the task minus the hear-rate during the resting period was used as a proxy of endured stress, even if it could be considered a rather rough measure.[3] Heart rate increases are typically correlated with endured psychosocial stress (Kirschbaum et al., 1993) and are also generally considered to be a sign of an increased physical activity or arousal. The caveat is that increased heart-rate may be a result of stimuli other than stress, like a sole effort without distress, which limits the interpretation of our results (Clow, 2001).[4]

Following Baddeley et al. (2007), some individuals with certain personality characteristics can be expected to be more prone to follow the behavior of others. To capture the personality profile of participants, the "Big Five" factors were assessed, where each factor represents a summary of a large number of specific personality characteristics (Openness to Experience, Conscientiousness, Extraversion, Agreeableness and Neuroticism; see Table 2-2 for their summary; Goldberg, 2010). The "Big Five" domains is a standard psychological tool for the assessment of personality traits that may be useful in the explanation of behavior in as much as preferences (Almlund, Duckworth, Heckman, & Kautz, 2011; Borghans, Duckworth, Heckman, & Weel, 2008; Heckman, 2011).

[3] Heart-rate monitors Polar R800 (Polar Electro, Finland) with a precision of one second were used.

[4] For the precise measurement of stress, heart-rate should be combined with several other measures, e.g. the concentration of cortisol in saliva, systolic blood pressure and self-reports (Jennings et al., 1981). However, the measurement of blood pressure would have significantly prolonged the experiment and it would not be possible to administer during the task; and the measurement of cortisol was at the time of conducting the experiment impossible. Therefore only heart-rate was used as the measure of physiological stress with the known limitations of this approach.

Table 2-2: The "Big Five" domains and their facets.

Factor	Facets	Definition of a factor
I. Openness to Experience	Fantasy, Aesthetics, Feelings, Actions, Ideas, Values	The degree to which a person needs intellectual stimulation, change, and variety.
II. Conscientiousness	Order, Dutifulness, Achievement striving, Competence, Self-discipline, Deliberation	The degree to which a person is willing to comply with conventional rules, norms, and standards.
III. Extraversion	Warmth, Gregariousness, Assertiveness, Activity, Excitement seeking, Positive emotions	The degree to which a person needs attention and social interaction.
IV. Agreeableness	Trust, Straightforwardness, Altruism, Compliance, Modesty, Tender-mindedness	The degree to which a person needs pleasant and harmonious relations with others.
V. Neuroticism (Emotional Stability)	Anxiety, Angry hostility, Depression, Self-consciousness, Impulsiveness, Vulnerability	The degree to which a person experiences the world as threatening and beyond his/her control.

Source: Hogan & Hogan (2007).

Procedures

The timeline of the experiment is summarized in Table 2-3. Before the start of the experiment, the heart-rate monitors were attached and during the rest of the experiment the heart-rate of the participants was recorded. After being read the instructions aloud and having them explained in detail, subjects were asked a few questions to check their understanding of the rules. The participants went through three main parts of the experiment that were based on the task described above. The first part included the first treatment to familiarize subjects with the task; the second and the third parts included the second and the third treatments, respectively. Each participant was supposed to solve two tasks in the first treatment, three tasks in the second treatment and six tasks in the third treatment. Participants were informed before each task about the level of time pressure, the time limit for the task and the time-dependent amount of payment they could get. This information was provided on a separate introductory screen. Participants saw their payoffs from the task always on a summary screen after each task and this screen also included the cumulative payoff from the treatment. At the end of each task, the participants had to answer a question on their subjective perception of the pressure they were under on a scale from 1 to 10 (Svenson & Benson, 1993) and had 30 seconds to rest before the next task.

Table 2-3: Timeline of the experiment.

Subjects arrive to the lab
Heart-rate monitors attached
Reading instructions aloud control questions
First part – practice 2 tasks to solve
Second part - introducing time pressure 3 tasks to solve
Risk-preferences protocol - lottery task **Task-confidence**
Third part 6 tasks to solve under varying levels of time pressure Possibility to see public information and revise a decision
Questionnaire personality profile - traits Personal characteristics
Sitting quiet 5mins payout & leave

Before the third part of the experiment where they could see the results of others, the participants were asked a non-incentivized question on their relative performance[5] in the task in order to measure how confident they felt. The answer ranged from one to five with five being expectation of being in the top 20% of the performance distribution and one being the bottom 20% and it enters the model in the form of the variable *Self Confidence*. After they had finished this, the participants were asked to fill out a separate sheet of paper with an extra paid-for task aimed at the assessment of their attitudes to risk (Dohmen et al., 2010). Prior to the end of the experiment, the participants filled out a questionnaire with questions on the personality profile and additional personal characteristics. After this they were asked to stay a few minutes at rest with their eyes closed which was necessary to establish a reference level for the heart rate.

Hypotheses description

Generally speaking, if participants were perfectly rational, they would neither fail in the task nor would seek information about the decisions of other participants since this is costly. If we relax this assumption by assuming that individual decision-making is based on individual bounded

[5] Exact wording of the question: “Please try to guess in which part of the distribution of results you are (i.e. if you think, that you are in the top 20%, please click on the "Top20%", which means how close you are to the top).”

rationality, we may expect a negative monotonic relationship between the level of time pressure and their performance in the task. Gilbert & Kogan (2005) show that the possibility to learn from others has an impact mostly on worse players, who tend to improve not only results, but also decision making processes. The reasoning in this case should be straightforward: the less time for completing the task (which corresponds to a higher level of time pressure) the less precise his/her private information and thus the more appropriate it is to seek for and use public information. Rieskamp & Hoffrage (2008) however show that when people are under increased time-pressure, they tend to process information faster and focus more selectively on more important information. Consider a participant who happens to see the first-guesses of a half of the participants. The faster subjects used less time to finish the task which suggests that their results may be more imprecise than his/hers. On the other hand, the faster participants could have had better individual abilities to solve the task in general which suggests that their guesses are more precise than his/hers. The effect of time pressure on herding will therefore most probably depend on the individual assessment of whether the public information is useful.

Hypothesis 1: Herding is not more frequent under higher levels of time pressure, conditional on seeing the public information.

The second hypothesis concerns the effect of time pressure on individual heart-rate. If time pressure increases heart-rate, it may be a sign of the stress reaction. If so, the increase should be positively correlated with the subjectively stated level of stress.

Hypothesis 2: Time pressure does not increase the individual's heart rate relative to the base level during the performance and is not positively correlated with the subjectively stated level of stress.

2.3 Model description

Binary variable *InfoUsed* was defined as equal to one for the situation when a subject changed his/her decision after being confronted with the decisions of others, and zero otherwise. These two outcomes are mutually exclusive and we assume that they arise with probability $\Pr[InfoUsed]$ and $1 - \Pr[InfoUsed]$, respectively. The standard probit regression[6] approach with standard errors clustered at the individual level to account for intra-individual correlations is used (Baddeley et al., 2007; Brock & Durlauf, 2001; Greene, 2003). We further assume that the error term ϵ_i is normally distributed white noise stochastic term with zero mean and a finite variance. It is important to note that revising the original guess is conditional on the decision *to see* the information in the first place, which limits our analysis only on this specific sub-group of

[6] Robustness check of the results by carrying out an estimation of the same model by logit and the linear probability model shows that the results were almost equivalent across the three techniques; results available upon request.

decisions, while leaving a considerable amount of decisions when subjects decided not to see others' decisions out of our analysis, which is however not the main point of this paper.

Description of variables

In the model specification, three sets of variables are incorporated: the first set represents the information that was on the screen with public information, the second group represents the individual personality and the third contains other task characteristics that may be important for the decision making.

Time Pressure indicators

The exogenously set level of time pressure (low/medium/high) the subjects endured during the task is indicated by 0/1 dummy variables. It enters the regression as a set of two variables *TP_Medium* and *TP_High*[7]. To test Hypothesis 1, these variables should be significant in the explanation of the tendency to herd, especially when indicating the “high” level of time pressure: the variable *TP_High=1*.

Time dimension: TimeLeft, TimeDeciding

Variable *TimeLeft* is the number of seconds participants had on the screen when they entered their original estimate and thus could use for the revision part of the task. A majority of subjects did not have much time to waste so if they had it, they would likely invest it wisely. On the other hand, the total time they had left should already be irrelevant if it was above a certain threshold - either there was useful info or less useful info, but the time to switch the estimate or to go further without switching was not dependent on the total time the subjects had. Due to the low variation in age, education and nationality these were not used as the control variables in the model, however it may be important in other settings.

Another explanatory dimension of time can be hidden in the time which subjects spent on the screen with the public information. Intuitively, because they were under time pressure, they must have decided fast whether to use the information and change the value, or to go further without changing the value, as described above. Had they decided to change their estimate, they had to think of the new value, which is already a deliberative process and needs more time, so the variable *TimeDeciding*, which indicates the time the subjects spent on the screen with the public info, is expected to be positively associated with the *InfoUsed*.

---

[7] *Time_Pressure_Medium* and *Time_Pressure_High*. Due to the perfect colinearity this provides, the indicator of the treatment with low time pressure, *TP_Low*, must have been omitted

Stress variables

The stress induced by the time pressure can also be an important variable and as part of Hypothesis 2 it is expected to positively influence the probability of herding - *InfoUsed*. There are shown two measures of it: the subjectively stated level of stress *SubjectiveStress* and the difference of the average level of heart-rate during the task to the base-line heart rate *HR_Increase.*

Measure of information: Similarity score

To capture the value of the information that the subjects had on their screens, we introduce the index *Similarity score* as the measure of the similarity of the subject's original estimate to the observed values of others. *Similarity score* was computed in the following way: if the subject's original estimate was not further than one from a value of an estimate on the screen, *Similarity score* got one point. The summation over all observed values yields the final value of *Similarity score*. The idea behind this variable is that the more similar one's guess to others' guesses is, the less meaningful it is to switch.

Risk attitudes

The risk-averse subjects could react to time pressure differently than the risk-seeking. Therefore we control for this possible effect by measuring the risk-preferences of subjects by a standard risk-protocol (Dohmen et al., 2010). Specifically we measure a certainty equivalent and include it in regression analysis as a continuous measure of risk-aversion.

Other personal characteristics: Female, Age, Self Confidence, TotalProfit, "Big-Five" Personality Traits

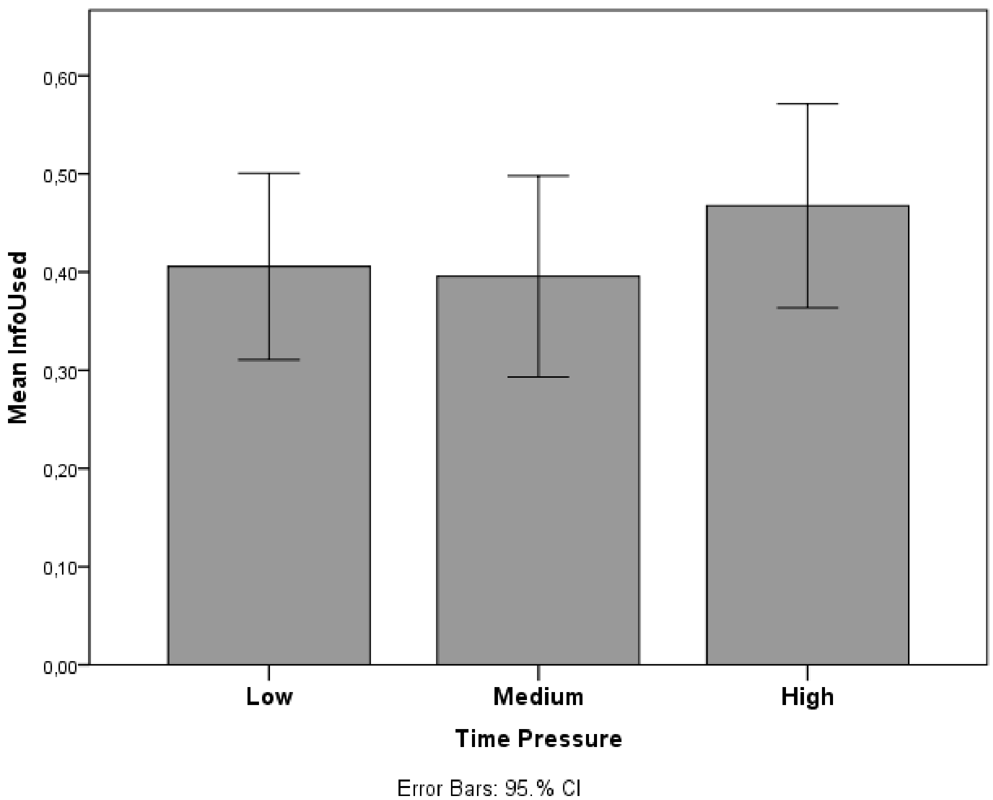
Generally speaking, we can also expect that the subjects with a higher task-specific self-confidence to have lower incentives to look at the public information and if they do, they will be reluctant to conform to the majority.

The endowment effect caused by the fact that the participants saw their earnings after each round was controlled for by adding total profit (variable *TotalProfit*) that the subject had already earned, which also serves as a control for individual performance. Because we expect it to behave similarly to the general behavior of wage-related variables; i.e. that it is likely to be log-normal, we transform it by using a natural logarithm so that the new variable *lnTotProf* is normally distributed. *Female* is a dummy variable indicating a female subject and it is added to control for the gender effect found by Baddeley et al. (2010), that a female is more likely to herd.

2.4 Main Findings

Figure 2-3 presents that the percentage of people using the public information is higher in the *High* level of time pressure. There were generally fewer people willing to see the public information, but once they saw it, they would have a slightly higher chance to use it than in the other lower levels of time pressure (47% vs 40%). However, standard F-test results in that the levels are insignificantly different from each other, also when compared pair-wise[8].

Figure 2-3: Percentage of choices when participants were affected by the information about the decisions of others (*InfoUsed*), conditionally on seeing the public information.



Qualitative analysis: subjects' "Player" profiles

In the experiment different types of subjects emerged: there were some that benefited from the possibility to see the public information, but also some for whom the information was useless. Out of 90 subjects, there were 13 subjects who never looked at the public info, and 8 out of them

[8] P-value=0.576. When High level of time pressure compared to the pooled other two, Wilcoxon rank sum test also yields insignificant results ($z = -1.07;\ p = 0.28$)

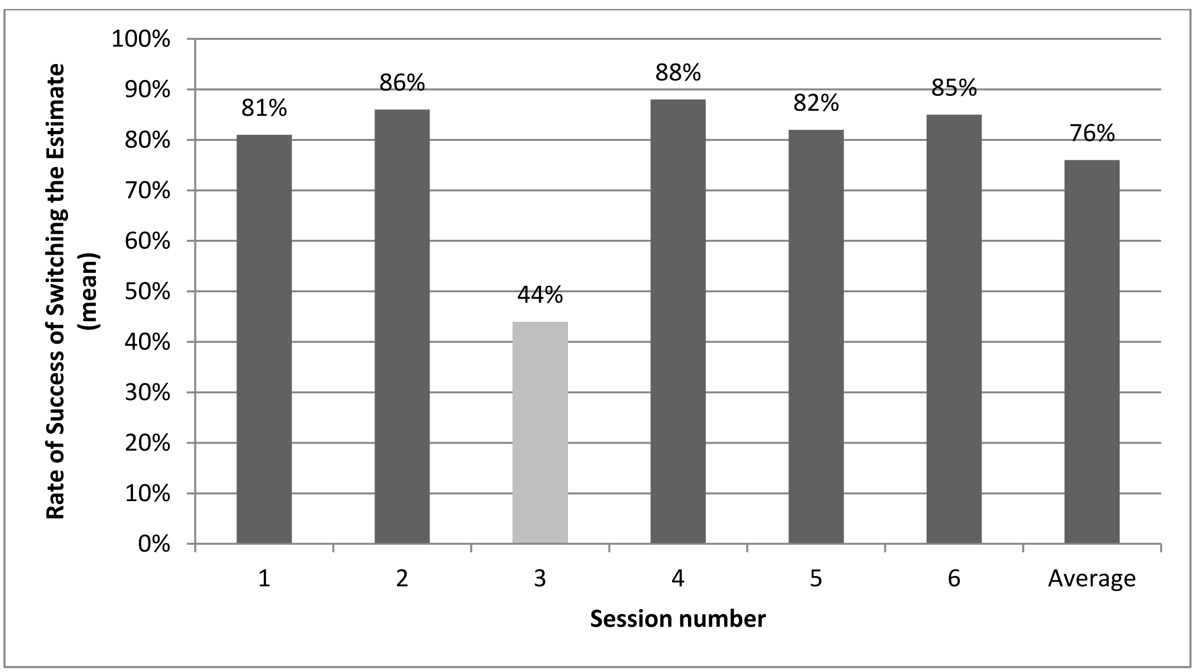
performed significantly better than average. This is the "successful" type of subject that would only lose money by viewing the public info. Apart from this, there was another type of subject who also never used the information, but this one must have had another motivation as their performance was mostly below average. We label this type "unsuccessful honest".[9]

On the one hand, there were 33 subjects who did look at the public information each time they had a chance to, but out of those 33 only five always used the information, so these "curious and imprecise" subjects were also not the only type of subjects. On the other hand, there were eight subjects who looked every time, but never switched – the "self-assuring" types. These eight subjects were mostly highly successful in the task, so they probably just assured themselves that their result was correct.

Was public information useful?

We can have a look at the rate of "success" of revision: if the new estimate brought a higher payoff than the original one. The percentage of successful changes is shown in Figure 2-4 – in most experimental sessions the subjects could improve using public information in more than 80% cases. However, session No. 3 was exceptional and had this rate lower than 50%.

Figure 2-4: Rate of success of switching the estimate after seeing public information.



[9] I found out in feedback that there was a type of player not willing to see the public info due to fear of getting distracted by the results of others and thus performing even worse.

In this exceptional session No. 3 there were four subjects who randomly guessed the number shortly after the beginning of each task, so they added significant noise to the information seen on the screen by other subjects. Interestingly, their results were in the first three periods followed by others. As a result, the rate of successful switch in this session was much lower than in the other sessions where there were on average 3 incorrect switches, but in this session there were 14 incorrect switches. There were even incorrect cascades when the number followed was far from the true one: it happened in the first part of a period and it was caused by the subjects who guessed the result who were followed by two to three other subjects. However, in the second half of the period, three to four "honest" participants arrived and brought the correct information to light. Then the next subjects mostly either entered the result correctly or did not use the public info at all. This result supports the idea of the fragility of cascades in a continuous setting: an incorrect cascade began, but was overrun by the arrival of the information brought by the subjects who counted well and whose estimate was more precise. In real life, we also cannot distinguish who, when in a cascade, ignores private information and follows the crowd and on the contrary, who accidentally gets the same result and falls into a cluster of subjects with the same results. The results generally suggest that if subjects expect the arrival of true information to the public, the moment of the arrival may with a high probability break the cascade.

Data from heart-rate monitors

The average heart rate[10] over the time when the task was performed minus the base-line heart-rate[11] gives the resulting difference between these two (*HR_Increase*), which should account for the personal physiological differences of different base-line heart-rate levels. The summary statistics of the HR-variables are shown in Table 2-4. Some subjects had average HR almost the same as when they stayed calm in the end, others had peaks as high as 151 beats per minute, which is equivalent to moderately demanding physical activity.

Table 2-4: Descriptive Statistics of variables concerning heart-rate.

	N	Min	Max	Mean	SE (Mean)	SD
Average heart-rate during the task	677	59	151	90.94	0.601	15.63
Base-line Heart Rate	677	50	98	74.47	0.391	10.18
Difference of base-line to actual HR (*HR_Increase*)	677	0	53	16.47	0.377	9.82

[10] further on HR
[11] Heart-rate measured in a "steady" state when no activity is performed; the interval after completion of a questionnaire and before collecting the money. Also sometimes referred to as "quiescent".

Qualitatively, there were different kinds of HR curves: a majority of them (over 50%) were very legible and fit the data well, i.e. there was a significant and stable increase during the performance of the task and HR went back to normal levels between the tasks; but some were rather similar to white noise. Interestingly, some subjects had a steep peak at the beginning of the task, probably when they decided to guess the number instead of performing the task (took only a short time of thinking), but others did not. Many subjects also had a short peak just before a task started and then the normal inverted-U shape followed, which is a sign of a reaction to the introduction screen of each task. Overall, HR during tasks was significantly different to the baseline rate, therefore we can reject the first part of Hypothesis 2 on 1% level (t=43.6; p<0.000).

Table 2-5: Pearson correlations.

		HR_Increase
SubjectiveStress	Pearson Correlation	0.103**
	p-value	0.015
	N	557
Self Confidence	Pearson Correlation	-0.150***
	p-value	0.000
	N	675
InfoUsed	Pearson Correlation	-0.242***
	p-value	0.000
	N	203

Note: *, ** and ** indicate significance on 10%, 5% and 1% levels respectively.

Hypothesis 2 also mentioned that if the increase in HR should be taken into account as a measure of physiological stress, it should positively correlate with subjectively stated levels of stress, in our case the variables *HR_Increase* and *SubjectiveStress*. Table 2-5 presents that indeed there is a significant positive relationship between the *HR_Increase* and subjective stress, but the size of the coefficient is rather small. Next the negative relationship between *HR_Increase* and *InfoUsed* suggests that the more aroused a person is (which may be a sign of stress, concentration or activity in general), the less willing he/she is to use public information. However, without another measure of stress, the reason for the increase of the HR cannot be distinguished , which limits the interpretation of the results, but suggests an interesting relationship. An indication of the relationship presents Table 2-6, where the correlation between *HR_Increase* and Subjective stress is broken down by gender and time pressure. We can observe that the positive relationship is driven mainly by women under high time pressure. This is a clear reason to control for gender in the regression analysis performed in section 2.5.

Table 2-6: Correlation of Subjective Stress and Heart-rate increase

		HR Increase			
		TP Low	TP Medium	TP High	all
SubjectiveStress	Pearson Corr	-0.006	0.080	0.132*	0.103**
	p-value	0.937	0.277	0.0716	0.0152
	N	184	185	188	557
		Female			
SubjectiveStress	Pearson Corr	0.064	0.183	0.261**	0.212***
	p-value	0.603	0.135	0.0289	0.0023
	N	68	68	70	206
		Male			
SubjectiveStress	Pearson Corr	-0.041	0.008	0.050	0.030
	p-value	0.665	0.933	0.588	0.572
	N	116	117	118	351

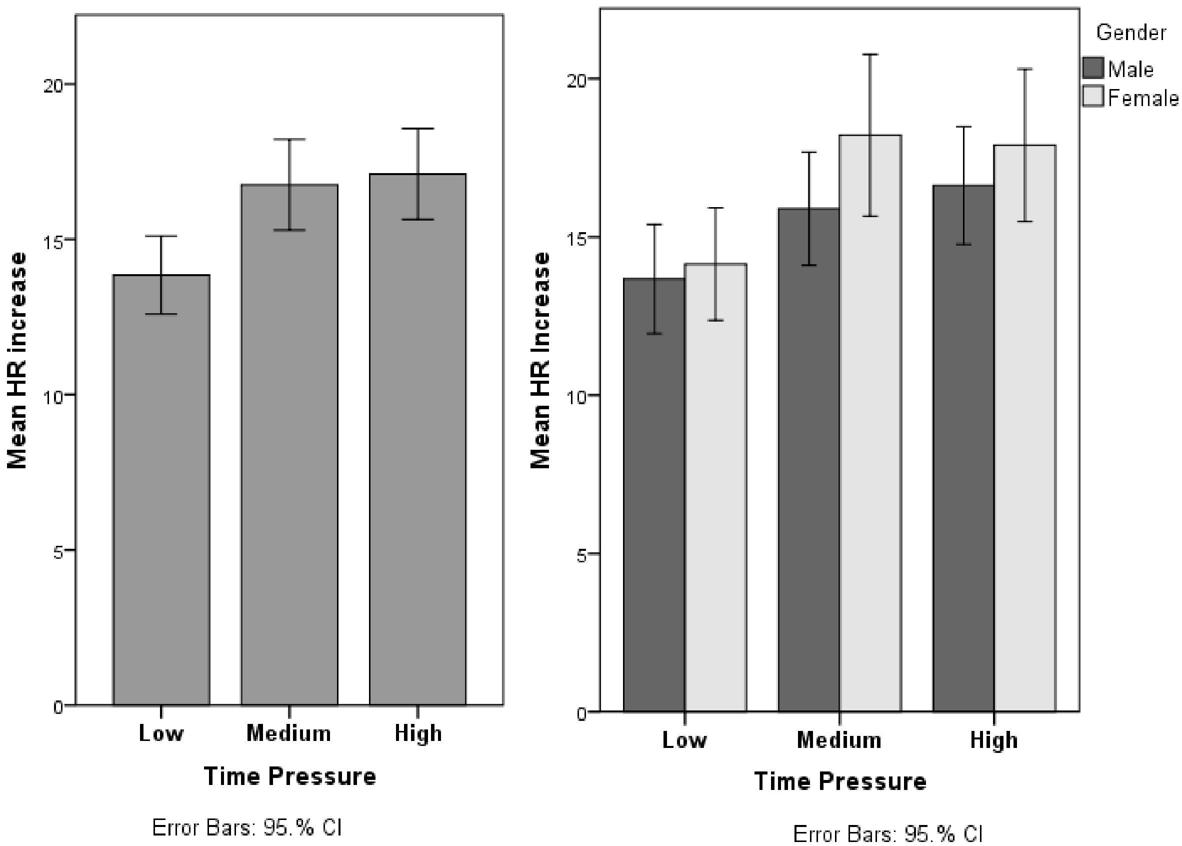
Note: *, ** and ** indicate significance on 10%, 5% and 1% levels respectively.

Stress, Heart-rate and Time Pressure

When we examine the differences in *HR_Increase* under the three levels of time pressure, we find that under Medium and High levels of time pressure the increase in heart-rate is significantly[12] higher than in the Low level, but the medium and high levels do not differ. There are also no gender differences as shown in the right part of Figure 2-5.

[12] T-test for comparison of levels High and Low: $p = 0.054$; Medium to Low: $p = 0.05$.

Figure 2-5: Comparison of heart-rate increases with respect to time pressure.

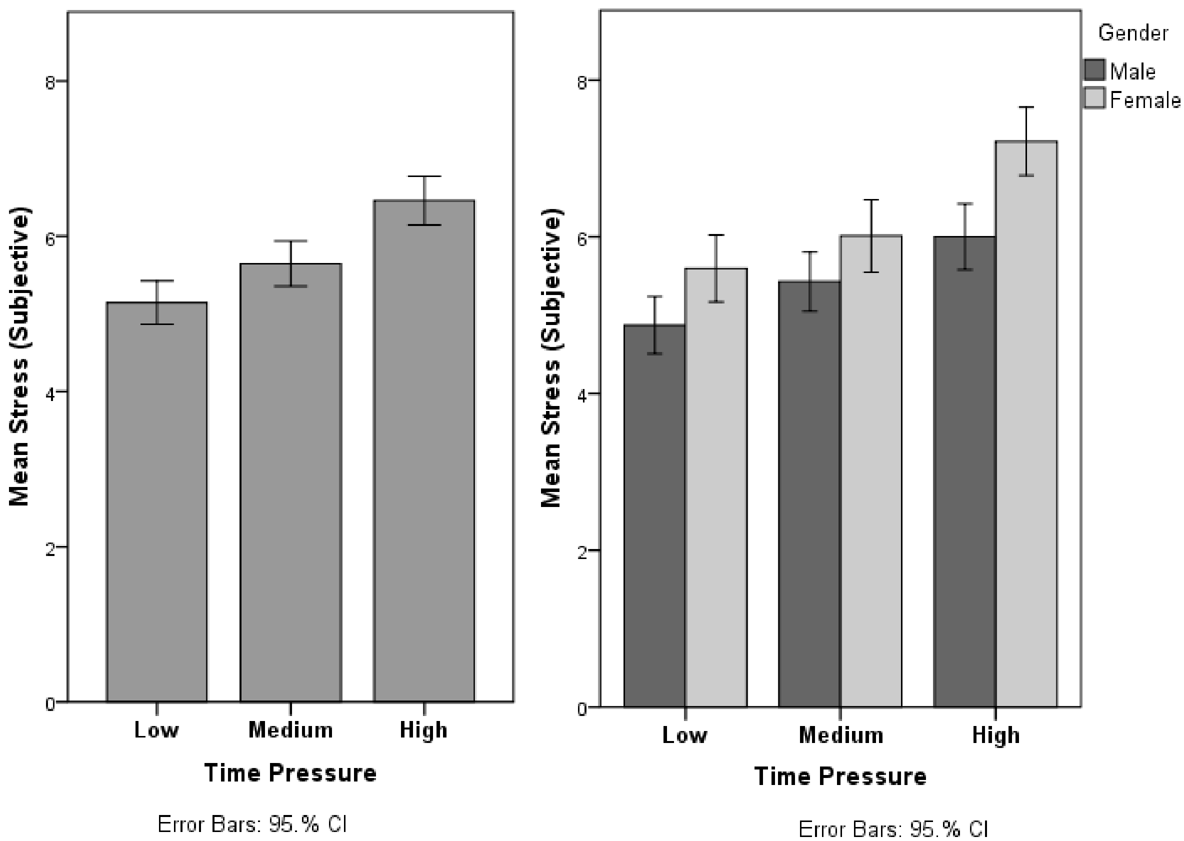


Note: Comparison of heart-rate increases (*HR_Increase*) with respect to time pressure (left) and divided by gender (right).

Figure 2-6 shows a similar result for the subjectively reported level of stress. In the left part of the figure you can see that, whereas the means of *SubjectiveStress* in Low and Medium levels of time pressure are marginally significantly[13] different from each other, in the High level of time pressure the mean is significantly higher than both of the other two levels. The psychological subjective stress increases almost in a linear way when subjects face tougher time constraints. When we inspect the gender differences in the same situation (right part of Figure 2-6), we observe that the increase in subjective stress in High level of time pressure is driven by women: they report a higher level of stress than males, where the difference is significant only under the High level of time pressure, although in both Low and Medium levels of time pressure the subjective stress for women is slightly higher than for men.

[13] T-test for comparison of levels High and Low as well as High and Medium: $p < 0.000$; Medium to Low: $p = 0.15$.

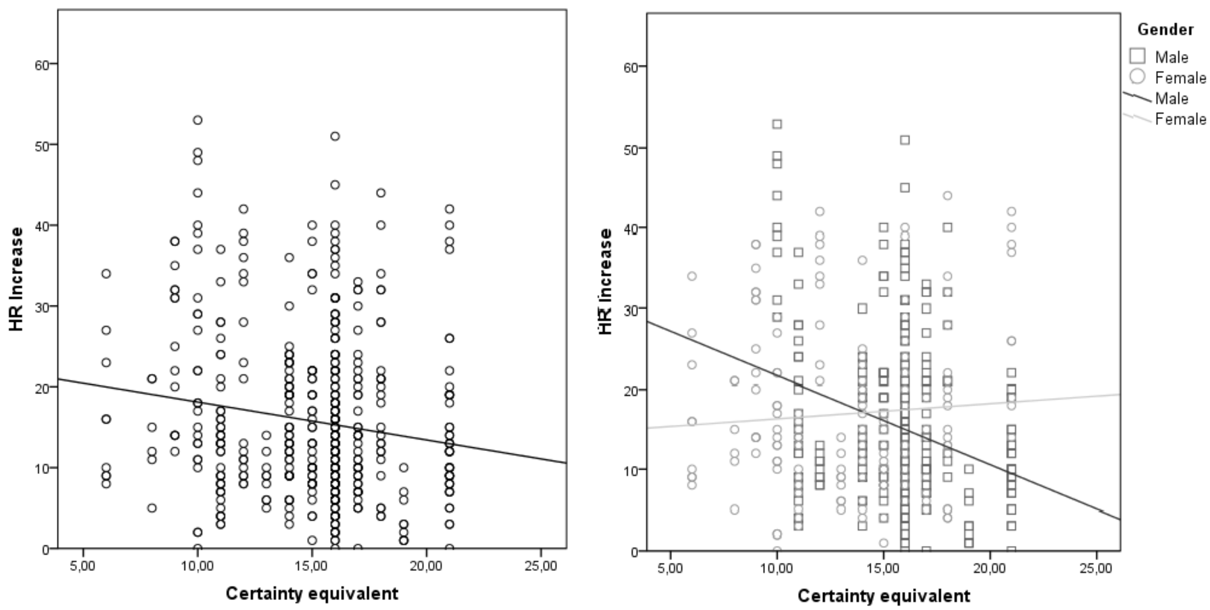
Figure 2-6: Comparison of subjectively stated levels of stress (*SubjectiveStress*) across different levels of time pressure (left) and divided by gender (right).



Heart rate and Risk Preferences

Next we compare the levels of both increase in heart-rate and subjective stress with respect to the risk attitudes. Figure 2-7 presents a scatter plot of heart-rate increase by the elicited certainty equivalent. In the left panel of Figure 2-7 a trend line indicates a significant negative correlation between an increase in heart-rate and certainty equivalent, which suggests that for subjects with a lower tolerance for risk, heart-rate increases by a smaller margin. If we interpret the increase in heart-rate as stress, then the results suggest that the more stressed participants were also more risk-averse. After the break-down by gender presented in the right panel it is obvious that the correlation is driven by men, while for women there is no relationship. However, since the risk-preferences of participants were elicited in between the tasks, they may be also affected by the stress reaction and thus we cannot say which way the causality flows: whether stress induced men to be more risk-averse or that the risk-averse participants react with a higher increase in their heart-rate. The breakdown by gender and by the levels of time pressure with the associated p-values of the correlation coefficients is presented in Table 2-11 in the Appendix.

Figure 2-7: Comparison of *HR_Increase* with respect to certainty equivalent (left) and divided by gender (right).



When we examine the correlation of the risk-preferences and the subjective stress levels, we do not find any significant effects for any level of time pressure or gender-specific effect (see Table 2-11 in the Appendix).

2.5 Model evaluation

Table 2-7 presents the regression results that are reported as marginal effects after probit estimation first with the personality controls (see Table 2-12 in the Appendix for the results without personality controls). A robust result across all specifications is that the coefficient of the dummy variable indicating a High level of time pressure is not significantly different from zero, including column 2 where the dummy for Medium time pressure is added, which means that there are no differences between the levels of time pressure in the probability to engage in herding behavior. In column 3 we add the variable *Self confidence* which is significant and negative, which suggests that more confident subjects were less likely to use public information. In column 4 the interaction term of *Self confidence* and *High time pressure* (variable *SelfConHigh*) is marginally significant and positive which shows that under a high level of time pressure, the normally more confident subjects are more likely to use public information. In column 5 the *Similarity score* indicating the value of similarity of the subject's first estimates to the first estimates seen on the screen with public information is added, the coefficient of which is significant on 1% level and negative. This means that when a subject had an estimate more similar to the estimates of others, she was less likely to change it. Column 6 then includes additional control for the cumulated profit earned in previous rounds which is significant and positive. This shows that the more ECU a subject had, the more likely she was to use public information, probably because subjects with higher earned money were less cautious about possible loss after changing their minds according to the public information. In the last column we control for risk preferences (adding the variable *Certainty equivalent*) which is insignificant and does not affect any of the coefficients. The personality characteristics included in the models are age, Female and the "Big Five" personality traits. Age is significant and positive across all specifications indicating that older subjects were more likely to switch from their original estimates. From the personality traits, Conscientiousness is marginally significant but this disappears with the addition of controls, when Extraversion gains marginal significance (columns 5 to 7), while its coefficient is negative, suggesting that extroverted individuals have a lower probability of being influenced by others. To contrast this result with the literature, Baddeley et al. (2010) used in a sample of 17 subjects a different set of personality traits which was, as in our case, also not interacted with gender to find that herding was less likely in extroverted and/or empathetic individuals. On the other hand, in a study of a large representative sample of the German population where the personality traits were interacted with gender, no impact was found on risk-preferences or impatience (Dohmen et al., 2010).

Table 2-7: Regression analysis.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES			InfoUsed				
High Time Pressure	0.0827	0.0787	0.0840	-0.102	-0.157	-0.161	-0.137
	(0.0528)	(0.0615)	(0.0538)	(0.105)	(0.120)	(0.122)	(0.128)
Medium Time Pressure		-0.00868					
		(0.0650)					
Age	0.0369**	0.0370**	0.0448***	0.0456***	0.0312*	0.0395**	0.0399**
	(0.0166)	(0.0166)	(0.0171)	(0.0173)	(0.0168)	(0.0183)	(0.0180)
Female	-0.0649	-0.0647	-0.103	-0.106	-0.0761	-0.0615	-0.0932
	(0.101)	(0.101)	(0.0953)	(0.0954)	(0.0856)	(0.0928)	(0.0944)
Openness to Experience	-0.00145	-0.00144	-0.00196	-0.00196	0.00146	7.86e-05	0.00429
	(0.00796)	(0.00797)	(0.00796)	(0.00800)	(0.00745)	(0.00776)	(0.00803)
Conscientiousness	-0.0151*	-0.0151*	-0.0115	-0.0117	-0.00970	-0.00889	-0.0115
	(0.00841)	(0.00841)	(0.00866)	(0.00874)	(0.00855)	(0.00866)	(0.00871)
Extraversion	-0.00391	-0.00389	-0.00809	-0.00829	-0.0135*	-0.0139*	-0.0159*
	(0.00788)	(0.00787)	(0.00822)	(0.00828)	(0.00760)	(0.00807)	(0.00883)
Agreeableness	0.00568	0.00565	0.00934	0.00943	0.0123	0.0126	0.00318
	(0.0106)	(0.0107)	(0.0100)	(0.0102)	(0.00890)	(0.00930)	(0.00983)
Neuroticism	-0.000637	-0.000621	-0.00462	-0.00488	-0.00875	-0.00728	-0.0123
	(0.00929)	(0.00926)	(0.00955)	(0.00963)	(0.00820)	(0.00874)	(0.00951)
Self confidence			-0.0873**	-0.111***	-0.129***	-0.134***	-0.114***
			(0.0386)	(0.0389)	(0.0316)	(0.0331)	(0.0327)
SelfConHigh				0.0727*	0.0780*	0.0802*	0.0786*
				(0.0408)	(0.0433)	(0.0444)	(0.0474)
Similarity score					-0.0685***	-0.0726***	-0.0726**
					(0.0256)	(0.0272)	(0.0284)
ln (Total Profit)						0.0397**	0.0349*
						(0.0172)	(0.0181)
Certainty equivalent							-0.0167
							(0.0104)
Observations	287	287	287	287	287	287	264
Pseudo R2	0.0401	0.0402	0.0638	0.0682	0.158	0.174	0.180
Log-Likelihood	-187.5	-187.5	-182.9	-182.1	-164.5	-161.3	-145.8
Chi2	11.47	11.79	17.00	20.07	31.37	33.38	35.04

Note: Marginal effects after probit. Dependent variable: *InfoUsed*. Robust standard errors clustered at individual level in parentheses. *, ** and *** indicate significance on 10%, 5% and 1% level, respectively.

Next we turn our attention to the role of stress. Since the treatment intervention increased both levels of subjective stress as well as heart-rate, we cannot put all these variables into a single regression due to endogeneity. However we provide an exercise where we substitute the dummy for the High time pressure with the two other variables; the results are presented in Table

2-8. When we regress *InfoUsed* only on the levels of subjective stress, this variable is significant and negative, similarly to when we use the increase in heart-rate instead. All of these results hold even after controlling for the personality variables as in Table 2-7 (columns 4 to 6). This suggests that with higher stress, people tend to use the public information less in their decisions.

Table 2-8: Regression analysis, focus on stress dimension.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES			InfoUsed			
High Time Pressure	0.0674			0.0827		
	(0.0499)			(0.0528)		
Subjective Stress		-0.0343**			-0.0357**	
		(0.0154)			(0.0150)	
HR increase			-0.0147**			-0.0153**
			(0.00610)			(0.00636)
Observations	287	287	203	287	287	203
Personality controls	NO	NO	NO	YES	YES	YES
Pseudo R2	0.00297	0.0194	0.0461	0.0401	0.0541	0.106
Log-likelihood	-194.8	-191.6	-130.2	-187.5	-184.8	-122.1
Chi2	1.834	4.873	5.783	11.47	17.64	10.79

Note: Marginal effects after probit. Robust standard errors clustered on individual level in parentheses. *, ** and *** indicate significance on 10%, 5% and 1% level, respectively. Personality controls include Age, Female, and the Big-Five personality traits; their coefficients behave similarly as in Table 2-7, results available upon request.

In the next step we focus on the role of the time. Similarly as in the preceding sections, we have to separate the time variables from the dummy indicating the level of time pressure because of potential endogeneity in estimation. In Table 2-9 we present the estimation results when the dummy indicating High time pressure is substituted by *TimeDeciding* which is the time subjects spent on the screen with the public information (column 2) and by *TimeLeft* which is the number of seconds they had remaining to finish the task. The variable *TimeDeciding* is highly significant and positive, which is a sign that the longer they examined the public information, the more likely they were to use it. An alternative interpretation is that after observing the public information, they either decided to switch to a new estimate or not; and if so, then they tried to identify the best new estimate which was time consuming. The coefficient of the variable *Time left* is not significant which tells us that there was no impact of how much time the subjects had left for their decision on the probability to use public information.

Table 2-9: Regression analysis, focus on time dimension.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES			*InfoUsed*			
High Time Pressure	0.0674			0.0827		
	(0.0499)			(0.0528)		
TimeDeciding		0.0361***			0.0395***	
		(0.00803)			(0.00800)	
Time left			0.000674			0.000539
			(0.00123)			(0.00124)
Observations	287	287	287	287	287	287
Personality controls	NO	NO	NO	YES	YES	YES
Pseudo R2	0.00297	0.136	0.00125	0.0401	0.179	0.0365
Log-likelihood	-194.8	-168.9	-195.1	-187.5	-160.4	-188.3
Chi2	1.834	21.25	0.301	11.47	48.26	9.307

Note: Marginal effects after probit. Robust standard errors clustered on individual level in parentheses. *, ** and *** indicate significance on 10%, 5% and 1% level, respectively. Personality controls include Age, Female, and the Big-Five personality traits; their coefficients behave similarly as in Table 2-7, results available upon request.

Hypothesis evaluation

Hypothesis 1 – Herding and time pressure

The dummy variables indicating the levels of time pressure are not significantly different from zero, and this result is fairly stable across various specifications except for one, so we can conclude that there is no general relationship between the level of time-pressure and tendency to herd. The time dimension which was different under the three levels of time pressure played an important role in the sense that the time they spent looking at the public information was significantly positively associated with the probability to use the public information, but the mechanism may be more complicated as noted above.

Hypothesis 2 – Stress and heart-rate increase

The average increase in the heart-rate during the task to the base level was 16.47 so the variable *HR_Increase* looks like a good measure of the induced stress, and it is significantly positively correlated with subjectively stated level of stress. The break-down by the level of time pressure and gender shows that it is driven by women under High time pressure. However, heart-rate can increase not only due to stress, but also due to effort, which could be our case. Therefore the correlation between subjective stress and heart-rate increase is significant but rather small in magnitude. When regressed on *InfoUsed*, both stress variables are significantly negatively associated with the probability to use public information on a 1% level of significance which can be interpreted that with higher stress levels, people have a lower tendency to engage in herding behavior.

2.6 Conclusion

The main purpose of this paper is to shed light on the relationship between the individual propensity to herd and time pressure. To do this, we designed and carried out a laboratory experiment where we measured the occurrence of herding as a 0/1 variable when participants changed their original decision after being exposed to information about the decisions of others. Apart from the behavior in the task, we also tracked individual attributes such as risk preferences, task-specific confidence, personality traits and subjective levels of stress as well as heart-rate which is a sign of physiological stress.

The central result of this experiment is that time pressure indicated by indicator variables plays no significant role in predicting the tendency to herd, even though there was a behavioral change indicative of higher herding under high time pressure. Nevertheless, variables indirectly associated with time pressure concerning the time dimension and stress, as revealed by the time spent on the screen with public information, reported subjective stress levels and heart-rate increases are robust and significant predictors of the tendency to herd. Contrary to our expectations, personality traits are not significantly associated with the tendency to herd, except for the trait Extroversion which is marginally significant after the addition of other control variables, however with a negative sign, contrary to results in other literature (Baddeley et al., 2010, 2007).

Apart from that, we show that time pressure can be used as a stressor: the level of reported subjectively perceived stress was significantly positively correlated to the heart-rate increase during a task solution, which was mostly driven by women under High time pressure. The correlation was rather weak which suggests that the heart-rate increase may have indicated rather physical arousal in general than stress. Another interesting finding is the positive correlation between the heart-rate increase and risk-aversion, mainly in men, which is an area for future research.

Generally speaking, even though the results from this experiment have to be treated with care due to the specific nature of the given task, this experiment has provided initial insights into the state of the analysis of behavior under time pressure in connection to the propensity to herd. Since we show that both stress variables positively influence the tendency to herd while there is no effect of time pressure *per se*, stress may be the channel which actually changes the propensity to herd and thus should be examined in further research.

2.7 Appendix

Table 2-10: Descriptive statistics of the variables used in the model.

variable	label	N	Minimum	Maximum	Mean	Std. Deviation
InfoUsed	If really used the info	287	0	1	0.42	0.49
Similarity score	Score of similarity of own estimate to the others' values	495	1	15	3.27	2.71
TimeDeciding	Time spent on screen with public information	942	0	67.38	3.34	6.72
TimeLeft	Time left when original estimate set	760	0	157	43.67	32.44
TP_Medium	Medium Time Pressure	760	0	1	0.33	0.47
TP_High	High Time Pressure	760	0	1	0.34	0.47
O	Openness to Experience	90	26	50	39.94	5.25
C	Conscientiousness	90	22	46	34.00	5.44
E	Extraversion	90	17	48	32.80	6.63
A	Agreeableness	90	24	48	34.60	4.65
N	Neuroticism	90	10	38	25.81	5.23
SubjectiveStress	Stress (Subjective)	760	1	10	5.76	2.45
Female	Female if 1	90	0	1	0.38	0.49
Certainty Equivalent	Certainty equivalent	90	2	21	14.59	3.45
RiskAverse	Weakly Risk Averse	90	0	1	0.92	0.28
Self Confidence	Self Confidence	90	1	5	3.17	1.24
TotalProfit	Total Profit	942	0	2017	347.54	397.71
HR_Increase	Difference of base-line to actual HR	677	0	53	16.47	9.82

Table 2-11: Correlations of certainty equivalent (CE) with stress measures across levels of time pressure.

		TP Low		TP Medium		TP High		all	
		HR_DIF	SubjStress	HR_DIF	SubjStress	HR_DIF	SubjStress	HR_DIF	SubjStress
CE	Pearson Corr	-0.166**	-0.050	-0.137	-0.070	-0.147**	-0.066	-0.154***	-0.062
	p-value	0.033	0.455	0.078	0.289	0.056	0.311	0.00	0.104
	N	166	229	167	185	170	235	609	696
					Female				
CE	Pearson Corr	-0.024	-0.019	0.143	-0.072	0.091	0.068	0.074	-0.010
	p-value	0.860	0.869	0.285	0.521	0.487	0.542	0.285	0.871
	N	58	81	58	82	60	84	212	247
					Male				
CE	Pearson Corr	-0.249***	0.083	-0.312***	0.051	-0.303***	0.053	-0.281***	0.059
	p-value	0.009	0.319	0.001	0.535	0.001	0.519	0.00	0.209
	N	108	148	109	150	110	151	397	449

Table 2-12: Regression analysis, no personality controls.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES				InfoUsed			
High Time Pressure	0.0674	0.0616	0.0662	-0.0798	-0.136	-0.139	-0.121
	(0.0499)	(0.0595)	(0.0504)	(0.102)	(0.115)	(0.117)	(0.120)
Self confidence			-0.0480	-0.0656*	-0.0842***	-0.0836**	-0.0811**
			(0.0360)	(0.0370)	(0.0321)	(0.0341)	(0.0369)
Self confidence * TP_High				0.0561	0.0646	0.0662	0.0657
				(0.0382)	(0.0405)	(0.0412)	(0.0433)
Similarity score					-0.0695***	-0.0737***	-0.0716***
					(0.0239)	(0.0256)	(0.0266)
ln (Total Profit)						0.0310	0.0272
						(0.0195)	(0.0208)
Certainty equivalent (CE)							-0.00551
							(0.00821)
CE * Female							-0.00966
							(0.00602)
Medium Time Pressure		-0.0125					
		(0.0650)					
Observations	287	287	287	287	287	287	264
Personality controls	NO	NO	NO	NO	NO	NO	NO
Pseudo R2	0.00297	0.00305	0.0125	0.0153	0.114	0.126	0.133
Log-likelihood	-194.8	-194.8	-192.9	-192.4	-173.1	-170.8	-154.3
Chi2	1.834	1.903	3.759	5.703	17.20	16.02	21.21

3 Chapter Three: Risk Preferences under Acute Stress[14]

Co-authored by Jana Cahlíková

Abstract

Many important decisions are made under stress and they often involve risky alternatives. There has been ample evidence that stress influences decision making, but still very little is known about whether individual attitudes to risk change with exposure to acute stress. To directly evaluate the causal effect of psychosocial stress on risk attitudes, we adopt an experimental approach in which we randomly expose participants to a stressor in the form of a standard laboratory stress-induction procedure: the Trier Social Stress Test for Groups. Risk preferences are elicited using a multiple price list format that has been previously shown to predict risk-oriented behavior out of the laboratory. Using three different measures (salivary cortisol levels, heart rate and multidimensional mood questionnaire scores), we show that stress was successfully induced on the treatment group. Our main result is that for men, the exposure to a stressor (intention-to-treat effect, ITT) and the exogenously induced psychosocial stress (the average treatment effect on the treated, ATT) significantly increase risk aversion when controlling for their personal characteristics. The estimated treatment difference in certainty equivalents is equivalent to 69% (ITT) and 89% (ATT) of the gender-difference in the control group. The effect on women goes in the same direction, but is weaker and insignificant.

[14] This chapter has been accepted in the journal Experimental Economics and has been published in a version slightly different from this chapter under Cingl, L., & Cahlíková, J. (2013). Risk Preferences under Acute Stress. IES Working Paper No. 17/201. IES FSV, Charles University in Prague.

3.1 Introduction

In recent decades, stress has become an integral part of society. Daily decision making in many professions involves risky choices under severe pressure or even stress, such as trading stocks, diagnosing patients in emergency rooms, or controlling air-traffic. Stress is an instinctive psychological, physiological and behavioral reaction to perceived threats and as such it cannot be controlled by human will (Goldstein & McEwen, 2002). Most people have to face stressful situations with risky choices throughout their lives, for instance university exams, job-interviews, asking for promotions, or starting their own businesses. The choices made in these situations are crucial determinants of economic outcomes and therefore we consider it important to understand whether they might be affected by stress.

In the context of developing countries, poverty remains one of the most pressing global issues, with 836 million people still living on less than 1.25 a day (United Nations, 2015). Recently it has been argued that poverty causes stress and a negative emotional state which can play an important role in the perpetuation of poverty by increasing risk-aversion and lowering patience (Haushofer & Fehr, 2014). Risk preferences are relevant for the housing, investment, schooling, and occupational decisions of the poor. Higher risk-aversion could lead to choices that make it hard to escape poverty, thus creating a feedback loop. Poverty is indeed found to be correlated with higher risk-aversion (Guiso & Paiella, 2008; Yesuf & Bluffstone, 2009) and the first part of the proposed relationship—poverty causes stress—has been well established (Haushofer & Fehr, 2014; Haushofer & Shapiro, 2013; Chemin et al., 2013). Still, much less is known about the causal relationship between stress and risk preferences, a question that we examine in this paper.

Moreover, risk preferences are incorporated in major economic theories in fields ranging from finance, labor economics, the economics of innovation to development economics. These theories typically assume the stability of risk preferences, which in turn allows for an elegant solution to the proposed models. However, increasingly more evidence shows that this assumption may not always hold: risk preferences may temporarily fluctuate (Cohn et al., 2015; Guiso et al., 2013), can be affected by the direct administration of cortisol (Kandasamy et al., 2014), and emotions (Nguyen & Noussair, 2014). We contribute to this literature by studying the stability of risk preferences with respect to stress.

Behavioral changes under stress have been studied extensively in the psychological literature, mainly looking at the effects of stress on memory and performance, but also on various other aspects of decision making (see review in Starcke & Brand, 2012). However, due to the methodological limitations of previously published studies, only little is known about the effect of stress on risk preferences. Our study differs from the previous literature by (i) using an efficient stressor and a risk task that is (ii) easy to understand and (iii) involves neither feedback processing nor learning which itself may be affected by stress (Petzold, Plessow, Goschke, & Kirschbaum, 2010).

In this paper, we identify the causal effect of stress on risk preferences using a laboratory experiment with 151 subjects, who are randomly assigned to a stress treatment or a control group. Our stress-inducing procedure, the Trier Social Stress Test (Kirschbaum et al., 1993) in the group modification (TSST-G, von Dawans et al., 2011), is well-established in the literature and has been shown to be one of the most efficient laboratory stressors in terms of physiological as well as psychological reactions (Dickerson & Kemeny, 2004). We use three different measures to validate the efficiency of the TSST-G procedure: two physiological (heart-rate and salivary cortisol concentration) and one psychological (Multi-Dimensional Mood Questionnaire scores, MDMQ, Steyer, Schwenkmezger, Notz, & Eid, 1997). To elicit risk-preferences we use the task of Dohmen, Falk, Huffman, & Sunde (2010), which is easily comprehensible to subjects, is incentive compatible and has been shown to predict risk-taking behavior outside of the laboratory in 30 countries (Vieider et al., 2014).

In addition, we measure the ”Big-Five” personality traits (Costa & McCrae, 1992; Goldberg et al., 2006) that are one of the most enduring and popular models of personality and include them in our analysis. We do so because recent laboratory experiments have shown that personality plays an important role in the explanation of individual risk-attitudes, potentially through the mediation of emotions that may be connected to stress; and because personality may reflect generally stable patterns in behavior, motivation and cognition (Capra, Jiang, Engelmann, & Berns, 2013; Deck, Lee, & Reyes, 2010; Deck, Lee, Reyes, & Rosen, 2012).

We were successful in inducing stress using the TSST-G procedure. All three measures of stress responded in the expected direction: compared to the reaction of the control group, the cortisol levels and heart-rates of the treatment group increased and their reported mood shifted towards the bad and nervous poles. On an individual level, when we focus on the increase of salivary cortisol as an indicator of stress, we show that the compliance rate i.e. the correct physiological response to either the TSST-G stress or control procedure is 78%.

Our main result is that acute psychosocial stress increases risk aversion in men, when controlling for personal characteristics. The estimated magnitude of the effect is comparable to the gender difference in risk-attitudes. Since not all subjects exposed to the stress-inducing procedure were actually stressed and vice-versa, we need to face the problem of imperfect compliance. Therefore in the analysis we distinguish between the intention-to-treat effects (ITT - effect of random exposure to the stressor on risk preferences) and the average treatment effect on treated (ATT, effect of being stressed on risk preferences). The ATT effect is estimated using a two-stage instrumental variable regression, with random exposure to the stressor used as an instrument for the physiological state of stress. The ITT and ATT effects of stress on risk preferences are significant for men at 10% and 5% level, respectively, when controlling for age and "Big-5" personality traits, showing that stress increases risk-aversion. The effect on women goes in the same direction, but is insignificant.

3.2 Methodology

3.2.1 Measurement of Risk Preferences

Risk preferences were elicited using a simple task similar to the one in Dohmen et al. (2010), where participants repeatedly chose between a lottery and different safe payments. Subjects had to fill in a table of 10 rows, where in each row the lottery stayed the same paying either 4,000 ECU or 0 ECU with 50% probability each, but the safe payment gradually increased from 0 ECU by increments of 300 ECU up to 2,700 ECU. Detailed instructions and a screenshot of the decision-making task can be found in the Appendix. Subjects knew that one row would be randomly determined for payment and that they would be paid according to their choices in that row. We allowed for inconsistent behavior; subjects filled in all 10 rows and were not in any way guided to a single switching point. The risk task was programmed in and conducted with the software Z-TREE (Fischbacher, 2007).

If the individual's behavior is consistent, then the row where the subject switches preferences indicates the individual certainty equivalent, i.e. the safe amount which makes the individual indifferent to choosing or not choosing the lottery. For the descriptive statistics, the individual certainty equivalent is determined as the central point of the switching interval. For interval regressions, the certainty equivalent is specified as lying in the interval between the two safe amounts where the switch occurred.[15] As the expected value of the lottery is 2,000 ECU, risk neutral subjects should start by preferring the lottery up to the safe amount equal to 1,800 ECU (row 7) and then switch to preferring the safe amounts. Risk-averse subjects may switch to preferring safe amounts earlier, with the switching row depending on their degree of risk-

[15] For example, if the participant preferred the lottery up to row 6 (safe amount=1,500 ECU) and switched to preferring the safe amount starting in row 7 (safe amount=1,800 ECU), 1,650 ECU is taken as the certainty equivalent. For the interval regression, the certainty equivalent is defined as lying between 1,500 and 1,800 ECU.

aversion (the more risk-averse they are, the earlier they switch). Only risk-loving subjects should choose lottery for the safe amounts greater than or equal to 2,100 ECU.

3.2.2 Trier Social Stress Test for Groups

Stress was induced by a standard validated stress procedure the Trier Social Stress Test for Groups (von Dawans et al., 2011) which is a modified version of an individual TSST originally developed in Kirschbaum et al. (1993). The TSST-G provides a combination of a social-evaluative threat and uncontrollable elements, which are the key attributes of an efficient psychosocial stressor (Dickerson & Kemeny, 2004). Specifically, the TSST-G treatment (i.e. stress-inducing) protocol consists of two parts -- a public speaking task and a mental arithmetic task that are performed in front of an evaluation committee. The control group faces cognitively similar tasks but with no stressful aspects present.

In our case, during the public speaking task each participant was asked to perform her best at a fictive job interview for two minutes. In the second part during the mental arithmetic task participants were asked one by one to serially subtract 17 from a high number (e.g. 4878) for two minutes. Participants were called one by one in random order, were separated by cardboard barriers and wore headphones so that they would not see or hear the other participants. The two committee members wore white laboratory coats and had two video cameras at their sides that recorded the performance of the participants. The committee was trained not to give any feedback on the subjects' performance, neither verbally or physically.

The full TSST-G control protocol was applied to the control group, which mirrors the activities of the treatment protocol but omits the stressful aspects of the situation. Participants also went through a public speaking task where they were asked to read a text out loud and then were given a simple mental arithmetic task, i.e. to count by multiples of a small number, e.g. 5-10-15 and so on. There was a committee present in the room, but they were not evaluating the performance of participants, did not wear white lab coats and was asked to act naturally. There were no cameras in the room and the participants did not have the headphones on.

To conform to the standards of experimental economics, we modified the TSST-G original protocol so that it did not contain any deception or false information. These modifications concerned mainly the information given to the participants in the treatment condition; they were not told that the panel members were trained in behavioral analysis, and we did not tell them that the video recordings would later be analyzed.[16]

[16] The detailed treatment and control instructions and protocol scripts can be provided on a request.

3.2.3 Measurement of Stress Response

To measure individual stress response, we combine two physiological measures, salivary cortisol concentration and heart rate, and one psychological measure of stress reaction. First, cortisol is the final hormone of the major endocrine stress axis of the human body (hypothalamic-pituitary-adrenal axis, Dedovic et al., 2009) and Foley & Kirschbaum (2010) show that it is highly predictive of psychosocial stress, while being the most commonly used measure of stress in general. Cortisol concentration peaks in the interval approximately 20 to 40 minutes after the onset of the stressor (Dickerson & Kemeny, 2004). Saliva sample 1 was collected right before the TSST-G procedure, sample 2 was collected right after the stress procedure, and sample 3 was gathered before the risk-preferences protocol, approximately 15 minutes after the cessation of the stressor. We decided to use three samples in order to be able to show that (i) the groups did not differ in the cortisol levels before the TSST-G protocol, (ii) the TSST-G administration was successful and (iii) the reaction lasted as in the comparable experiments.[17]

Second, as shown in Kirschbaum et al. (1993), heart rate increases are correlated with endured psychosocial stress and can be used as a proxy for the immediate reaction of the sympathetic nervous system. The heart-rate of participants was measured with standard heart-rate monitors.[18] The individual difference between the average heart-rate during the TSST-G procedure and the average baseline level can be used as one measure of the induced stress.

Third, Multidimensional Mood Questionnaire (MDMQ, Steyer et al., 1997) was used to assess the effects of the TSST-G procedure on the mood of the participants.[19] Mood is measured in three dimensions: good-bad, awake-tired, and calm-nervous. The MDMQ questionnaire has two parts. In our case, participants filled in one part of the MDMQ right before the TSST-G procedure and the other part right after the TSST-G procedure, where the order of the two parts was randomized across sessions. Based on previous literature, we expected that the stress response would be associated with scores closer to the "bad" and "nervous" poles of the respective dimension (Allen, Kennedy, Cryan, Dinan, & Clarke, 2014).

---

[17] Saliva samples were collected using a standard sampling device Salivette. The samples were frozen to -20˘C after each experimental session and the salivary cortisol concentration was analyzed by the laboratory of the Biopsychology department at TU Dresden and by the Department of the Clinical Biochemistry at the Military Hospital in Prague. Prior to the experiment we conducted a separate pilot session where only the TSST-G procedure was administered and five saliva samples were collected and analyzed. The dynamics of the cortisol elevation in the pilot session followed the trajectory common in the literature (e.g. in von Dawans et al., 2011) including the recovery phase and therefore we assume the same trajectory in our subjects. Moreover, cortisol levels show a short-term pulsatility and therefore only one post-stress sample is insufficient to prove the increase in cortisol levels (Young, Abelson, & Lightman, 2004).

[18] The types used are Polar RS400 and Polar S725X which are composed of a wireless chest transmitter and a wrist monitor. The recording precision was 1s (Polar RS400) or 5s (Polar S725X).

[19] An English version of the MDMQ was used. Available at: http://www.metheval.uni-jena.de/mdbf.php

3.2.4 Measurement of Personality Traits

Apart from basic observable characteristics, such as gender or age, personality traits can also explain individual differences in risk attitudes (Borghans et al., 2008; Heckman, 2011). Becker, Deckers, Dohmen, Falk, & Kosse (2012) find that economic preferences and personality traits are not substitute, but rather complementary concepts for explaining economic choices. To capture the personality profile of participants, we used a battery of 50 questions to construct the "Big Five" factors that are Openness to Experience, Conscientiousness, Extraversion, Agreeableness and Neuroticism (Goldberg, 2010). The "Big Five" factors are the most commonly used measure of personality traits, where each factor represents a summary of a large number of specific personality characteristics (Costa & McCrae, 1992).

3.3 Experimental Procedure

The experiment was run at the Laboratory of Experimental Economics in Prague in two batches: the first six sessions were run in May/June 2012 and the additional five in November 2014. All the procedures were identical so we pooled the results. Each session included treatment and control group with 7 subjects in each.[20] All of the sessions were conducted between 4:30 PM and 7:00 PM to control for the impact of the circadian variability in cortisol levels. Each session lasted on average a little less than two and a half hours. The average payment was 500 CZK (about EUR 20), including the fixed show-up fee of 150 CZK (about EUR 6). Throughout the experiment, all payoffs were denominated in experimental currency units (ECU), with the conversion rate was set to 32 ECU = 1 CZK. The whole experiment was run in English, which is the standard working language in this laboratory. No communication among the participants was allowed. The study was approved by the Internal Review Board of the Laboratory of Experimental Economics.

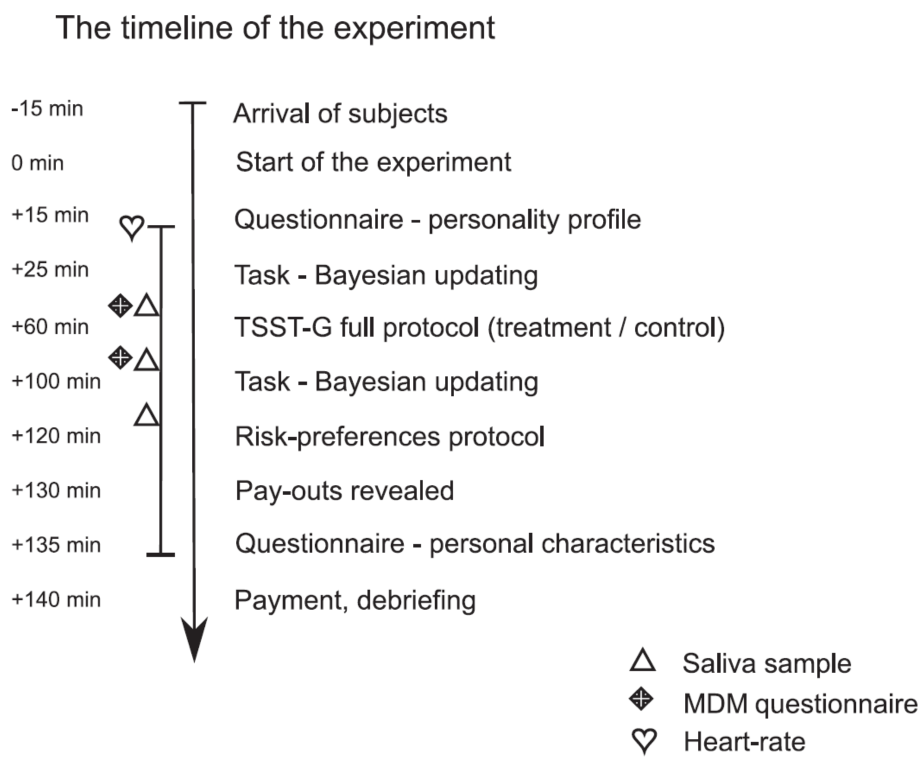
Subjects were recruited via the standard on-line recruitment-system ORSEE (Greiner, 2004). In addition to standard invitation, subjects were informed in the recruitment e-mail that through-out the experiment, the physiological responses of their bodies would be measured using standard procedures. For this reason, they were instructed to abstain from heavy food, nicotine intake and strenuous exercise at least two hours prior to the experiment. No further specification regarding the content of the experiment was given, in order to avoid self-selection.

Before the start of the experiment, the participants filled in a screening questionnaire in order to find out if there were any circumstances that would interfere with the cortisol

[20] For session 1 only 11 participants arrived.

measurement. Before entering the laboratory, subjects were randomly assigned into either the control or treatment group. We made sure that women taking oral contraceptives were evenly distributed across the two groups.

Figure 3-1: The timeline of the experiment



The timeline of the experiment is summarized in Figure 3-1. The instructions explaining the general procedure of the experiment were read aloud first and subjects were then asked to sign an informed consent form. In the consent form and through-out the experiment, the TSST-G protocol was referred to as a "challenge task". It was emphasized in the consent form that subjects could leave at any point of the experiment, still receiving their show-up fee.

The heart-rate monitors were attached and subjects were asked to fill-out a questionnaire to measure their personality traits. They were then given instructions on a task studying Bayesian updating and completed two trial and five real rounds of this task (results from this task are not reported in this paper).[21] Next, the first saliva samples were collected and participants filled in the first part of the MDMQ questionnaire.

[21] See Chapter 4 for details about the design of the Bayesian updating task. This task does not confound the results in this paper as subjects learned about their payment from the Bayesian updating task only at the end of the experiment. Even though subjects' expected earnings may still matter, we do not consider this as issue as the TSST-

Afterwards, instructions to either the TSST-G stress-inducing treatment or TSST-G stress-free control procedure were distributed, describing the tasks that would follow. Subjects in the treatment group were informed that they would be evaluated in public and recorded on video. Subjects read the instructions quietly and had five minutes for preparation. Then the groups were taken to two separate rooms where they completed the TSST-G treatment or control procedure, which lasted about 30 minutes.

When finished, the participants arrived back in the laboratory, gave the second sample of their saliva, filled in the second part of the MDMQ questionnaire and continued in the task aimed at Bayesian updating for the following 15 minutes. Afterwards, the third saliva sample was collected and the risk-preferences task was run, which did not last more than five minutes. Then the payments for the whole experiment were revealed, subjects were asked to fill-out a questionnaire regarding their personal characteristics, returned the heart-rate monitors and were paid. After the participants from the control group had left, a thorough debriefing about the TSST-G treatment procedure was conducted.

3.3.1 Sample

In total 70 female (mean age 22.2, SD = 2.0 years) and 81 male subjects (mean age 22.8, SD = 3.1 years) took part in the experiment. Participants were mostly students of economics or related disciplines (73.5%). The participants had not participated in a TSST-G-related study before. With one exception the participants were all normal body-weight and 26 women indicated taking oral contraceptives.[22] From the end-questionnaire, we confirm that all subjects were unfamiliar with the stress-inducing procedure and they mostly did not know other participants. We repeat that they were required to sign an informed consent form, which emphasized an option to leave at any point of the experiment.[23] Out of the 151 participants, none decided to leave, but five were dropped from the analysis due to inconsistent answers in the risk-preferences task (see below), so we were left with 71 observations in the treatment group (39 men and 32 women) and 75 observations in the control group (41 men and 34 women).

Descriptive statistics of the sample with respect to our main control variables are presented in the Appendix Table 3-10. Our treatment and control groups are balanced regarding

---

G treatment group actually earned slightly more money in the Bayesian task compared to the control group, but the difference is not significant.

[22] Above-normal weight (BMI above 25) and the intake of hormonal contraceptives may affect cortisol response to stress (Kudielka et al., 2009). Out of the 26 women indicating intake of oral contraceptives, 13 were assigned to the treatment group.

[23] One subject left in the pilot session prior to the TSST-G procedure, confirming that this option was salient enough.

gender and age. The sample of men is balanced for all observed characteristics except for the "Big-5" personality trait Neuroticism, while for women we saw an imbalance in Extraversion. To make sure potential imbalances in personality traits do not influence our results regarding the effect of the exposure to the stressor on risk preferences, we control for the "Big-5" personality traits in the following analysis.

3.4 Results

3.4.1 Stress Response

First, we show that our external manipulation was successful: stress was induced in the participants in the TSST-G treatment procedure but not in the participants in the control procedure.

The dynamics of our primary measure of stress, the cortisol reaction, are presented in Figure 3-2. As a response to the TSST-G procedure, salivary cortisol levels significantly increased for the treatment group, but remained stable over time for the control group. The average maximum cortisol response, calculated as the maximum difference between the baseline sample (sample 1) and samples taken after the stress-inducing procedure (sample 2 or 3), was an increase of 10.47 nmol/l in the treatment group (SD=11.38) and a decrease of -0.31 nmol/l in the control group (SD=2.96).

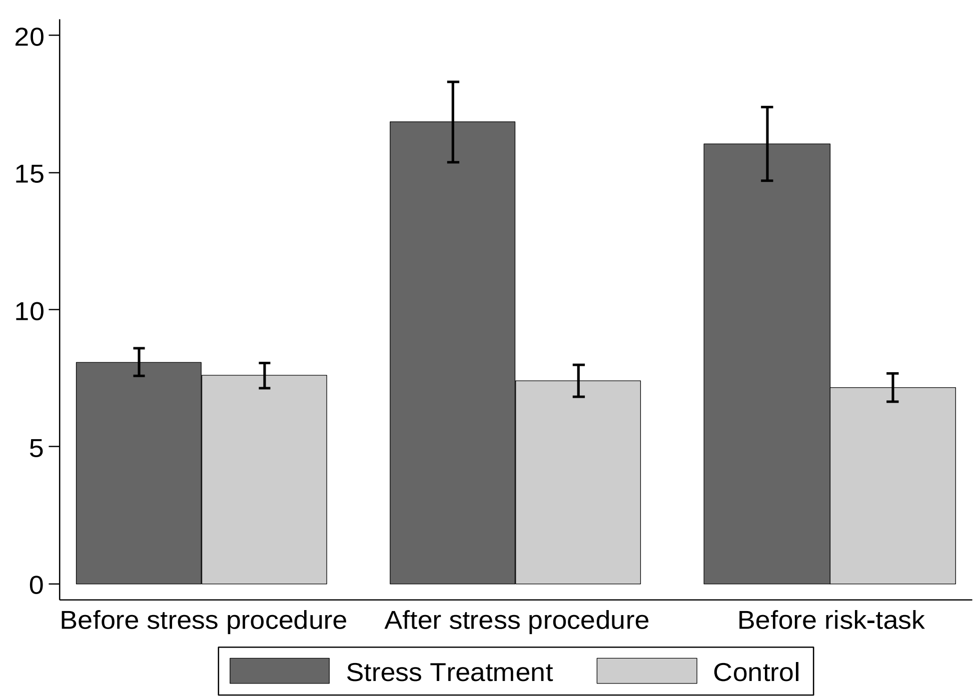
In other words, the treatment and the control group do not differ in cortisol levels before the stress procedure (sample 1: p=0.570, d=-0.13), but the cortisol level is significantly higher for the treatment group both immediately after the TSST-G procedure (sample 2: p<0.001, d=-1.10) and 15-20 minutes after its end, right before the risk-preferences task (sample 3: p<0.001, d=-1.09). The differences are tested using a two-sample Wilcoxon rank-sum test and the reported effect sizes are Cohen's *d*, unless stated otherwise. The stress manipulation was successful for both genders, as reported in Figure 3-6 in the Appendix. In line with results from comparable studies, the cortisol response to the stress treatment was stronger among males (Kudielka, Hellhammer, & Wüst, 2009).

Similarly, the average heart-rate of subjects during the TSST-G stress procedure is significantly higher than the heart-rate of subjects during the control procedure (p=0.058, d=-0.42), but not afterwards (p=0.231, d=-0.16). When we look at the average heart rate response associated with the TSST-G procedure (average heart rate during the procedure - average heart rate prior to the procedure), the average heart rate increases for both treatment and the control group, but significantly more for the treatment group (p=0.023, d=-0.46). Heart-rate dynamics is plotted in Figure 3-7.

To measure the psychological response to stress, we test the effect of the TSST-G stress-induction/control procedure on the mood of the participants, using a good-bad dimension, awake-tired dimension and calm-nervous dimension from the Multidimensional Mood Questionnaire. As summarized in Figure 3-8, the treatment and control group score similarly in all three dimensions before the TSST-G procedure, but subjects who underwent the TSST-G stress-induction procedure feel worse ($p<0.001$, d=0.71) and more nervous ($p<0.001$, d=0.63) compared to subjects who underwent the TSST-G control procedure. The treatment group also feels more awake, but the difference is not significant (p=0.177, d=-0.17). These results are robust across gender, see Figure 3-9 in the Appendix.

The results of our stress manipulation confirm that stress reaction is complex and cortisol can be used only as a proxy for the stress response. The maximum cortisol response is correlated not only with the heart rate response (ρ =0.344, $p<0.001$, Spearman's rank correlations), but also with the psychological measures in the good-bad dimension (ρ=-0.296, $p<0.001$) and in the calm-nervous dimension (ρ =-0.208, p=0.013).

Figure 3-2: Induced Stress Reaction: Mean levels of free salivary cortisol.



Note: *Stress Treatment*: indicator variable equal to 1 if subjects were exposed to the TSST-G stress-induction procedure, *Control*: subjects were exposed to the TSST-G control procedure. Sample 1 was collected before the TSST-G stress-induction/control procedure, sample 2 after the TSST-G procedure and sample 3 before the risk task. Error bars indicate mean +/- SEM.

3.4.2 Compliance

We have shown that the manipulation of the stress condition was successful on the aggregate level. To analyze compliance on an individual level, we focus on the cortisol response.

We define that a participant is stressed if their maximum cortisol response is greater than 2.5 nmol/l as is standard in the literature and may be even overly conservative (R. Miller, Plessow, Kirschbaum, & Stalder, 2013). Following this classification, 52 out of 75 subjects in the treatment group are stressed and 60 out of 71 subjects in the control group are not stressed, so the compliance rate is 78%.[24] We have a lower compliance rate among women in the treatment group, which is consistent with women showing weaker cortisol response to TSST in general (Allen et al., 2014).

Of course, stress reaction is generally highly complex and cortisol reactivity individual, so this approach is necessarily a simplification. However, we still consider using the cortisol response as a proxy for being stressed a useful simplification as it enables us to distinguish the effect of random exposure to the stress treatment from the physiological effect of stress on risk preferences (see below).

3.4.3 Risk Preferences

Starting with the descriptive statistics of the elicited risk attitudes, we see that inconsistent behavior, i.e. multiple switches between preferring lottery and safe payment in the risk task occurred in five cases (four in the control group, one in the treatment group). These subjects were dropped from the analysis, as their certainty equivalent could not be inferred.[25] For the remaining 146 observations (75 in the treatment group and 71 in the control group), the modal certainty equivalent is 1,950 ECU, the median is 1,650 ECU and 83% of subjects are weakly

[24] The maximum cortisol response is not available for two subjects in the control group, where saliva samples could not be analyzed.

[25] We perform two robustness checks of our results, in which we do not drop the multiple switchers from the analysis. In the first robustness check, risk preferences are measured not using the elicited certainty equivalent, but using the number of risky choices made. We then estimate the intention-to-treat effect of stress on risk preferences using ordered probit. As a second robustness check, we treat the inconsistent subjects as indifferent between the safe amounts and the lottery for the entire interval in which multiple switches occur, as suggested by Andersen, Harrison, Lau, & Rutström (2006). This means that the certainty equivalent of these subjects is elicited in a wider interval than the certainty equivalent of subjects who switch just once. The intention-to-treat effect of stress on risk preferences is then estimated using interval regression. The results of both robustness checks are reported in Table 3-7 in the Appendix and show that results presented in the main text are robust to including the multiple switchers.

risk-averse, i.e. their certainty equivalent is below 2,000 for a lottery paying either 4,000 ECU or 0 ECU with 50% probability each.

To talk about the effect of stress on risk preferences, we need to distinguish the effect of random exposure to the stressor (the TSST-G stress-induction procedure) on risk preferences from the effect of stress (a physiological state of the body) on risk preferences. The problem of imperfect compliance does not usually arise in economic experiments performed in the laboratory, but it is a relevant issue when estimating the effects of laboratory-induced stress.

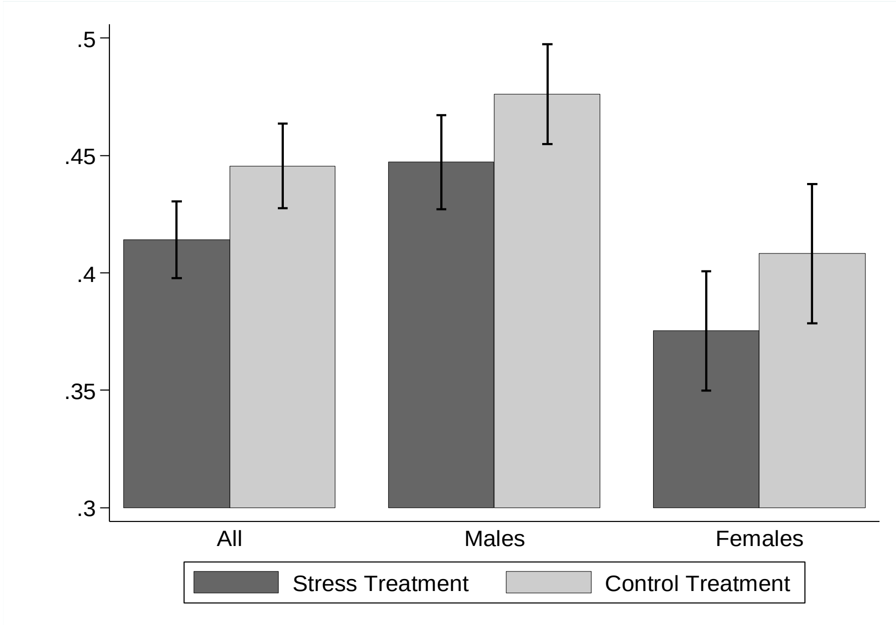
We start the analysis by presenting the differences in risk attitudes between the TSST-G treatment and control group, to estimate the effect of random exposure to the psychosocial stressor on risk preferences (intention-to-treat effect, ITT). Next, we show correlation between induced physiological stress and risk attitudes, using cortisol response as a proxy for the endured stress. To estimate the causal effect of physiological stress on risk preferences (the average treatment effect on the treated, ATT), we apply a two-stage instrumental variable regression with random exposure to the stressor as an instrument for the induced physiological stress.

3.4.4 Effect of Exposure to Stressor - ITT

Risk preferences of the TSST-G stress and control groups are summarized in Figure 3-3, which presents the elicited certainty equivalent for a lottery paying either 4,000 ECU or 0 ECU with 50% probability each. The differences between the treatment and control groups will first be tested using a two-sample Wilcoxon rank-sum test, the reported effect sizes are Cohen's *d*.

Figure 3-3 shows that the group exposed to psychosocial stressor is more risk-averse than the control group, but the difference is not statistically significant for our sample size (N=146, p=0.192, d=0.2). As can be seen in Figure 3-3, the effect goes in the same direction for men and women, but is not significant for either group (Males: N=80,p=0.299, d=0.23; Females: N=66, p=0.447, d=0.18). Note that women in our sample are in general more risk-averse than men (p=0.001, d=0.51), which is a standard result in the literature, and this is true both for the treatment group (p=0.013, d=0.54) and for the control group (p=0.037, d=0.50).

Figure 3-3: Risk preferences by Stress Treatment.



Note: Risk preferences are presented using an elicited certainty equivalent for a lottery paying 4,000 ECU or 0 ECU with 50% probability each. *Stress Treatment*: indicator variable equal to 1 if subjects were exposed to the TSST-G stress-induction procedure, *Control*: subjects were exposed to the TSST-G control procedure. Error bars indicate mean +/- SEM.

Even though exposure to the stressor does not have significant effects on risk preferences using a simple mean comparison, we need to control for other observable characteristics that have been shown to affect risk preferences. Therefore, we conduct a more detailed analysis by regressing the elicited certainty equivalent on the treatment status *Exposed to stressor* and additional controls: gender, age, and personality traits measured prior to the stress procedure ("Big Five" – openness to experience, conscientiousness, extraversion, agreeableness and neuroticism), which have been found to be important determinants of risk preferences in the literature (Borghans et al., 2008; Dohmen et al., 2010; Dohmen & Falk, 2011). We also allow for different responses to treatment across gender by including an interaction term *Exposed to stressor*Female*. Effects are estimated using an interval regression, to account for the fact that certainty equivalents were elicited in intervals.

The results for the whole sample are reported in columns 1-3 of Table 3-1. Controlling for age and personality traits in column 3, we find that the assignment to treatment increases risk aversion (p=0.089) and we cannot reject the hypothesis that the effect is the same for both genders, as the interaction term *Exposed to stressor*Female* is insignificant (p=0.582). Still, running the regressions separately for men and women in columns 4 and 5, respectively, we show that the effect is driven by men (p=0.052); the effect on women is weaker and insignificant when estimated for this subsample separately (p=0.415). Ordered probit regression is used as a robustness check, marginal fixed effects are reported in the Appendix Table 3-5 for men, and in Table 3-6 for women. The results confirm that men exposed to the stressor are more likely to have the lower values of the certainty equivalent (1,350 and 1,650, for a lottery paying 4,000 ECU or 0 ECU with a 50% probability each) and less likely to have certainty equivalents of 1,950 and 2,250. The effects on women are again weak and insignificant.

To illustrate the size of the treatment effect estimated in columns 4 and 5, in Panel A of Appendix Table 3-12 we generate predicted certainty equivalents for an average man and an average woman in our sample, meaning that we fix their age and personality profile on the gender-specific average. Men in the control group have a predicted certainty equivalent equal to 1939 ECU (for a lottery paying 4,000 ECU or 0 ECU with a 50% probability each), while men exposed to the stressor have 1696 ECU. The prediction for women in the control and treatment groups yields values of 1587 ECU and 1469 ECU, respectively. Thus, the effect size among men is about twice the size of that found among women, and the estimated treatment effect for men is equivalent to 69% of the gender difference in the control group.

In Appendix Table 3-11 we run a sensitivity analysis to check which of the additional controls in Table 3-1 influence the results in the gender-specific regressions. For women, adding additional controls does not change the estimated treatment effect much. For men, it is controlling for the personality trait neuroticism alone which makes the difference (compare columns 4 and 3). Neuroticism is the trait that is not balanced across men in our treatment and control group and as it significantly affects risk-preferences in our sample, we find it appropriate to control for personality traits in our baseline analysis.

Table 3-1: Effects of random exposure to stressor on risk preferences

	(1)	(2)	(3)	(4)	(5)
	Interval regression				
Dependent variable	Certainty equivalent				
Sample	All	All	All	Males	Females
Exposed to stressor	-136.15	-145.27	-215.74*	-242.74*	-118.16
	(102.80)	(130.38)	(126.96)	(125.10)	(145.08)
Female		-300.30*	-203.41		
		(155.23)	(149.43)		
Exposed to stressor*Female		28.41	97.69		
		(203.97)	(177.70)		
Age		157.54	203.32	399.08**	-700.54
		(122.05)	(125.51)	(157.15)	(483.08)
Age squared		-2.82	-3.74*	-7.31***	15.08
		(2.21)	(2.25)	(2.77)	(10.51)
Big Five Personality Traits:					
Openness to experience			-2.26	-0.68	-9.43
			(11.74)	(11.18)	(20.40)
Conscientiousness			-3.37	-1.90	-7.63
			(8.30)	(9.76)	(12.97)
Extraversion			-0.61	-3.69	7.01
			(7.76)	(8.86)	(11.78)
Agreeableness			-17.07*	-1.01	-46.43***
			(9.61)	(10.55)	(15.56)
Neuroticism			16.28**	26.15***	1.48
			(7.54)	(9.73)	(10.54)
Constant	1,755.35***	-209.22	-450.74	-3,890.76	11,766.59**
	(77.68)	(1,637.60)	(2,160.63)	(2,657.66)	(5,911.69)
chi2	1.75	10.78	19.73	15.80	10.53
Observations	146	146	146	80	66

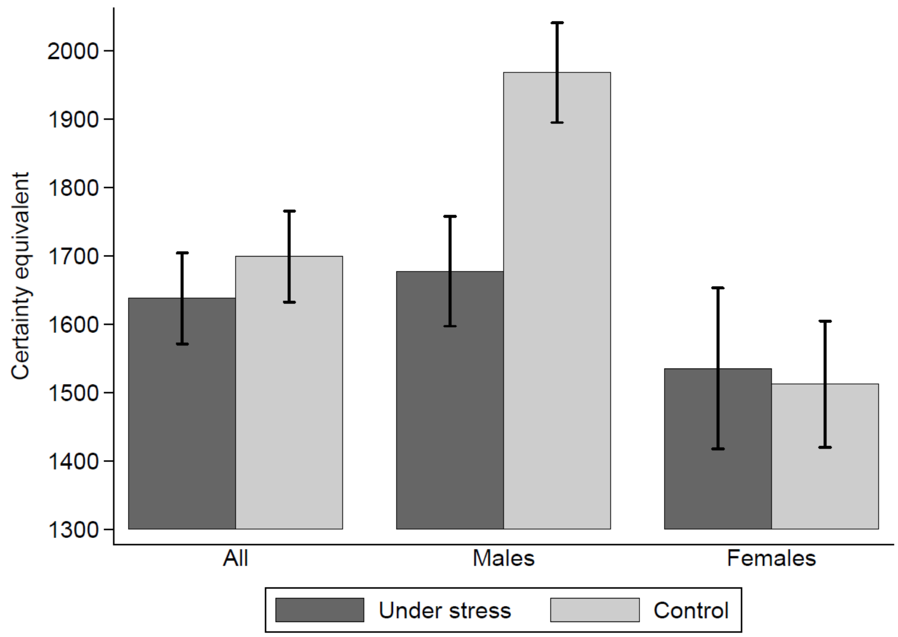
Notes: The dependent variable is the certainty equivalent for a lottery paying 4,000 ECU or 0 ECU with 50% probability each, calculated from the binary choices in the risk preferences task. *Exposed to stressor*: indicator variable equal to 1 if subjects were exposed to the TSST-G stress-induction procedure. The reported coefficients in columns 1-5 are marginal effects, estimated using interval regressions to correct for the fact that the dependent variable is elicited in intervals. Robust standard errors in the parentheses. *** p<0.01, ** p<0.05, * p<0.1

3.4.5 Induced Stress and Risk Preferences - correlation and ATT

Before we identify the causal effect of physiological stress on risk preferences, we present differences in risk preferences across participants who are under stress and who are not, independent of treatment. A participant is considered to be under stress if her cortisol increase exceeds 2.5 nmol/l.

As can be seen in Figure 3-4, there is a strong difference in risk preferences between men who are under stress and men who are not (N=78,p=0.031, d=0.60). For women, the difference is much smaller and insignificant (N=66,p=0.953, d=-0.04).

Figure 3-4: Risk preferences by induced stress



Notes: Risk preferences are presented using an elicited certainty equivalent for a lottery paying 4,000 ECU or 0 ECU with 50% probability each. *Under stress* = 1 if the maximum cortisol response of the subject, calculated as the maximum difference between the baseline sample (sample 1) and samples taken after the stress-inducing procedure (sample 2 or 3), was above 2.5 nmol/l. Error bars indicate mean +/- SEM.

Table 3-2: Risk preferences by induced stress (measured by cortisol response)

	(1)	(2)	(3)	(4)	(5)
	Interval regression				
Dependent variable	Certainty equivalent				
Sample	All	All	All	Males	Females
Under stress	-88.77	-354.08***	-353.13***	-338.62***	66.25
	(102.68)	(126.88)	(124.58)	(119.46)	(149.32)
Female		385.32*	415.61**		
		(202.96)	(199.67)		
Under stress*Female		-502.72***	-375.95***		
		(133.35)	(138.21)		
Age		152.59	192.84	366.72**	-729.80
		(123.16)	(127.45)	(157.41)	(465.41)
Age squared		-2.86	-3.67	-6.83**	15.81
		(2.24)	(2.31)	(2.78)	(10.05)
Big Five Personality Traits:					
Openness to experience			1.34	3.42	-6.60
			(11.88)	(11.45)	(19.93)
Conscientiousness			-4.92	-5.07	-5.68
			(8.04)	(9.80)	(12.40)
Extroversion			-2.70	-5.13	4.57
			(7.80)	(9.01)	(11.67)
Agreeableness			-16.64*	0.61	-47.32***
			(9.63)	(10.72)	(15.39)
Neuroticism			15.34**	23.70**	1.76
			(7.38)	(9.37)	(10.42)
Constant	1,723.58***	56.18	-156.51	-3,317.33	11,918.75**
	(73.48)	(1,631.64)	(2,138.99)	(2,641.36)	(5,745.51)
chi2	0.75	17.39	25.06	15.99	10.69
Observations	144	144	144	78	66

Notes: The dependent variable is the certainty equivalent for a lottery paying 4,000 ECU or 0 ECU with 50% probability each, calculated from the binary choices in the Risk preferences task. *Under stress* = indicator variable equal to one if the difference in cortisol levels between baseline (sample 1) and sample 2 or sample 3 is bigger than 2.5 nmol/l. The reported coefficients in columns 1-5 are marginal effects, estimated using interval regressions to correct for the fact that the dependent variable is elicited in intervals.

Next, we run a more detailed analysis, which controls for additional observables. The results of an interval regression with the indicator variable *Under Stress* are presented in the first three columns of Table 3-2 for the whole sample, and then separately for men and women. The results confirm that on average, there is no significant correlation between the cortisol response and the certainty equivalent (column 1 in Table 3-2). However, there are significant gender differences as captured by the coefficient *Under Stress*Female* in columns 2-3. Men under stress are more risk averse than men who are not under stress, with the effect being significant at the 1% level (column 4 in Table 3-2, p=0.005). The size of the effect is economically important. The estimated certainty equivalent for a lottery paying either 4,000 ECU or 0 ECU with 50 % probability each is around 350 ECU lower for men under stress, meaning that men under stress switch to preferring the safe amount about 1.2 rows prior to men not under stress on the scale of 10 rows. On the other hand, the link between physiological stress and the risk preferences of women is weak and insignificant and actually goes in the other direction (column 5 in Table 3-2, p=0.657). As a consequence, while there is a significant gender difference in risk preferences among participants not under stress (coefficient of the variable *Female* in column 3 of Table 3-2), the gender difference disappears for the participants who are under stress (as measured by the term *Female+Under stress*Female* in column 3, p=0.801).

Yet, the observed strong correlation between stress and risk preferences in men could be driven both by the effect of stress on risk preferences and by the different underlying risk preferences of compliers and non-compliers. Subjects that get stressed in the TSST-G control procedure are most likely different from subjects who do not get stressed during the TSST-G stress procedure. Therefore, to identify the causal effect of physiological stress on risk preferences, we next look at which part of the effect is due to the random assignment to treatment.

Therefore, we analyze the data using an instrumental variable (IV) interval regression[26] using stress treatment (variable *Exposed to stressor*) as an IV for the indicator of physiological stress (*Under stress*). The first stages are fitted using an OLS model and the second stage is fitted using an interval regression. Here we are assuming that stress treatment affects risk preferences only through cortisol increase, which is merely a simplification of the complex stress reaction. Apart from that, we are aware that IV is an asymptotic estimator, so applying it in small samples generally leads to biased estimates. However, this should not be a problem in our case as the instruments are very strong.

The results of the IV interval regression are presented in

[26] This was calculated using the cmp module in Stata (Roodman, 2012).

Table 3-3 for the whole sample and then again separately for men and women. The first stages show that the assignment to treatment is strongly correlated with the stress (cortisol) response and therefore confirm that the assignment to treatment is a strong instrument. The second-stage results reveal that for men, the strong correlation between physiological stress and risk preferences was not driven by selection. The estimated causal effect of stress on risk preferences in column 4 is still strong and significant (p=0.042), showing that physiological stress makes men more risk averse, when controlling for age and personality traits.[27] For women, where there was no significant correlation between physiological stress and risk preferences, the causal effect of physiological stress on risk-preferences (column 5) again points towards increased risk-aversion, but this effect is weaker and insignificant, p=0.426). Still, we cannot reject the hypothesis that the effect is the same across both genders, as the estimated coefficient *Under stress*Female* in column 3 is not significantly different from zero (p=0.663).

The size of the ATT effect is illustrated in Panel B of Appendix Table 3-12. We use estimation results from regressions reported in columns 4 and 5 of

[27] As was the case in the ITT estimation, the results are very similar if we control for neuroticism only. Estimation results are available upon request.

Table 3-3 and generate predicted certainty equivalents for an average (in terms of age and personality traits) man and an average woman in our sample. Men who are under exogenously induced stress have a predicted certainty equivalent of 1638 ECU (for a lottery paying 4,000 ECU or 0 ECU with a 50% probability each), while those who are not have 2053 ECU. The prediction for women in the same respective groups yields values of 1356 ECU and 1585 ECU, respectively. Therefore, the effect size among men is almost twice the effect size among women and the estimated treatment effect for men is equivalent to 89% of the gender difference in the control group.

To sum up, the estimated effect of physiological stress on risk preferences (ATT) confirms the results obtained by estimating the effect of random exposure to the stressor (ITT) on risk preferences, both showing that stress leads to increased risk aversion for men, when controlling for other personal characteristics. The effect on women goes in the same direction, but is weaker and insignificant when estimated for this subsample separately.

Table 3-3: Effect of stress on risk preferences: IV interval regression

	(1)	(2)	(3)	(4)	(5)
	IV Interval regression				
Sample	All	All	All	Males	Females
	Second stage: Certainty equivalent				
Under stress	-247.70	-261.95	-381.49*	-414.51**	-229.90
	(187.30)	(220.79)	(208.95)	(203.95)	(288.79)
Female		25.11	148.29		
		(387.01)	(340.11)		
Under stress*Female		-379.47**	-324.03*		
		(190.13)	(178.36)		
Age		151.74	191.46	360.69**	-712.87
		(121.92)	(127.09)	(159.32)	(505.68)
Age squared		-2.79	-3.65	-6.79**	15.40
		(2.20)	(2.28)	(2.79)	(11.04)
Big Five Personality Traits:	No	No	Yes	Yes	Yes
	First stage: Under stress				
Exposed to stressor	0.56***	0.59***	0.62***	0.62***	0.51***
	(0.07)	(0.09)	(0.09)	(0.09)	(0.09)
Exposed to stressor*Female		-0.10	-0.11		
		(0.13)	(0.13)		
	First stage: Under stress*Female				
Exposed to stressor		0.00	0.01		
		(0.00)	(0.02)		
Exposed to stressor*Female		0.50***	0.49***		
		(0.09)	(0.09)		
chi2	76.57	474.87	560.77	283.27	61.92
Observations	144	144	144	78	66

Notes: The dependent variable is the certainty equivalent for a lottery paying 4,000 ECU or 0 ECU with 50% probability each, calculated from the binary choices in the Risk preferences task. Under stress = indicator variable equal to one if the difference in cortisol levels between the baseline (sample 1) and sample 2 or sample 3 is greater than 2.5 nmol/L. Exposed to stressor: indicator variable equal to 1 if subjects were exposed to the TSST-G stress-induction procedure. IV interval regression is calculated as a mixed-process regression using the *cmp* module in Stata (Roodman, 2012), where the first stages are fitted using a linear probability model and the second stage is fitted using an interval regression. Robust standard errors in the parentheses. *** p<0.01, ** p<0.05, * p<0.1

3.5 Discussion

3.5.1 Physiological or Psychological Effects of Stress

We cannot clearly distinguish whether the change in risk preferences we observe is caused by the physiological or the psychological reaction to the stressor. This is because the cortisol response is strongly correlated with the heart-rate response and also with the mood response, as shown above, and possibly with other aspects of stress that we do not measure.

When we focus on cortisol response only, we find a strong correlation between cortisol response and risk-aversion among men. We can also look at the link between risk-preferences and other measures of stress. The correlation between the heart-rate response and risk-aversion is weaker, but still statistically significant at the 10% level for men, when controlling for other observable characteristics (see Table 3-8 in the Appendix). Similarly, if we focus just on the change in mood, we find a significant correlation between a mood change in the good-bad direction and the elicited certainty equivalent (see Table 3-9 in the Appendix). This shows that the response to the stressor is complex and may operate through physiological as well as psychological channels.

The relative importance of the physiological and psychological aspect of stress can be subject-specific and can also differ by the type of stressor. In this paper we concentrate on psycho-social stressors as we believe they are the most widespread types of stressors in developed countries: it is social status, not physical survival that is being threatened in subjectively uncontrollable situations (Dickerson & Kemeny, 2004). Stressors generally differ from each other by the effects they cause in the body: a physical stressor (stemming from e.g. blood loss and sleep deprivation) may eventually produce a different response than a psychological stressor (e.g. interpersonal conflict or death in the family; Baum & Grunberg, 1997; Clow, 2001). Another way of inducing stress could be increasing the stakes involved. The "choking under pressure" literature (Ariely, Gneezy, Loewenstein, & Mazar, 2009; Dohmen, 2008) shows the negative effects of high stakes on performance, which may operate through stress. However, our paper is different from this literature as it concentrates on the effects of stress on preferences and not performance.

Our results are related to the emerging literature on the effects of mood on risk preferences, since TSST has been found to generally increase negative emotions (Allen et al., 2014). Our results that exposure to the stressor increases risk aversion are in line with the findings of Michl, Koellinger, & Picot (2011), who found that for no stakes, a sad mood induced risk-aversion (but no effect was present for high stakes). Similarly, Nguyen & Noussair (2014) used face-reading software to show that positive emotions correlate with more risk-taking.

Further, we can relate our findings to the existing literature on the effects of cortisol on decision making. On the sample of 17 professional traders, Coates & Herbert (2008) found an increase in their salivary cortisol levels when anticipating higher volatility and thus higher uncertainty in their trading market. The authors hypothesized that there is a direct positive association between stress, cortisol and risk-aversion, but could not prove it. Following up on that, Kandasamy et al. (2014) induced in a sample of students increases in cortisol comparable to the findings from traders by direct administration of hydrocortisone. They found no effect when they measured risk-preferences shortly after the first dose, but after long term administration (8 days) they found increased risk-aversion in the treatment group.

However, we argue that the effects of stress are more complex than effects of cortisol only, since the stress reaction includes a complicated interplay of physiological and psychological changes (allostasis).[28] This can be demonstrated by the opposing results of the following two studies on the link between time-preferences, stress and cortisol: Cornelisse et al. (2013) directly administered hydrocortisone and found that subjects 15 minutes after application revealed increased preferences for a small, more immediate reward compared to the placebo group. Contrary to that, Haushofer et al. (2013) employed the TSST protocol to obtain no effect of stress on time-discounting that they measured at three distinct time-points after the manipulation.

Therefore we acknowledge the results of Kandasamy et al. (2014), which moreover support our findings of increased risk-aversion, but claim that our study is not directly comparable as we study the effects of psychosocial stress and not of cortisol only. We believe that direct hydrocortisone administration may not provide enough insight into the complex effects of stress that people experience in everyday life and that we aim to measure in this paper. Our ATT effect estimation which assumed that the TSST-G treatment affected risk-preferences only through cortisol is necessarily a simplification as we show that other channels are possibly in operation.

[28] To support this argument, consider that under stress, there are many other hormones released: First, the autonomic nervous system activates the adrenal medulla to release adrenaline and nor-adrenaline. Second, the hypothalamus-pituitary-adrenal axis follows with the secretion of vasopressin and corticotropin-releasing hormones in the hypothalamus. These hormones in turn stimulate the secretion of adrenocorticotropic hormone in the pituitary, which then triggers the massive secretion of cortisol in the adrenal glands (Kemeny, 2003). We take cortisol as a proxy of the physiological response mainly due to the convenience of its measurement, but we do not claim that it is only cortisol which causes the effects on behavior.

To summarize, studying the effects of psychosocial stress is different from studying the effects of direct hydrocortisone administration or mood induction alone, since the stress reaction includes a complex interplay of physiological as well as psychological aspects. In this paper, we estimate the effect of a random exposure to the stressor which captures the effects of all of the above. The results show that exposure to the stressor (the ITT effect) increases risk aversion for men, when controlling for other characteristics, and it should be taken as the principle finding of this paper.

3.5.2 Gender-specific Response to Stressor

Our results show that stress leads to increased risk-aversion among men, when controlling for age and personality characteristics. Even though we cannot reject the hypothesis that the effect of stress is the same for both genders, the effect among women is weaker and insignificant when analyzing this subsample separately. There can be several reasons why the response among women is less strong.

As reviewed in Kajantie & Phillips (2006) and confirmed by our data, female physiological reaction to stress is typically of a smaller magnitude than the reaction of men of the same age, including the secretion of cortisol. In our sample, only 50% of women after the stress procedure show a cortisol increase above 2.5 nmol/l. This can be partially attributed to a weaker cortisol response among women who take hormonal contraceptives (see Table 3-4 in the Appendix; Kudielka et al., 2009). Therefore, if the main channel causing the effect we observe is the increase in cortisol, women should be less affected than men, which is what we find in our results.

We acknowledge the fact that our findings concerning women are limited due to the fact that we did not ask about the phase of the menstrual cycle, since the cortisol reaction may depend on it (Kajantie & Phillips, 2006). However, there is emerging evidence that risk-preferences are stable throughout the cycle (Schipper, 2012) so we believe that the overall results are not affected.

Second, as women are typically found to be more risk-averse than men (Charness & Gneezy, 2012), which holds in our sample, it is possible that there is a floor effect in the sense that the downward reactivity of risk preferences is lower compared to men.

Moreover, recent studies suggest behavioral response to stress may be gender-specific. The "fight-or-flight" behavioral response is considered to be a rather male reaction to acute stress, while the typical female reaction may be characterized as "tend-and-befriend" (Taylor et al., 2000). In brief, the "tend-and-befriend" reaction means that females under stress show tendencies to maximize the chance of survival themselves and their offspring by seeking help in social networks or groups. An evolutionary perspective can help to explain both the facts that women are more risk-averse under normal conditions and that stress should increase risk-aversion especially in men. In human history, the division of gender roles has typically been such that men had to expose themselves to riskier conditions than women, for example while hunting. In this sense, males generally needed to be more risk-seeking than women, but this tendency had to be regulated when facing an immediate threat.

This leads us to a general note: most of the laboratory research on behavioral decisions under stress has been carried out only on men, mainly because their cortisol response is affected by fewer other factors, such as the use of hormonal contraceptives or the phase of the menstrual cycle (Kirschbaum, Kudielka, Gaab, Schommer, & Hellhammer, 1999). But since gender differences in preferences and decision-making can be large (Croson & Gneezy, 2009), studying the effects of stress on men only gives half of the story. More emphasis in the future should be put on understanding gender-specific responses to stressors.

3.5.3 Link to Other Studies on Stress and Risk Preferences

Several studies have already been published on the topic of stress and risk-preferences, but overall they do not provide conclusive results. Some studies point to increased risk-taking under stress (Starcke et al., 2008), others find men take more risks under stress, while women take fewer (Lighthall et al., 2009; van den Bos et al., 2009), or conclude on no change in risk preferences under stress (von Dawans et al., 2012). Pabst, Brand, & Wolf (2013) found a time trend in risk-taking behavior with respect to the time elapsed from the onset of the stressor. Porcelli & Delgado (2009) obtain increased risk-aversion for gain domains, but increased risk-seeking for loss domains. Buckert, Schwieren, Kudielka, & Fiebach (2014) found that cortisol increase correlates with risk-taking in the gain domain, but not in loss domain.[29] However, the problem with these studies is that they either do not show a causal relationship, are unable to effectively induce stress in the majority of subjects, or use tasks for elicitation of risk-preferences that include feedback-processing which itself can be affected by stress and thus confound the results (Petzold et al., 2010; Starcke et al., 2008).[30]

[29] See Buckert et al. (2014) for a detailed comparison of psychological studies on this topic.
[30] The risk-preferences tasks that have been used in previous studies such as the Balloon Analogue Task (Lejuez et al., 2002), the Game of Dice Task (Starcke et al., 2008) and the Iowa Gambling Task (Bechara et al., 1994) all include feedback processing, which is a potential confound. Other standard measures like Holt & Laury (2002) and

The closest study to ours is by von Dawans et al. (2012), who included a risk-game as a control task in their framework for studying social preferences under successfully induced psychosocial stress in men. The risk game consisted of a repeated choice between high-risk and low-risk lotteries and was executed in the middle and right after the end of the TSST-G protocol. Contrary to our results, no difference was found between the treatment and control groups in terms of risk-preferences. This may have been caused by several factors: First, our task was administered relatively later after exposure to the stressor. As suggested in Pabst et al. (2013), hormones adrenaline and noradrenaline which are released immediately after the onset of the stressor and disappear from the body within several minutes after the cessation of the stressor may have opposing effects to cortisol, which is released later than adrenaline and its presence lasts longer (Starcke & Brand, 2012). Second, the task of von Dawans et al. (2012) combined positive and negative payoffs and it is possible that the effect of stress on risk preferences is heterogeneous over the gain and the loss domains (Buckert, Schwieren, et al., 2014; Pabst et al., 2013b; Porcelli & Delgado, 2009). As risk preferences in von Dawans et al. (2012) were measured just by the number of risky choices made (the task does not allow for the direct computation of a risk-aversion parameter), it is possible that the effects in the gain domain and loss domain canceled each other out. Third, the elicited risk preferences may depend on the framing of the risk-task. In our risk-elicitation protocol subjects made their choices between a risky lottery and a safe payment, whereas in von Dawans et al. (2012) subjects faced two different lotteries. Lastly, the recruited subjects in von Dawans et al. (2012) anticipated the stress procedure since it was literally stated in the advertisement, which may have led to self-selection for the experiment, possibly directly linked to risk attitudes. Although we cannot distinguish between these factors in our data, related literature suggest the timing explanation seems to be the most promising and thus should be explored by future studies.

3.6 Conclusion

In this paper we contribute to the literature by studying the effect of acute psychosocial stress on individual risk attitudes. We induce stress with an effective laboratory stressor Trier Social Stress Test for Groups (von Dawans et al., 2011). Subjects are divided randomly to experience either the treatment "stress procedure", or the control "no-stress" procedure. Individual risk-preferences are elicited using the task similar to Dohmen et al. (2010) which is an easily comprehensible, incentive compatible and externally validated measure of risk attitudes. By using three different measures (salivary cortisol concentration, heart rate and multi-dimensional mood questionnaire

G. M. Becker, DeGroot, & Marschak (1964) may be too complicated to understand, which may be amplified under stress and thus again confound the results.

scores) we show that subjects exposed to the stressor were indeed stressed, while the subjects in the control group were not, with the compliance rate around 78%. Our main result is that stress increases risk aversion when controlling for additional observable characteristics. The effect is mostly driven by men; the effect on women goes in the same direction, but is weaker and insignificant.

Overall, if risk-aversion indeed increases under stress, it has important consequences. First, the assumption of the stability of risk preferences should be relaxed if the economic models incorporating them are to provide more accurate predictions including for periods of stress.

Second, our results are relevant for the previous literature finding that people who have experienced some sort of negative shock are more risk-averse. To name a few, people who went through the Great Depression or financial crisis in 2008 choose more conservative investment strategies (Guiso et al., 2013; Malmendier & Nagel, 2011). Other studies document that risk-preferences are altered as a result of natural disasters (Cameron, Erkal, Gangadharan, & Zhang, 2015; Cassar, Andrew, & von Kessler, 2011; Eckel, El-Gamal, & Wilson, 2009) or exposure to violence (Callen, Long, & Sprenger, 2014; Voors et al., 2012), although evidence regarding the direction of the change is mixed. It could be well expected that all of these circumstances are highly stressful and thus stress should be considered as a possible driving mechanism behind the observed change in preferences. In a similar vein, our results support the hypothesis of Haushofer & Fehr (2014) that extreme poverty may decrease the willingness to accept risk through increased stress, resulting in choices that make it hard to escape poverty. By showing that stress increases risk-aversion, we provide evidence of the latter part of the link.

Furthermore, our findings help to explain observed phenomena from financial markets. During periods of market stress there tends to be a high demand for "safe-haven assets", such as safe government bonds (Upper, 2000) safe currencies (Kaul & Sapp, 2006), and gold (Baur & McDermott, 2010). We suggest stress can be an important operating channel even in financial markets, with the high probability of losing money acting as a stressor.

Generally, it could be argued that professions involving high levels of stress attract people who are less sensitive to the effects of stress. Trading floors are a good example of such a stressful environment that also includes strict selection and self-selection (Oberlechner & Nimgade, 2005). Still, as Coates & Herbert (2008) show, active traders still respond to market volatility with increased stress, as measured by cortisol levels. Cohn et al. (2015) further document that the risk-preferences of professional traders change when primed with market boom or bust, with higher risk-aversion under the bust scenario. We therefore argue that the relationship uncovered in this paper is relevant even for people who self-select into high-stress environments.

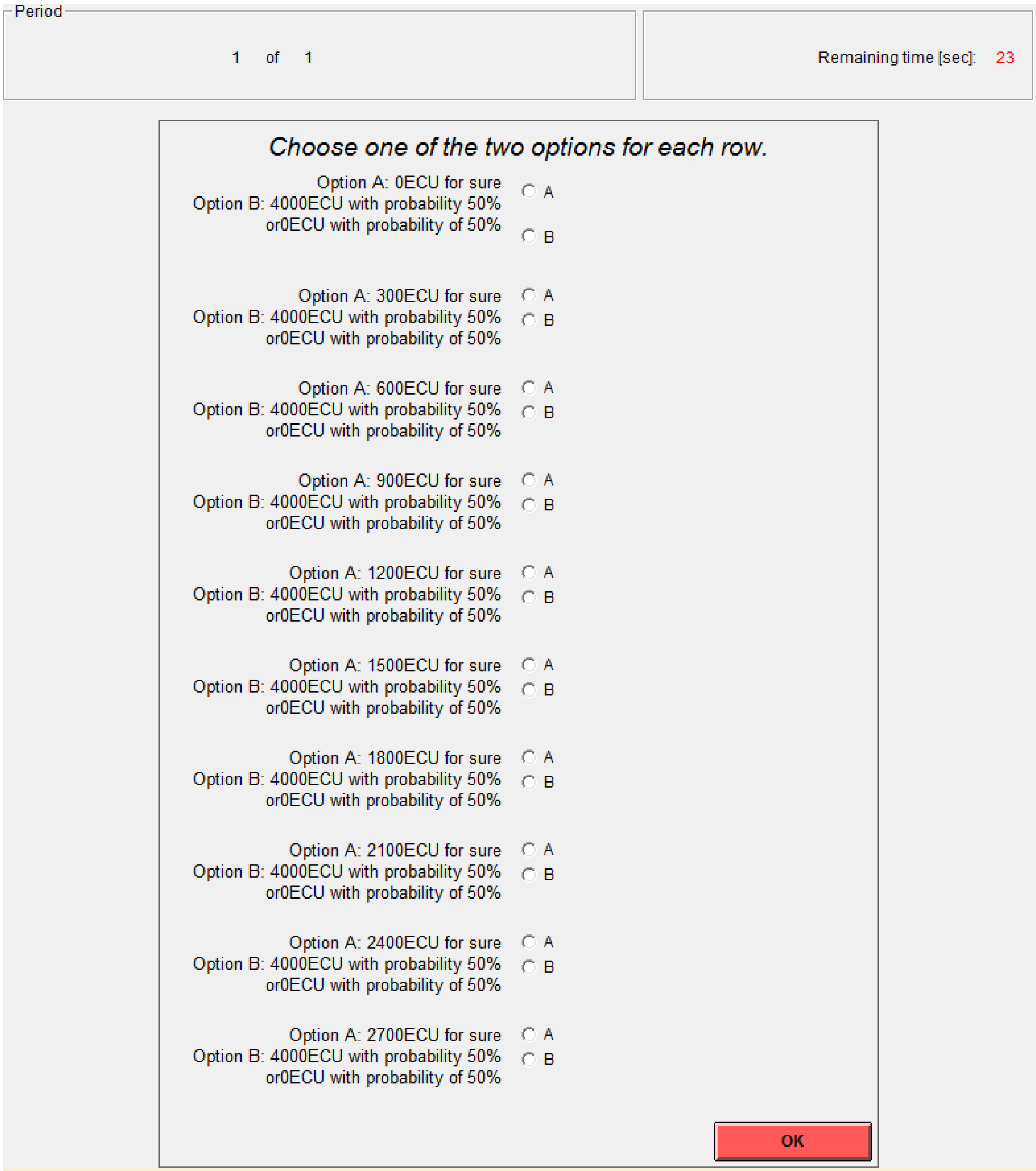
As a policy implication we suggest in accordance with Haushofer & Fehr (2014) that targeting the psychological consequences of poverty is a promising new strategy for the eradication of poverty in developing countries and as such should be tested in the field. Similarly, the economic consequences of stress should be considered when designing programs targeting people who experience negative income shocks such as unemployment or bankruptcy.

Last but not least, for professions that encounter stress regularly, higher risk-aversion may not be desirable, for example with managers who should pursue risky innovations, police during strikes, or doctors trying new medical treatments. This highlights the necessity of guidelines for times of stress and panic. Furthermore, training and simulations should be widely used when possible, since the physiological reaction to a specific stressor diminishes with regular exposure (Kudielka et al., 2009).

We should note that our study concerns only immediate reactions to an acute stressor. Even though our results are consistent with much field evidence from situations involving chronic stress, the behavioral effects of acute and chronic stress can in principle be different (as the physiological changes are; Goldstein & McEwen, 2002). More research is thus needed to understand how the interplay between acute and chronic stress influences economic outcomes.

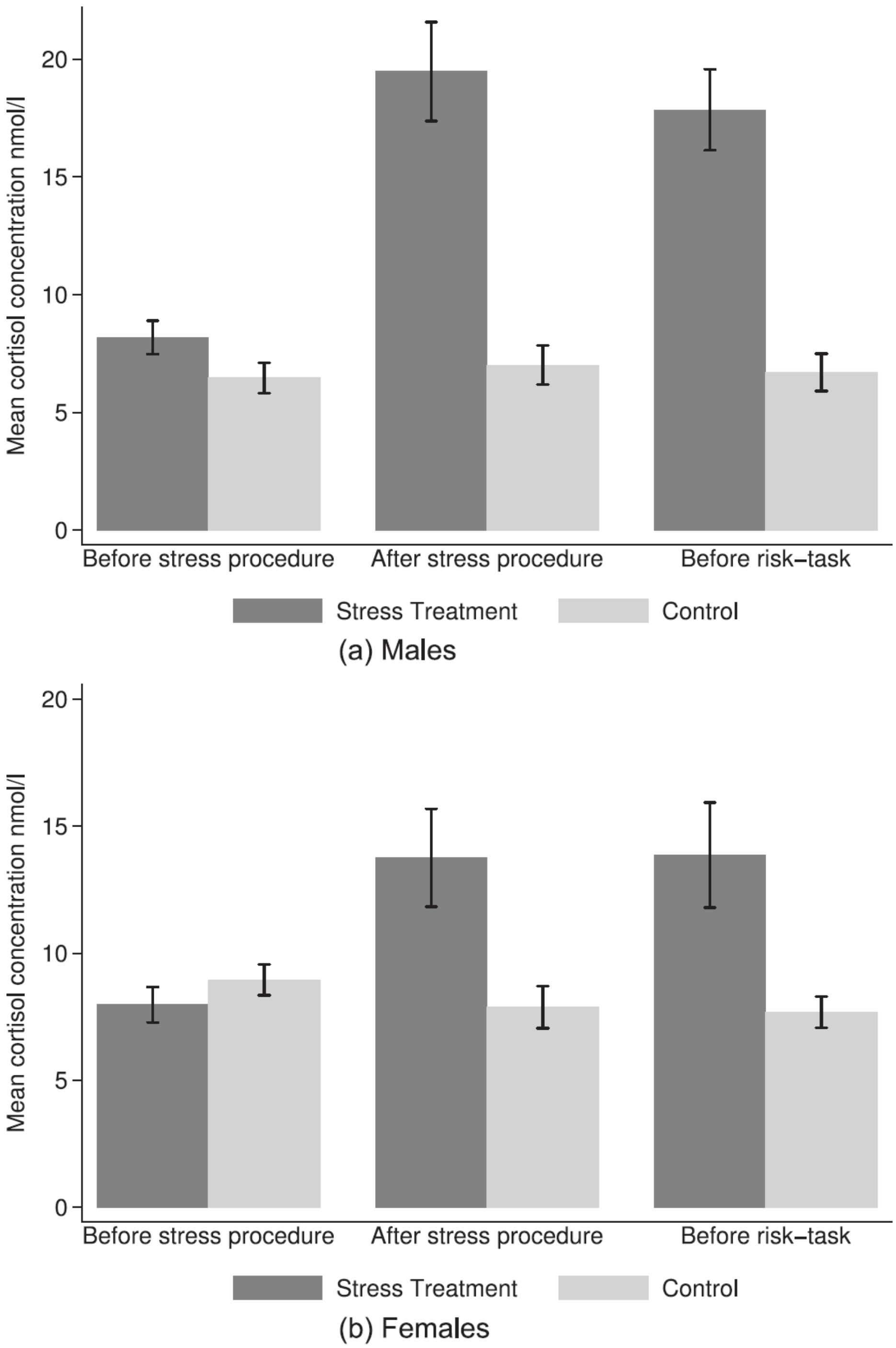
3.7 Appendix A - Instructions: Risk task

Figure 3-5: Screen shot of the experimental instructions.



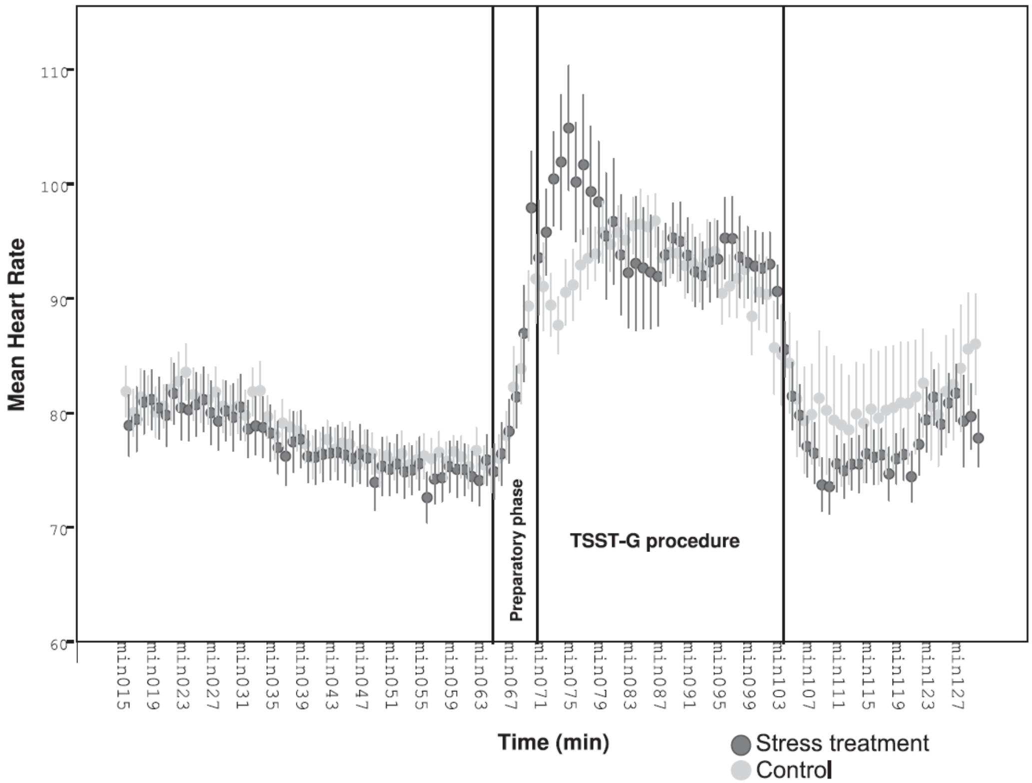
3.8 Appendix B - Additional results

Figure 3-6: Induced Stress Reaction by gender: Mean levels of free salivary cortisol.



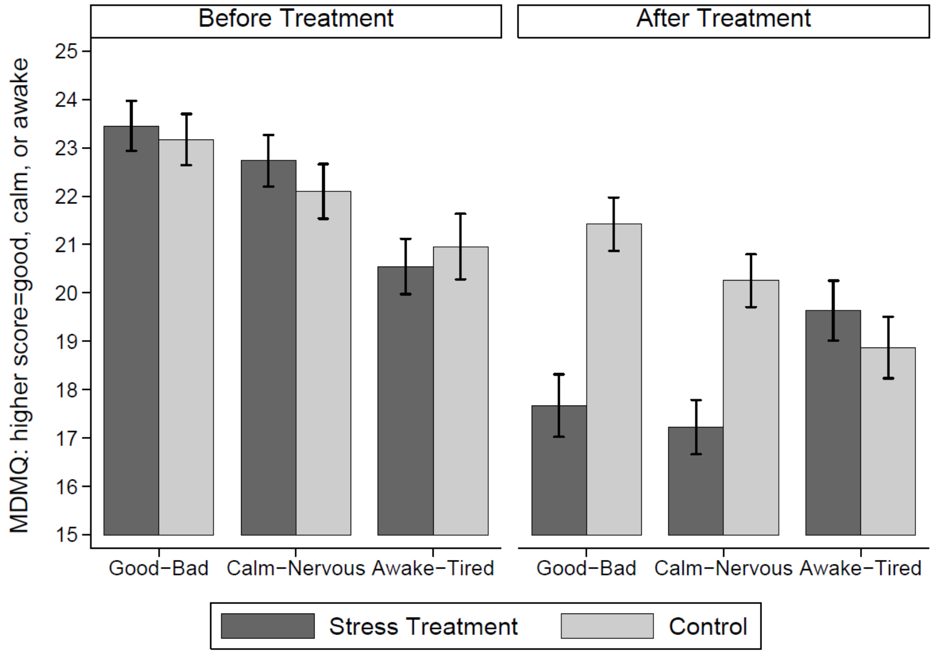
Notes: *Stress Treatment*: indicator variable equal to 1 if subjects were exposed to the TSST-G stress-induction procedure, Control: subjects were exposed to the TSST-G control procedure. Sample 1 was collected before the TSST-G stress-induction procedure, sample 2 after the TSST-G procedure and sample 3 before the risk task. Error bars indicate mean +/- SEM.

Figure 3-7: Induced Stress Reaction: Development of mean heart rate during the experiment



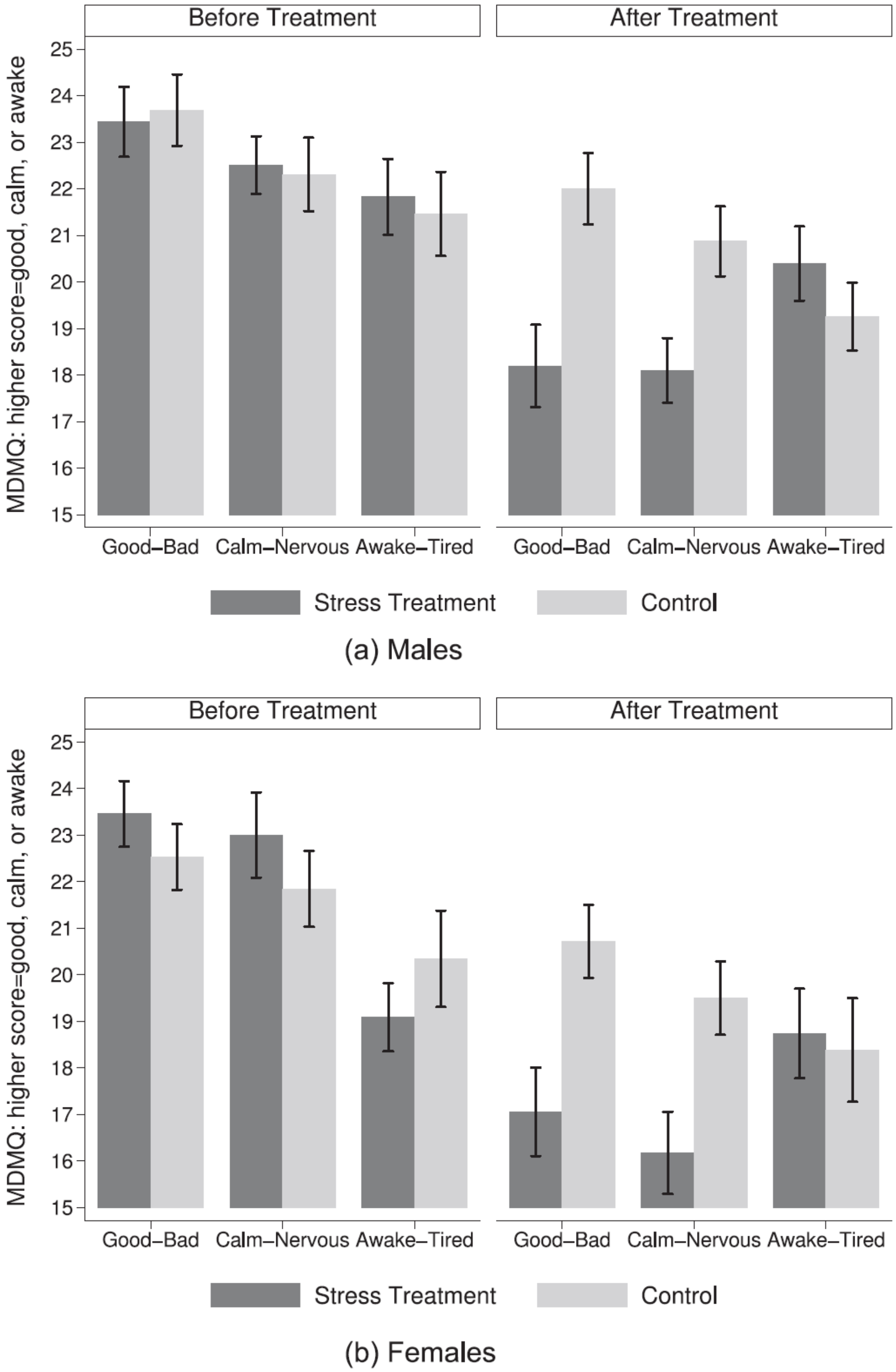
Notes: Points indicate averages over minute intervals. Stress Treatment: indicator variable equal to 1 if subjects were exposed to the TSST-G stress-induction procedure, Control: subjects were exposed to the TSST-G control procedure. Error bars indicate mean +/- SEM.

Figure 3-8: Induced Stress Reaction: Mood



Notes: Mood - scores from the Multidimensional Mood Questionnaire before and after the TSST-G stress-induction procedure. Stress Treatment: indicator variable equal to 1 if subjects were exposed to the TSST-G stress-induction procedure, Control: subjects were exposed to the TSST-G control procedure. Error bars indicate mean +/- SEM.

Figure 3-9: Induced Stress Reaction by gender: Mood -



Notes: Induced Stress Reaction by gender: Mood - scores from the Multidimensional Mood Questionnaire before and after the TSST-G stress-induction procedure. *Stress Treatment*: indicator variable equal to 1 if subjects were exposed to the TSST-G stress-induction procedure, *Control*: subjects were exposed to the TSST-G control procedure. Error bars indicate mean +/- SEM.

Table 3-4: Induced cortisol response among women, by the intake of oral contraceptives

	(1)	(2)	(3)
		OLS	
Dependent variable		Maximum cortisol response	
Sample		Females	
Exposed to stressor	8.94***	8.97***	11.75***
	(1.79)	(1.77)	(2.65)
Taking oral contraceptives		-3.47**	0.33
		(1.60)	(0.65)
Exposed to stressor*Taking oral contraceptives			-7.36**
			(2.95)
Constant	-1.35***	-0.05	-1.48***
	(0.32)	(0.73)	(0.42)
Observations	66	66	66
R-squared	0.27	0.31	0.35

Notes: The dependent variable is the maximum cortisol response of a subject, calculated as the maximum difference between the baseline sample (sample 1) and samples taken after the stress-inducing procedure (sample 2 or 3). Taking oral contraceptives = dummy variable equal to one if the women states that she takes oral (hormonal) contraceptives. Exposed to stressor: indicator variable equal to 1 if subjects were exposed to the TSST-G stress-induction procedure. Robust standard errors in the parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3-5: The effects of random exposure to stressor on risk preferences (Males) - ordered probit

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable	Ordered probit Certainty equivalent	Marginal fixed effects after ordered probit Probability of the certainty equivalent being equal to:					
		750	1050	1350	1650	1950	2250
Sample	Males	Males	Males	Males	Males	Males	Males
Exposed to stressor	-0.510**	0.010	0.019	0.099**	0.051*	-0.072*	-0.048*
	(0.244)	(0.012)	(0.015)	(0.050)	(0.029)	(0.039)	(0.028)
Age	0.792***	-0.016	-0.030	-0.156**	-0.080**	0.116*	0.075*
	(0.296)	(0.017)	(0.022)	(0.069)	(0.038)	(0.064)	(0.038)
Age squared	-0.015***	0.000	0.001	0.003**	0.001**	-0.002*	-0.001**
	(0.005)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Big Five Personality Traits:							
Openness to experience	-0.005	0.000	0.000	0.001	0.001	-0.001	-0.000
	(0.020)	(0.000)	(0.001)	(0.004)	(0.002)	(0.003)	(0.002)
Conscientiousness	-0.009	0.000	0.000	0.002	0.001	-0.001	-0.001
	(0.020)	(0.000)	(0.001)	(0.004)	(0.002)	(0.003)	(0.002)
Extroversion	-0.017	0.000	0.001	0.003	0.002	-0.002	-0.002
	(0.017)	(0.000)	(0.001)	(0.004)	(0.002)	(0.003)	(0.002)
Agreeableness	-0.001	0.000	0.000	0.000	0.000	-0.000	-0.000
	(0.020)	(0.000)	(0.001)	(0.004)	(0.002)	(0.003)	(0.002)
Neuroticism	0.054***	-0.001	-0.002	-0.011***	-0.005**	0.008**	0.005**
	(0.017)	(0.001)	(0.001)	(0.004)	(0.003)	(0.004)	(0.002)
chi2	20.79	20.79	20.79	20.79	20.79	20.79	20.79
Observations	80	80	80	80	80	80	80

Notes: The dependent variable is the certainty equivalent for a lottery paying 4,000 ECU or 0 ECU with 50% probability each, calculated from the binary choices in the risk preferences task. Column 1 presents the overall results of ordered probit estimation, while columns 2-7 present marginal fixed effects obtained from the estimation, i.e. present estimated probabilities of certainty equivalent being equal to the specified amounts. The results are presented only for certainty equivalent equal to 750-2,250, which is true for 87% of the subjects in our sample. Exposed to stressor: indicator variable equal to 1 if subjects were exposed to the TSST-G stress-induction procedure. Robust standard errors clustered on the individual level in the parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3-6: The effects of random exposure to stressor on risk preferences (Females) - ordered probit

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Ordered probit	Marginal fixed effects after ordered probit					
Dependent variable	Certainty equivalent	Probability of the certainty equivalent being equal to:					
		750	1050	1350	1650	1950	2250
Sample	Females	Females	Females	Females	Females	Females	Females
Exposed to stressor	-0.211	0.019	0.036	0.011	-0.010	-0.029	-0.020
	(0.254)	(0.024)	(0.043)	(0.015)	(0.013)	(0.034)	(0.027)
Age	-1.264	0.112	0.217	0.066	-0.062	-0.172	-0.120
	(0.889)	(0.095)	(0.169)	(0.059)	(0.062)	(0.139)	(0.090)
Age squared	0.027	-0.002	-0.005	-0.001	0.001	0.004	0.003
	(0.019)	(0.002)	(0.004)	(0.001)	(0.001)	(0.003)	(0.002)
Big Five Personality Traits:							
Openness to experience	-0.014	0.001	0.002	0.001	-0.001	-0.002	-0.001
	(0.035)	(0.003)	(0.006)	(0.002)	(0.002)	(0.005)	(0.003)
Conscientiousness	-0.013	0.001	0.002	0.001	-0.001	-0.002	-0.001
	(0.022)	(0.002)	(0.004)	(0.001)	(0.001)	(0.003)	(0.002)
Extroversion	0.010	-0.001	-0.002	-0.001	0.000	0.001	0.001
	(0.020)	(0.002)	(0.003)	(0.001)	(0.001)	(0.003)	(0.002)
Agreeableness	-0.080***	0.007*	0.014**	0.004	-0.004	-0.011**	-0.008**
	(0.028)	(0.004)	(0.006)	(0.003)	(0.003)	(0.005)	(0.004)
Neuroticism	0.004	-0.000	-0.001	-0.000	0.000	0.000	0.000
	(0.018)	(0.002)	(0.003)	(0.001)	(0.001)	(0.002)	(0.002)
chi2	9.59	9.59	9.59	9.59	9.59	9.59	9.59
Observations	66	66	66	66	66	66	66

Notes: The dependent variable is the certainty equivalent for a lottery paying 4,000 ECU or 0 ECU with 50% probability each, calculated from the binary choices in the risk preferences task. Column 1 presents the overall results of ordered probit estimation, while columns 2-7 present marginal fixed effects obtained from the estimation, i.e. present estimated probabilities of certainty equivalent being equal to the specified amounts. The results are presented only for certainty equivalent equal to 750-2,250, which is true for 87% of the subjects in our sample. Exposed to stressor: indicator variable equal to 1 if subjects were exposed to the TSST-G stress-induction procedure. Robust standard errors clustered on the individual level in the parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3-7: The effects of random exposure to stressor (TSST-G stress procedure) on risk preferences - including subjects with multiple switches in the risk task

	(1)	(2)	(3)	(4)	(5)	(6)
	Ordered Probit			Interval regression		
Dependent variable	Number or risky choices			Certainty equivalent		
Exposed to stressor	-0.22	-0.25	-0.39*	-127.16	-146.40	-222.71*
	(0.17)	(0.22)	(0.22)	(102.26)	(130.38)	(126.62)
Female		-0.60**	-0.45*		-323.07**	-223.10
		(0.26)	(0.27)		(153.85)	(149.63)
Exposed to Stressor*Female		0.04	0.18		46.71	117.99
		(0.34)	(0.32)		(201.99)	(177.01)
Age		0.21	0.34		142.42	197.99
		(0.22)	(0.22)		(121.46)	(125.88)
Age squared		-0.00	-0.01		-2.56	-3.68
		(0.00)	(0.00)		(2.20)	(2.26)
Big Five Personality Traits:						
Openness to experience			0.00			-1.13
			(0.02)			(11.68)
Conscientiousness			-0.01			-4.78
			(0.01)			(8.22)
Extroversion			-0.01			-1.26
			(0.01)			(7.73)
Agreeableness			-0.02			-15.71*
			(0.02)			(9.46)
Neuroticism			0.03***			17.69**
			(0.01)			(7.34)
Constant				1,744.21***	-0.45	-424.78
				(77.38)	(1,627.63)	(2,156.77)
chi2	1.688	12.17	21.14	1.546	11.22	21.08
Observations	151	151	151	151	151	151

Notes:The dependent variable in columns 1-3 is the number of risky choices in the Risk preferences task. The dependent variable in columns 4-6 is the certainty equivalent calculated from the binary choices in the Risk preferences task. Subjects with multiple switches between lottery and safe amount are not dropped as inconsistent, as throughout the paper, but considered indifferent for the entire switching interval. Exposed to stressor: indicator variable equal to 1 if subjects were exposed to the TSST-G stress-induction procedure. Columns 1-3 are estimated using ordered probit, columns 4-6 are estimated using interval regressions to account for the fact that the dependent variable was elicited in intervals. Robust standard errors clustered on the individual level in the parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3-8: Risk preferences by induced stress (measured by heart-rate response)

	(1)	(2)	(3)	(4)	(5)	(6)
	Interval regression			Ordered Probit		
Dependent variable	Certainty equivalent			Certainty equivalent		
Heart-rate response	-1.81	-8.40	-8.92*	-0.00	-0.01	-0.01
	(3.13)	(5.93)	(5.33)	(0.01)	(0.01)	(0.01)
Heart-rate response*Female		9.49	10.59*		0.01	0.01
		(6.47)	(5.84)		(0.01)	(0.01)
Female		-464.81***	-306.47*		-0.61**	-0.36
		(159.79)	(163.19)		(0.26)	(0.28)
Age		149.94	190.24		0.15	0.24
		(132.14)	(134.49)		(0.21)	(0.21)
Age squared		-2.67	-3.44		-0.00	-0.00
		(2.37)	(2.41)		(0.00)	(0.00)
Big Five Personality Traits:						0.00
						(0.02)
Openness to experience			-3.90			-0.00
			(12.75)			(0.01)
Conscientiousness			-1.78			-0.01
			(9.00)			(0.01)
Extroversion			-1.79			-0.04**
			(8.92)			(0.02)
Agreeableness			-20.46**			0.03**
			(10.42)			(0.01)
Neuroticism			16.88**			
			(8.45)			
Constant	(80.51)	(1,771.09)	(2,327.30)			
	1,720.98***	-44.31	-135.19			
chi2	0.33	10.22	22.03	0.02	6.76	17.07
Observations	131	131	131	131	131	131

Notes: The dependent variable is the certainty equivalent calculated from the binary choices in the Risk preferences task. Heart-rate response = individual difference between the baseline heart rate (average heart rate before the TSST-G stress induction procedure) and the average heart rate during the TSST-G stress or control procedure. The reported coefficients in columns 1-3 are marginal effects, estimated using interval regressions to correct for the fact that the dependent variable is elicited in intervals. Reported coefficients in columns 4-6 are estimated using ordered probit estimation. Robust standard errors clustered on the individual level in the parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3-9: Risk preferences by induced stress (measured by change in mood - MDMQ)

	(1)	(2)	(3)	(4)	(5)	(6)
	Interval regression			Ordered Probit		
Dependent variable	Certainty equivalent			Certainty equivalent		
Change in Mood State						
Good-Bad	24.62*	28.84	29.42	0.04*	0.05	0.05*
	(14.65)	(22.23)	(20.30)	(0.02)	(0.03)	(0.03)
Awake-Tired	6.59	-2.49	-2.17	0.01	-0.00	-0.00
	(10.58)	(9.95)	(10.01)	(0.02)	(0.02)	(0.02)
Calm-Nervous	-11.71	-14.56	-14.14	-0.01	-0.02	-0.02
	(11.95)	(16.93)	(15.64)	(0.02)	(0.03)	(0.02)
Good-Bad*Female		-16.22	-25.43		-0.02	-0.04
		(26.50)	(26.40)		(0.04)	(0.04)
Awake-Tired*Female		32.56*	38.08**		0.05	0.06**
		(18.77)	(17.11)		(0.03)	(0.03)
Calm-Nervous*Female		3.70	5.84		0.01	0.01
		(23.01)	(22.83)		(0.04)	(0.04)
Female		-295.47**	-177.22		-0.46**	-0.28
		(121.47)	(117.09)		(0.22)	(0.23)
Age		174.53	242.92*		0.23	0.36
		(131.71)	(131.49)		(0.22)	(0.22)
Age squared		-3.09	-4.47*		-0.00	-0.01*
		(2.43)	(2.38)		(0.00)	(0.00)
Big Five Personality Traits:						
Openness to experience			4.13			0.02
			(11.66)			(0.02)
Conscientiousness			2.49			0.00
			(8.05)			(0.01)
Extroversion			-6.60			-0.02
			(7.39)			(0.01)
Agreeableness			-12.51			-0.02
			(9.83)			(0.02)
Neuroticism			17.37**			0.03**
			(7.65)			(0.01)
Constant	(58.36)	(1,744.17)	(2,218.09)			
	1,746.63***	-474.99	-1,451.97			
chi2	6.02	15.69	36.53	7.26	12.4	31.01
Observations	142	142	142	142	142	142

Notes: The dependent variable is the certainty equivalent calculated from the binary choices in the Risk preferences task. Change in Mood = change between the Multidimensional-mood-state-questionnaire (MDMQ) scores before and after the TSST-G stress induction procedure. All three MDMQ dimensions are considered: good-bad, awake-tired and calm-nervous. The reported coefficients in columns 1-3 are marginal effects, estimated using interval regressions to correct for the fact that the dependent variable is elicited in intervals. The reported coefficients in columns 4-6 are estimated using ordered probit estimation. Robust standard errors clustered on the individual level in the parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3-10: Sample characteristics - randomization check

Panel A: Whole Sample			
	Stress Treatment	Control	Diff p-value
Female	0.45	0.45	0.975
age mean	22.11	22.89	0.260
age sd.	1.78	3.29	
Big Five Personality Traits:			
Openness to experience	36.67	37.13	0.273
Conscientiousness	33.16	34.07	0.386
Extraversion	34.29	32.20	0.087
Agreeableness	36.47	36.23	0.596
Neuroticism	31.73	29.51	0.094
N	75	71	

Panel B: Males			
	Stress Treatment	Control	Diff p-value
age mean	22.24	23.33	0.428
age sd.	1.79	3.94	
Openness to experience	37.05	36.90	0.714
Conscientiousness	33.12	33.69	0.710
Extraversion	32.32	31.79	0.686
Agreeableness	34.10	34.54	0.927
Neuroticism	33.83	30.46	0.057
N	41	39	

Panel C: Females			
	Stress Treatment	Control	Diff p-value
age mean	21.94	22.34	0.401
age sd.	1.79	2.21	
Openness to experience	36.21	37.41	0.208
Conscientiousness	33.21	34.53	0.418
Extraversion	36.68	32.69	0.040
Agreeableness	39.32	38.28	0.392
Neuroticism	29.21	28.34	0.508
N	34	32	

Notes: Means. Differences are tested using a Wilcoxon rank-sum test.

Table 3-11: Effects of random exposure to stressor on risk preferences: Sensitivity analysis with respect to additional control variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Interval regression							
Dependent variable	Certainty equivalent							
Sample	Males	Males	Males	Males	Females	Females	Females	Females
Exposed to stressor	-140.69	-136.93	-242.74*	-220.49*	-127.13	-120.83	-118.16	-122.01
	(126.49)	(127.96)	(125.10)	(126.23)	(158.89)	(161.55)	(145.08)	(153.92)
Age		376.03**	399.08**			-472.53	-700.54	
		(156.17)	(157.15)			(477.81)	(483.08)	
Age squared		-6.60**	-7.31***			10.11	15.08	
		(2.73)	(2.77)			(10.28)	(10.51)	
Big Five Personality Traits:								
Openness to experience			-0.68				-9.43	
			(11.18)				(20.40)	
Conscientiousness			-1.90				-7.63	
			(9.76)				(12.97)	
Extroversion			-3.69				7.01	-1.31
			(8.86)				(11.78)	(10.21)
Agreeableness			-1.01				-46.43***	
			(10.55)				(15.56)	
Neuroticism			26.15***	23.87**			1.48	
			(9.73)	(10.07)			(10.54)	
Constant	1,887.16***	-3,193.52	-3,890.76	1,159.09***	1,592.44***	7,057.38	11,766.59**	1,635.15***
	(96.07)	(2,146.64)	(2,657.66)	(336.59)	(119.32)	(5,512.51)	(5,911.69)	(369.63)
chi2	1.237	7.065	15.80	6.762	0.640	1.915	10.53	0.646
Observations	80	80	80	80	66	66	66	66

Notes: The dependent variable is the certainty equivalent for a lottery paying 4,000 ECU or 0 ECU with 50% probability each, calculated from the binary choices in the risk preferences task. Exposed to stressor: indicator variable equal to 1 if subjects were exposed to the TSST-G stress-induction procedure. The reported coefficients in columns 1-8 are marginal effects, estimated using interval regressions to correct for the fact that the dependent variable is elicited in intervals. Regressions in column 4 and 8 control for the personality trait which is not balanced across the treatment and control group for the given gender, see Table 3-10. Robust standard errors clustered on the individual level in the parentheses. *** p<0.01, ** p<0.05, * p<0

Table 3-12: Predicted certainty equivalents for a lottery paying 4,000 ECU or 0 ECu with 50% probability each, by treatment and gender.

	Predicted certainty equivalent	Delta method standard error:	95% confidence interval
Panel A: Effects of random exposure to stressor on risk preferences (ITT)			
Males			
Exposed to stressor	1695,93	79,11	(1540.87; 1850.98)
Control	1938,67	90,26	(1761.77; 2115.57)
Treatment effect	242,74		
Females			
Exposed to stressor	1469,00	89,72	(1293.15; 1644.84)
Control	1587,15	114,94	(1361.87; 1812.43)
Treatment effect	118,16		
Gender difference in the control group	351,52		
Treatment effect MEN as % of the gender diff.	69%		
Treatment effect WOMEN as % of the gender diff.	34%		
Panel B: Effect of exogenously induced stress on risk preferences (ATT)			
	Predicted certainty equivalent	Delta method standard error:	95% confidence interval
Males			
Under stress	1638,10	105,52	(1431.294; 1844.91)
Not under stress	2052,61	128,52	(1800.72; 2304.50)
Treatment effect	414,51		
Females			
Under stress	1355,52	215,60	(932.94; 1778.10)
Not under stress	1585,42	1355,52	(1362.97; 1807.88)
Treatment effect	229,90		
Gender difference in the control group	467,19		
Treatment effect MEN as % of the gender diff.	89%		
Treatment effect WOMEN as % of the gender diff.	49%		

Notes: Panel A presents predicted values from the regressions reported in columns 4 (Males) and 5 (Females) of Table 3-1, fixing age and personality profiles on the gender-specific sample averages. Panel B presents predicted values from the regressions reported in columns 4 (Males) and 5 (Females) of Table 3-3, fixing age and personality profiles on the gender-specific sample averages.

4 Chapter Four: Herding under Acute Stress

Abstract

Individual decisions are often made simultaneously under social influence and acute stress, yet despite its importance, it has been unknown whether and how stress influences the weight which people give others' decisions. To answer this question we ran a laboratory experiment where we exposed 140 healthy subjects to either an acute stressor or a control procedure, immediately after which we tested their behavior in a simple Bayesian updating task. Using three measures (salivary cortisol, heart-rate and multidimensional mood questionnaire) we show that subjects in the treatment group were under considerable levels of stress. Even though we predicted that stress would increase the weight they put on information coming from the observation of others, we observe no effect of stress on the updating behavior, neither after private nor after public signals, nor on the precision of the updating behavior. This result holds across different specifications and after the addition of various personal controls, including Big-Five personality traits and the psychological measure of conformity.

4.1 Introduction

The effects of social interaction on individual decision making are ubiquitous – be it the "lemming-like" behavior of investors in financial markets, teenagers' experiments with illegal drugs, conforming to peers at school, coordinating fertility practices, or purchase behavior according to fads, fashion and top-10 lists (Bikhchandani, Hirshleifer, & Welch, 1998; Bikhchandani & Sharma, 2000; Zafar, 2011). Moreover, choices in social context are often made under stress. Traders, lawyers, politicians, and other professionals regularly have to make decisions under severe pressure and stress while they may be influenced by the behavior of others. Like other behavioral biases, stress reaction cannot be controlled by will while it may seriously affect behavior (Starcke & Brand, 2012). Consider a bursting bubble in a stock or financial market, when traders are in a situation where they need to immediately decide about enormous amounts of money on the basis of information from either objective sources like technical analysis, or from what all the other traders are doing. If they tend to be influenced more by others' behavior in the times of stress, it may have huge consequences in many areas since their trading behavior influences world market prices, which are crucial for the stability and growth of economies. However, how stress affects herding behavior is still largely unknown. Even though at least one paper has aimed in a similar direction (Buckert, Oechssler, et al., 2014), this paper is one of the first studies that clearly identifies the causal effects of stress on individual herding behavior. To do so, we run a laboratory experiment where we expose subjects to an acute psychosocial stressor and examine changes in their reaction to signals coming from private and public sources that we have full control over.

The influence of others on one's decisions resulting in a convergent social behavior has been labeled differently in different disciplines, be it social learning, herding, group-mind, crowd- or mob-behavior, social imitation or mimicry (Raafat, Chater, & Frith, 2009). In economics this phenomenon has mostly been studied in the context of herding in financial markets[31] (Avery & Zemsky, 1998; Park & Sabourian, 2011). So far, two main theoretical explanations of herding behavior have been proposed: (i) bounded-rationality and (ii) behavioral explanation (Baddeley et al., 2010, 2007; Baddeley, 2010; Cao & Hirshleifer, 2000). The bounded-rationality explanation posits that herding is just a bounded rational use of information a decision-maker obtains from the observation of the decisions of others, while

[31] The existence of herding in financial and capital markets in various countries has been addressed in many papers (Avery & Zemsky, 1998; Hirshleifer & Hong Teoh, 2003; Sharma & Bikhchandani, 2000). It has been documented and modeled also in other areas such as asset markets (Hott, 2009; Choi & Skiba, 2015) and online-product choice (Huang & Chen, 2006; Chen, Ma, Li, & Wang, 2010).

behavioral biases are neglected, with information cascades[32] being a prominent example (Banerjee, 1992; Bikhchandani et al., 1992; Welch, 1992). The behavioral explanation suggests that herding is caused by various social and psychological factors such as personality type, peer-pressure and a natural preference for conformity (Asch, 1951; Sanfey, 2007) while it disregards the informational reasons. Baddeley et al. (2010) identified that a younger female with high scores in the personality traits[33] venturesomeness and impulsivity has a higher probability of following others. The identification and separation of these channels has already been made (Baddeley et al., 2010, 2007) and in our design we have full control over both aforementioned explanations: the information provided to participants as well as their personality characteristics and observe how these influence individual herding behavior under stress.

Documented physiological and neurological responses to stress suggest that both the abovementioned drivers of herding behavior can be affected under stress. Apart from the protective and adaptive effects of acute stress[34] on the body, one of the main physiological effects is the down-regulation of prefrontal cortex activity (PFC, McEwen, 2007; Porcelli & Delgado, 2009). The prefrontal cortex is generally known to be the brain centre of executive and cognitive control and will power (E. K. Miller & Cohen, 2001; E. K. Miller, 2000) and can be considered the part of the brain which executes the bounded-rational driver of herding.[35] With the expected deterioration of higher cognitive abilities we therefore hypothesized that the precision of the information updating process would decline under stress. Moreover, we hypothesized that stress would cause individuals to rely more on public information than the control group since the precision of one's updating process deteriorates.

[32] This theory has been extensively experimentally tested, (see e.g. Anderson & Holt, 1997; and a review in Weizsäcker, 2010) with the general result that people behave more or less according to the theory, they only rely too much on their private signals compared to the optimal reaction. The caveat of this informational approach is that it neglects individual behavioral differences and focuses solely on information processing.

[33] Personal characteristics are usually tracked by standardized psychometric protocols. The most commonly used protocols are those that measure the "Big Five" dimensions such as NEO-PI-R (Costa and McCrae 1992) or the freely available IPIP-NEO (Goldberg 2010). The latter is used in our design.

[34] The change of behavior under stress is mostly documented in the areas of memory impairment and attitudes to risk, see e.g. Lundberg (1993) or the review in (Starcke & Brand, 2012). The neural and physiological responses are very complex and it is not in the scope of this text to cover them, see e.g. Everly & Lating (2013).

[35] Particularly the medial part of prefrontal cortex is associated with social behavior as has been shown in a number of autism studies (Gazzaniga, Ivry, & Mangun, 2008) and studies using fMRI (Burke, Tobler, Baddeley, & Schultz, 2010; Klucharev, Hytönen, Rijpkema, Smidts, & Fernández, 2009; Klucharev, Munneke, Smidts, & Fernández, 2011)

To illustrate that reasoning in an example, consider traders in the stock market that suddenly experience a shock that induces a stress reaction. The first effect of stress (on the bounded-rational channel) may be that due to stress reaction their cognitive abilities deteriorate and in turn their response to new information is not optimal – they may simply have higher variance in their judgment. Second, the behavioral channel may be affected in the way that under stress, traders become more sensitive to the observed behavior of others and put more weight on what others do relative to what they should do; both directly due to physiological processes in brain caused by the stress reaction, and also indirectly through knowing about their deterioration of cognitive abilities. In the latter case, traders may be aware that others under stress may also suffer from the same cognitive decline and thus not change their behavior: this would however require traders to be sophisticated and know how they react to stress relative to others, or that others react similarly as they do. This may be the case in the real markets, but not in our experiment, where the subjects are anonymous to each other and have no prior knowledge of the reaction to stress of others.

The subjects in the treatment group were indeed physiologically and psychologically stressed: The success of our manipulation is demonstrated using two physiological (salivary cortisol levels and heart-rate) and one psychological (Multidimensional Mood Questionnaire scores, Steyer, Schwenkmezger, Notz, & Eid, 1997) measures.[36] While not different between the groups during the baseline measurement, cortisol levels slightly decreased in the control group during the TSST-Procedure while they almost doubled in the treatment group. Heart-rate was on average 10 beats per minute higher for the treatment group than for the control group; and the treatment group felt significantly worse and more nervous than the control group. Overall, these measures show that we induced stress in a comparable manner as in the related literature (Allen et al., 2014; von Dawans et al., 2011).

[36] Regarding the physiological reaction to stress, we advise the reader to read Everly & Lating (2013) and only note that many complicated processes occur there that can be measurable in some of their outcomes, with salivary cortisol being one of them, but not the only one. To make sure that an individual is really under stress, we combine three measures of stress since some measures may increase, but actually due to another cause (e.g. heart-rate may increase due to stress, but also due to increased focus or physical exercise). We focus on heart rate and salivary cortisol since both have been established as reliable biomarkers of acute stress (Hellhammer, Wüst, & Kudielka, 2009; Kudielka, Buske-Kirschbaum, Hellhammer, & Kirschbaum, 2004). We complement the two physiological measures with one subjective measure which is administered with the English version of Multidimensional Mood Questionnaire (MDM questionnaire, Steyer et al., 1997).

Our main result stemming from an experiment with 140 subjects[37] is that stress has no effect on herding behavior, i.e. the weight in which the public and private signals are given is the same for both groups and the precision of the resulting estimates as well. This result is robust to the addition of various control variables, including psychological measures of conformity and personality traits. Moreover, our data replicates common findings in the literature concerning the updating behavior as we observe behavioral regularities, such as the clustering of probability estimates on multiples of five, conservativeness and an updating behavior generally consistent with the Bayes theorem since it aligns with reinforcing a win-stay heuristic (Charness & Levin, 2005; Kahneman & Tversky, 1973; Salop, 1987). Contrary to Baddeley et al. (2007), we find personality trait Extroversion insignificant; it is rather Neuroticism and Agreeableness which negatively influence the stated probability of an event.

To induce stress[38] we employ the Trier Social Stress Test for Groups (Kirschbaum et al., 1993; von Dawans et al., 2011) which has been considered the most efficient laboratory stressor in terms of the magnitude of cortisol increase it stimulates (Dickerson & Kemeny, 2004). Moreover, the type of stress it induces in subjects, acute psycho-social stress, is the most common type of stress experienced by the general public in the workplace (Ganster & Rosen, 2013; Goh et al., 2015). The peak of the cortisol response occurs 20 to 40 minutes after the start of the stressor and the whole cortisol response lasts 40 to 60 minutes after the stressor ceases (Allen et al., 2014; Kemeny, 2003). We use this fact in our design when the behavioral task is administered right after the end of the stress procedure when the stress response should be the highest.

As a measure of the difference in using public and private information signals we use a simple probabilistic task based on Anderson & Holt, (1997) and Grether (1980) which allows for maximum control over the information provided so that we can exactly calculate the optimal stated probability according to the Bayes formula. In the task there are two possible states of the world, one of them being randomly

[37] This number of subjects is comparable or larger than what has typically been used in the literature and assures sufficient statistical power, see section Discussion of Results (Goette et al., 2015; Haushofer et al., 2013; von Dawans et al., 2012)

[38] We define stress as the physiological, psychological and behavioral reaction arising from perceived environmental demands threatening an important goal of an organism (Dickerson & Kemeny, 2004; Goldstein & McEwen, 2002). Generally speaking, an individual's reaction to stress is highly complex and differs with respect to the type and duration of stressor (Joëls & Baram, 2009) as well as with respect to various individual characteristics (Kudielka et al., 2009; McEwen, 2007) and has been subjected to a number of models (for a summary of physiological models, see Everly & Laitin, 2013; for an example of applications to health-related issues see Ganster & Rosen, 2013).

selected by a computer, but kept secret to subjects until the end of each round. The goal of the subjects is to state their beliefs about which state of the world is more probable to have occurred and re-adjust their beliefs after each signal they get, according to which they are then paid. The signals are first "private" then "public"; private signals are not revealed to others, while the public signal is information about the decisions of some other participants. We then compare the stated beliefs for the treatment and control groups while controlling for the optimal prediction of the Bayes formula, personality profile and the performance in the task before stress using a difference-in-differences approach.

As to studies focusing on social learning under stress, conformity under stress has already been studied but stress was induced rather indirectly: the authors experimentally tested conformity within the ranks of male U.S. Navy students under the threat of tear-gas infusion into the room (Driskell & Salas, 1991). Both the high and low status subjects behaved in a similar manner and became more willing to accept the opinion of their partner who was not exposed to the stress condition. Unfortunately, the authors do not provide any evidence that the subjects were under stress and their measure of conformity is rather crude. In another study subjects were exposed to time pressure and a Stroop test while their cortisol and heart rate were measured (Buckert, Oechssler, et al., 2014). However, such manipulations are normally used as distractions in order to deplete the cognitive resources and thus produce intuitive responses rather than stress. Their task of interest was a repeated Cournot oligopoly game where the players could request the price and quantity set by other players as opposed to using a profit calculator. The authors argue that because the cortisol levels slightly increased, their manipulation was successful. They further claim that both groups show signs of more imitation relative to control since (i) the participants in the two "stress" groups requested more information on the prices and quantities set by others and (ii) based on this information there were more occurrences of setting very similar prices to the observed ones in the Time-pressure group than in the other two groups. Lastly they show that subjects with higher physiological responses are more likely to imitate the choices of others, though with no difference across the treatments. As is usual for time-pressure studies (see e.g. the discussion on the intuition and cooperation in Tinghög et al., 2013) the authors in their construction of the design disregard all choices that were not made in time in the time-pressure treatment. Moreover, from the observed choices of prices and quantities, it is hard to infer what the original decision of the subjects was and whether they changed it due to new information or there was just more similar behavior among subjects in general, as the convergence toward equilibrium tends to be faster under time pressure (Kocher & Sutter, 2006). In contrast to this, we use an efficient stressor and prove subjects were under considerable stress; and in our task we are able to perfectly measure the difference in the weight of private vs. public signals.

In the literature other outcomes than herding that change under stress have also been investigated. Relatively lot of attention has been devoted to attitudes to risk, but no consensus has been achieved as is shown in the introduction of this dissertation and this topic has been addressed in Chapter 3 (for a summary of previous work refer to Allen et al., 2014; Buckert, Schwieren, et al., 2014). Apart from that, social stress has been found to induce more pro-social preferences in men (Vinkers et al., 2013; von Dawans et al., 2012) but no effect was observed on time preferences (Haushofer et al., 2013). Stress also decreases strategizing abilities (Leder et al., 2013, 2015) and depending on trait anxiety, it can increase or decrease individual confidence (Goette, Bendahan, Thoresen, Hollis, & Sandi, 2015).

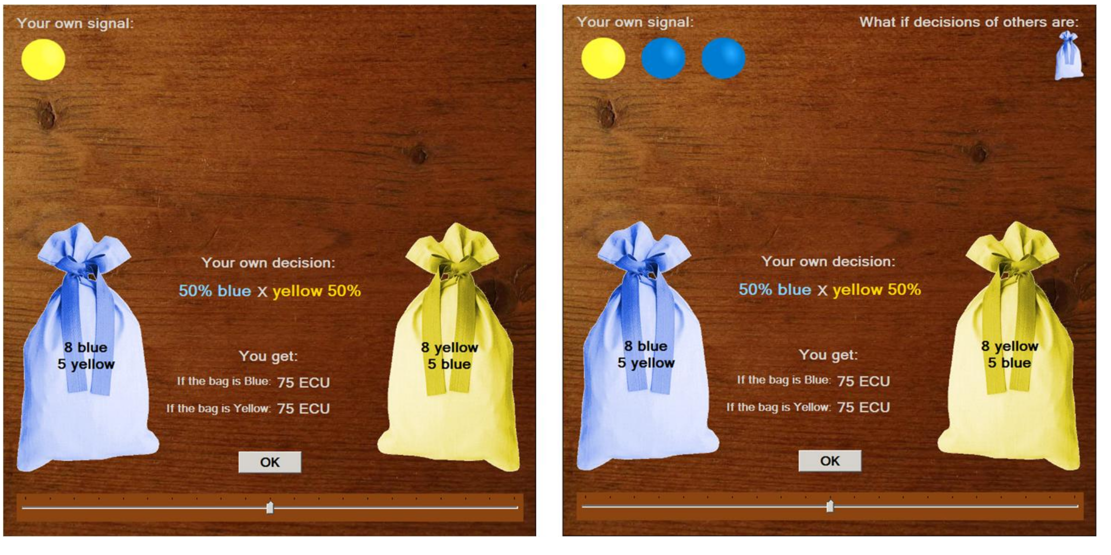
Our findings generally imply that observed phenomena in the real world, such as bank runs and herding behavior in financial markets are more likely the result of changes in different dimensions of human behavior than the increased propensity to engage in herding behavior, like change in expectations or change in risk-preferences, and their investigation is suggested for future research.

4.2 Methodology

Task

In order to have an environment with the maximum possible control over the information that the participants receive, we use the following task about Bayesian updating based on Anderson and Holt (1997) and Grether (1980). In the task, subjects state their beliefs about which of the two possible states of the world occurred based on the information they receive, and are monetarily rewarded for a correct prediction. Particularly, the states of the world are framed as two possible unmarked bags containing marbles of two colors, blue and yellow. The “Yellow” bag contains more yellow marbles than blue marbles whereas in the “Blue” bag the ratio of the colors is symmetrically reversed. At the beginning of each round, one of the bags is randomly chosen by the computer with a 50% chance; the same bag for all participants in a given round. First of all, subjects are informed about the composition of the colors in both bags. With each new signal, subjects are asked to state or revise their beliefs using a slider that indicates a percentage probability of both outcomes (visualized in Figure 4-1). A *private signal* is the information about the color of a ball drawn with replacement from the chosen bag. After receiving private signals, participants are presented with the *public signal* in one of the forms described further. At the end of each round, subjects receive feedback on which bag was really chosen by the computer and how much ECU this round would pay if selected for payoff. Subjects are paid for each decision according to the quadratic scoring rule[39] for stating their beliefs in a given round, and all decisions in a given round added up to a total amount of ECU which could be earned from this round. The amount of ECU paid for the outcomes updated on the screen simultaneously with the movement of the slider. Prior to starting the task, subjects were informed that out of the 13 rounds, three would be randomly chosen for payoff at the end of the experiment. The ratio of the colors as well as the number of private and public signals varied across the rounds so that the subjects (i) would not get bored and (ii) would not develop a simple rule of thumb.

Figure 4-1: The layout of the decision-making environment.



Note: Representation of the decision-making environment of the subjects. The left part of the figure shows the decision after the arrival of the first private signal (top-left corner). The right part of the figure shows the representation of public information in the upper right corner; particularly in the strategic form ("What if" scenario).

In each round after all private signals had been revealed, public information was presented, i.e. information about the decisions of some other randomly chosen players. Subjects were randomly divided into small groups and presented with the beliefs of all other players in the group, where the size of the groups changed across rounds. The public information was conveyed by showing a small bag in the upper

[39] The quadratic scoring rule was explained and demonstrated by a table with selected probabilities and respective payments in the instructions. Moreover, as they moved the slider, the respective amount paid in case one of the bags was chosen changed in real time. As this approach is incentive compatible only if the subjects are risk-neutral, we discuss the effects of risk preferences in the Appendix.

right corner of a blue or yellow color (see right part of Figure 4-1). The color of the small bags represented the color the other subjects indicated to be more probable; each subject was presented as one small bag. If the odds were 50/50, the color of the small bag was chosen randomly. Participants either saw the color of the bag(s) and made a direct response, which was framed as "Scenario: Reality", or were presented with all possible combinations of the actions of others and were asked to state the probability conditionally for each situation. This strategy method was framed as the "Scenario: What if" and participants were paid only according to the situation that really occurred. Here we also manipulated the order of the public signal so that in five rounds the opposite signal to the current beliefs of participant was presented first, whereas a random order of the signals was implemented in another three rounds (see Table 4-1). For the sake of simplicity we assume that all subjects are rational and have symmetric expectations about other subjects which allows us to calculate the optimal response based on the information contained in the signals using the Bayes formula.

Table 4-1: Round structure: number of balls in the "Blue" bag

Round number	Number of blue balls	Number of yellow balls	Number of private signals	Players per group	Type of public signal	Strategy method: Order of public signals
trial 1	10	3	2	4	Direct response	
trial 2	8	5	3	3	Strategy method	Real
round 1	7	2	2	4	Strategy method	Opposite signal first
round 2	10	7	2	5	Direct response	
round 3	5	4	2	3	Strategy method	Real
round 4	10	5	4	4	Direct response	
round 5	13	4	3	3	Strategy method	Opposite signal first
round 6	7	2	3	3	Strategy method	Real
round 7	13	4	2	4	Direct response	
round 8	5	4	3	2	Strategy method	Opposite signal first
round 9	7	2	4	2	Direct response	
round 10	10	7	3	3	Strategy method	Real
round 11	5	4	3	3	Direct response	
round 12	13	4	4	2	Strategy method	Opposite signal first
round 13	10	5	3	3	Strategy method	Opposite signal first

Treatment manipulation: Stress-inducing procedure

Subjects were exposed to a slightly modified[40] Trier Social Stress Test for Groups (TSST-G, von Dawans et al., 2011), which is a standardized psychological protocol for inducing psychosocial stress. The approval of the Institutional Review Board of the Laboratory of Experimental Economics was obtained prior to the experiment. The subjects were randomly divided into two groups of seven and after reading the instructions silently for 3 minutes, they went into two separate rooms adjacent to the lab that were set-up for the procedures. The treatment (stress-inducing) TSST-G condition consisted of two parts: a public speaking and a mental arithmetic part, which were framed as a mock job-interview and a serial subtraction of 17 from 4578, respectively.[41] The instructions obtained in the laboratory mentioned only the first part, i.e. the mock job interview. Further the instructions informed the participants that there would be two people closely observing their behavior during their speech and that there would be a video-camera recording the whole procedure. After entering the room, the participants stood in places separated by cardboard dividers so that they would not interact with each other, and had on headphones connected to MP3 players with ambient traffic noise on so that they would not hear others and could not infer relative performance. Two additional experimenters, who were referred to as a "committee" during the procedure, sat at a desk in front of the participants, wore white laboratory coats and had a video camera by their side. The committee had been trained not to give any feedback on the subjects' performance either verbally or physically. With a neutral expression on their faces, they called subjects in a random order, who then had two minutes to present their job-interview. When all subjects had finished their job-interviews, the committee asked the subjects again one-by-one to complete the arithmetic task for one minute. The committee made notes during the whole procedure. In the control condition, subjects jointly read a scientific text aloud in a low voice, also while standing in a group and facing two panel members, but the panel members wore normal clothes, they did not take any notes, had no video cameras by their side and were allowed to behave naturally. The arithmetic part of the control procedure consisted of counting in steps of a certain magnitude, e.g. 5, 10, 15, 20 etc. A careful debriefing was carried out with the treatment group before they received the payments at the end of the experiment.

[40] The original script of Von Dawans et al. was slightly modified so that no deception was present. The changes to the original protocol concerned mainly the information given to participants regarding the behavioral training of the panel members and regarding the fact that the video recordings would later be analyzed.

[41] The numbers differed across subjects so that they could not learn from others in case they could hear them.

4.3 Procedures

By using ORSEE (Greiner, 2004) 140 healthy subjects were recruited: 67 females (mean age 22.1, SD = 2 years) and 73 males (mean age 22.6, SD = 2.7 years).[42] They were mostly students of economics, management or related disciplines (72%). We followed best practice in order to avoid any factors confounding cortisol measurement (Nicolson, 2007).[43] A majority of the subjects had no acquaintances among the other participants thus the possible social support which may have disrupted the effect of the stress procedure was minimized (Heinrichs, Baumgartner, Kirschbaum, & Ehlert, 2003). They did not receive any information about the purpose of the experiment beforehand in order to minimize selection bias. All participants signed an informed consent form which referred to the treatment procedure as a "challenge" task. They were specifically informed about the chance to leave the experiment at any point in time while still obtaining a show-up fee in such a case. The details of the treatment protocol were only revealed before its start. None decided to leave before the regular end of the experiment.

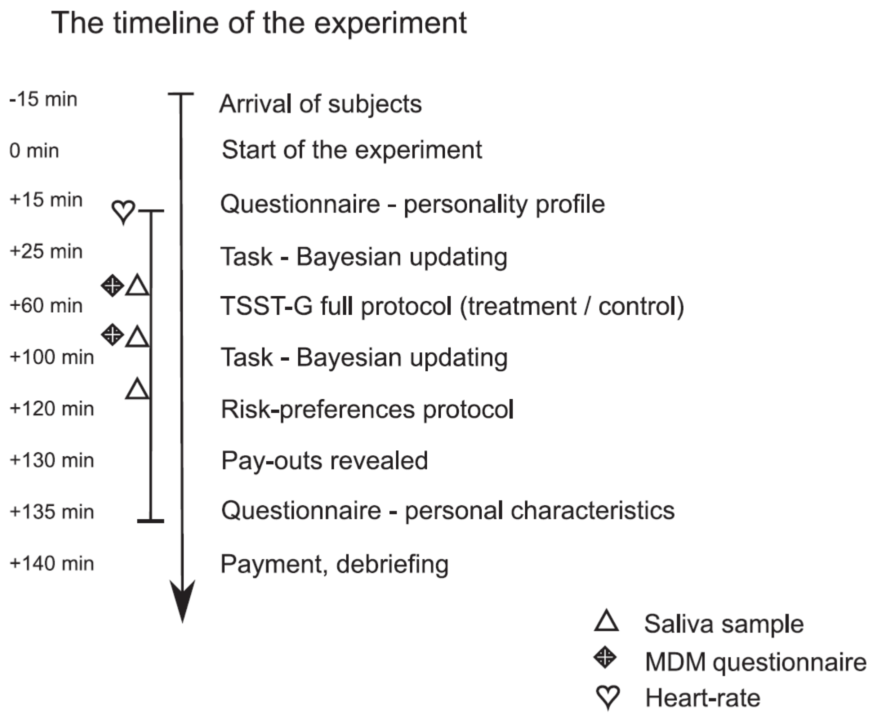
All experimental payoffs were denominated in experimental currency units (ECUs) and were converted to Czech crowns at the end of the experiment.[44] The experiment lasted on average a little less than 2.5 hours and was conducted in English. All subjects were listed in the database for experiments conducted in English and indicated no difficulties understanding the instructions or speaking. One experimental session included 14 subjects (seven in the treatment and seven in the control group), two experimenters and four members of the committee for the TSST-G procedure. All sessions started at 16:30 in order to make the cortisol measurement comparable across sessions due to the natural diurnal cortisol cycle. The average payoff was 490 CZK, i.e. 19.6 EUR.

[42] The sessions were run in two batches with identical procedures, experimenters and committee members, therefore we pool the results. The first five sessions were run in April 2012 and the next five sessions in November 2014.

[43] Subjects received an invitation email already with instructions to abstain from fatty food, nicotine and heavy exercise at least 2 hours prior to the experiment. Immediately before the experiment subjects were screened for any circumstances that could potentially disrupt the cortisol response: health status, drug intake, caffeine, heavy meals, and contraceptive intake. We then performed robustness checks and none of the problematic factors mattered for the main results (available upon request). With one exception the participants were all normal body-weight and twelve women indicated taking oral contraceptives. Out of these twelve women, five were assigned to the treatment group; two of these did not show the expected cortisol increase.

[44] The conversion rate was 32 ECU=1 CZK.

Figure 4-2: The timeline of the experiment.



The timeline of the experiment is summarized in Figure 4-2: After arriving at the laboratory the subjects were randomly assigned to computers, signed the consent form and the general instructions were read aloud by the experimenter. Participants got the heart-rate monitors, and were asked to fill-in a questionnaire assessing their personality profile. The instructions for the task were then read aloud and subjects had to answer three questions confirming their understanding. Then they had two trial and five real rounds of the task. At this point they were asked to give the first sample of saliva and fill in the first part of the MDM questionnaire. Instructions to the TSST-G treatment and control procedure were distributed next. Participants read them silently and had few minutes to either prepare for the job interview or for reading a scientific text which was subsequently performed in adjacent separate rooms, i.e. the full TSST-G treatment and control procedures were carried out. After this, the participants returned to the lab, were seated back at computers, the second sample of saliva was collected and they filled in the second part of the MDM questionnaire. Then the participants were to solve eight more rounds of the previous task. When finished, the participants gave their third saliva sample and completed a simple paid-for task aimed at measuring their risk-preferences (protocol based on Dohmen et al., 2010). At the end of the experiment, three rounds of the task were randomly drawn for payment,[45] subjects completed a short questionnaire on their personal

[45] The reason for using random incentive scheme is purely to minimize hedging of the subjects resulting from a wealth effect. We acknowledge that due to recent evidence on the differences in

characteristics and proceeded to payment. All subjects were paid in private, and when the control group had left the laboratory, a thorough debriefing of the TSST-G procedure was carried out with the treatment group. Participants were asked to sign a statement of confidentiality with respect to the experimental procedure.

Questionnaires - Personality measurement

Participants filled in the 50-item set of IPIP Big-Five Factor Markers (Goldberg et al., 2006) which is a measure of the five major factors of personality, openness to experience, conscientiousness, extraversion, agreeableness and neuroticism. In addition to that, we included a conformity inventory IPIP measuring construct similar to the revised Jackson Personality Inventory (Jackson, 1983) to control for the natural behavioral propensity to conform to the opinion of others.

outcomes depending on different payment scheme, the elicited parameters may not be generally valid beyond this setting (Cox et al., 2015). However, the main purpose of this experiment is the dif-in-dif comparison of treatment and control groups only and not establishing the parameters as in the case of e.g. the experiments on trust, so the bias potentially induced by the payment method should be similar in both groups and cancel out.

4.4 Results

Randomization check

We perform a randomization check of observable characteristics that may influence the stated probability after public signals. Table 4-6 in the Appendix shows that the treatment and control groups were balanced with respect to gender, age and education. Further factors that may influence the results are the "Big-5" personality traits and conformity. The treatment group was higher in extraversion and neuroticism, while not statistically different in the other dimensions, which is the reason to add these controls to the regression analysis.

Manipulation check

Using three measures we show that stress induction was successful.[46] First we present in panel (a) of Figure 4-3 the cortisol reaction that we consider the most reliable indicator of induced stress. The level of concentration of salivary cortisol is not different for the treatment and control groups before the TSST-G procedure (two-sample Wilcoxon ranksum test: $z = -0.21$, $p = 0.83$, $d = -0.1$),[47] but the sample taken after the procedure as well as the sample taken after the end of the task show a significant increase for the treatment group ($z = -6.22$, $p < 0.001$, $d = -1.1$ and $z = -6.05$, $p < 0.001$, $d = -1.04$, respectively).[48]

Second, panel (b) of Figure 4-3 summarizes the heart-rate before, during and after the stress procedure.[49] Heart-rate does not differ between the treatment and control groups before ($z = -0.77$, $p = 0.44$, $d = -0.14$) and after ($z = -0.99$, $p = 0.32$, $d = -0.12$) the TSST-G procedure, however, there is a significant difference during the

[46] See Table 4-7 in the Appendix for the descriptive statistics of all the variables

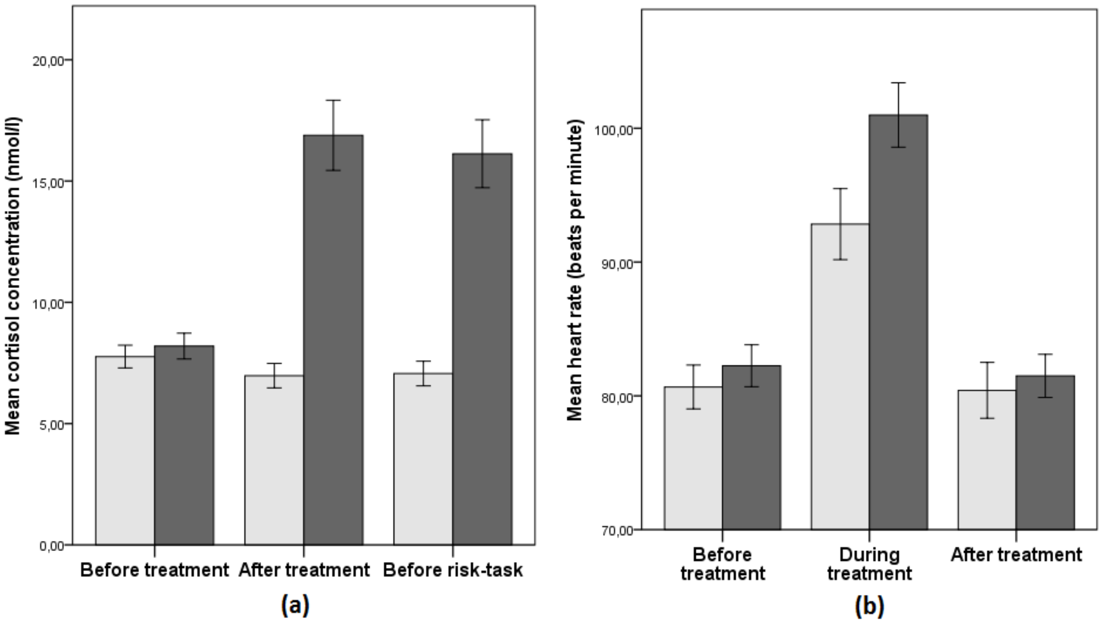
[47] Reported effect sizes are Cohen's *d*, corrected for uneven groups.

[48] The procedure of saliva sampling as well as the administration of the heart-rate monitor chest belts may have been by some perceived as stressful, which would confound our baseline measurement and thus the control group would be also under the influence of stress. To capture this we for the sake of simplicity focus only on salivary cortisol and compare the levels in our control group (7.7 +/- 3.9 nmol/l) with the values observed in similar studies (cca 12 nmol/l, von Dawans, Fischbacher, Kirschbaum, Fehr, & Heinrichs, 2012, 7 nmol/l, von Dawans et al., 2011 and 9 nmol/l, Kirschbaum et al., 1993) as well as in the general population for this type of physical activity and part of the day (refer to Appendix Figure 4-8). We conclude that the levels in our group were smaller or equal than those in the relevant literature and they do not substantially differ from the reference values for general population. This suggests that the subjects were not stressed already at the baseline. Moreover, the types of measurement used of both variables are considered to be the least obtrusive from all the available methods (Baum et al., 1982).

[49] We note that there were technical problems with measurement in several subjects. With some we were completely unable to find the signal while with others the signal kept turning on and off during the procedure. Therefore we do not have a full number of observations for this measure.

procedure (z = -1.84, p = 0.066, d = -0.41) which supports the claim that subjects in the treatment group were physiologically under stress.

Figure 4-3: Induced Stress Reaction: Cortisol and Heart-Rate.

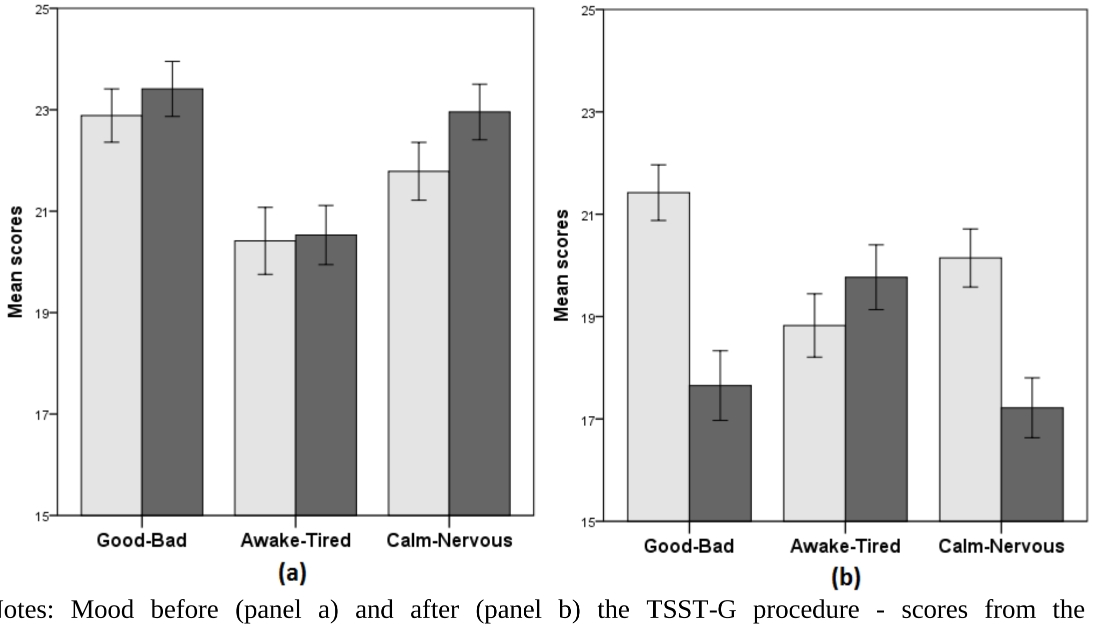


Notes: The darker color indicates the treatment group. Panel (a): Mean levels of free salivary cortisol; Sample 1 was collected before the treatment or control TSST-G procedure, sample 2 after the TSST-G procedure and sample 3 before the risk task. Panel (b): Mean levels of heart-rate calculated from individual averages over the time periods before, during and after the TSST-G procedure. Error bars indicate standard errors of the mean.

The subjective effect of stress was captured by the change in the subjects' mood reported in the MDM questionnaire. Panel (a) of Figure 4-4 shows that before the treatment procedure, the treatment and control groups' scores were not different in any of the three dimensions ("good-bad": z = -1.05; p = 0.29; d = -0.11; "awake-tired": z = -0.83; p = 0.83; d = -0.00; "calm-nervous": z = -1.2; p = 0.23; d = -1.12). Panel (b) of Figure 4-4 reveals that after the TSST-G procedure, the treatment group reported scores significantly different than the control group: the treatment group scored closer to the "bad" (z = 3.60; p < 0.001; d = 0.68) and the "nervous" (z = 3.44; p < 0.001; d = 0.61) dimensions. The last "awake-tired" dimension was not different across the two groups (z=-1.59; p = 0.11; d = -0.1). This finding shows that subjects in the treatment group were also under psychological stress.

The changes of the two physiological measures (cortisol and heart-rate) are significantly correlated, (ρ= 0.385; p < 0.001). The cortisol response is further correlated with the MDM score in the good-bad dimension (ρ = -0.259; p < 0.01) and in the calm-nervous dimension (ρ = -0.23; $p < 0.01$). The association of heart-rate and psychological measures is significant in the calm-nervous dimension (ρ = -0.21; p = 0.02) and the awake-tired dimension (ρ = 0.15; p = 0.09). The three mood dimensions are further highly correlated, as could be expected.

Figure 4-4: Induced Stress Reaction: Mood.



Notes: Mood before (panel a) and after (panel b) the TSST-G procedure - scores from the Multidimensional Mood State Questionnaire. The darker color indicates the treatment group. Error bars indicate standard errors of the mean.

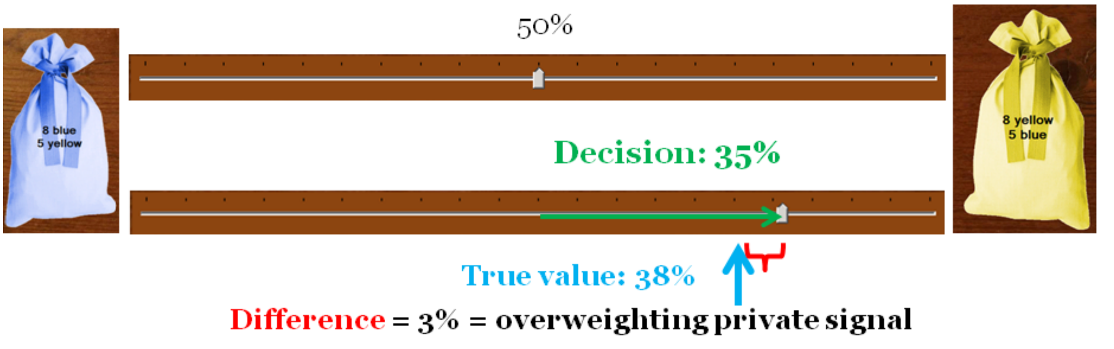
Herding behavior

The variable of interest in our analysis, *Decision*, is the stated probability entered by subjects after each new signal using a slider that they moved from the initial point 50/50. We take the value of the distance from the 50/50 point to the new position of the slider in the direction of the new signal (see Figure 4-5). Apart from the actual decision of the subjects we also calculate the optimal decision ("*True*" value), given all information a subject had received prior to the current decision in a given round. While calculating *True* we assume that a decision maker is rational in that she uses the Bayes formula[50] for updating his/her priors and disregards any irrelevant information in the sense that there is no interdependence between the answers in the "What-if" scenario. Further, we assume that for calculating the public information, subjects also took into account the possibility that when the other subjects stated exactly the same probabilities of both bags having been selected, the resulting signal was chosen at random.

[50] We are aware of the on-going debate as to whether people really use the Bayes formula in their decision making and thus we note that it is a rather simplified assumption made for the sake of convenience.

We can then easily define a new variable *Difference* as the difference between *Decision* and *True*, which then shows whether subjects over- or under-valued the signal compared to the *True* value, if the *Decision* was higher or lower than the *True*, respectively (Figure 4-5). *True* captures the informational content of the signals, therefore also the composition of the bag, number of signals received and the share of signals for the chosen color.

Figure 4-5: Variables of interest.



Note: Example of a situation when the chosen bag was blue, subject received one private "yellow" signal and moved the slider to the position where the stated probability of the event “selected bag is Blue” was 35%.

Figure 4-6 illustrates that subjects suffered from typical behavioral biases identified in the literature, such as stating more likely probabilities rounded to 5 or 10 and being reluctant to state the probability closer to the extreme, when contrasted with the True probability.

Figure 4-6: Histograms of variables *True* and *Decision*.

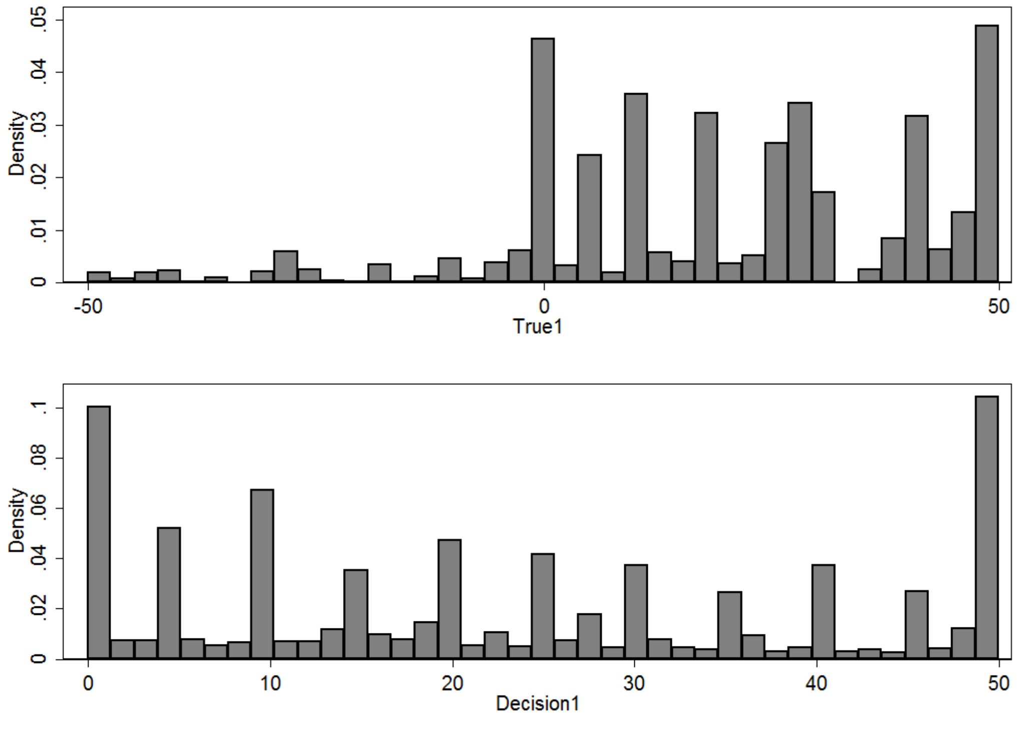
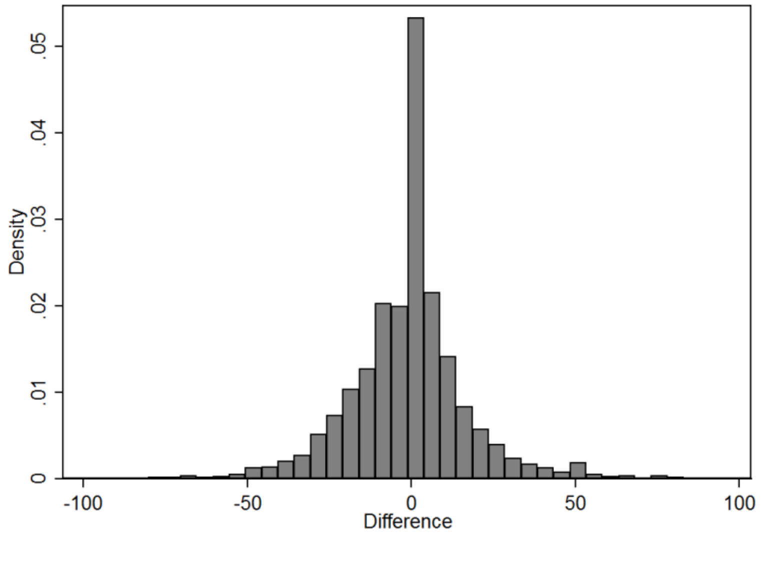


Figure 4-7: Histogram of variable *Difference*, both types of signals pooled.



When examining the density of the variable *Difference* (Figure 4-7), it reveals that the subjects reacted rather rationally to the signals they had received since the distribution is centered on the mean of zero is not skewed to either side. When divided into the two types of signals, qualitatively no difference emerges.

Regression analysis

Since we observe the decisions of both groups before and after the treatment manipulation, we analyze the level differences using the difference-in-differences approach. First we look at the differences in updating only after the private signals, which should answer the question whether the subjects' cognitive abilities were affected by stress. To do this, we regress the variable *Decision* on *Treatment* dummy, the dummy indicating decisions made after the treatment procedure *Round after stress* and their interaction *Treatment *Round after stress* while controlling for *True* probability. In Table 4-2 we show that the interaction term *Treatment *Round after stress* is not significantly different from zero (p=0.259) in the baseline specification in column 1, and stays insignificant when we add fixed effects for sessions to account for the unobserved heterogeneity across sessions (column 2). The significance of the control variable *True* shows that subjects used the information contained in the signals, and for each percentage point in the probability predicted by the Bayes formula they moved the slider by 0.65 points in the correct direction. The insignificance of the term *Treatment* reveals that there are no systematic differences between the two groups in decision making and the term *Round after stress* shows no difference between the decisions made before the treatment procedure and after the procedure. Further we test a gender-specific effect of the stressor by adding a set of dummy variables *Female*, *Treatment*Female* and *Treatment*Female*Round after stress* (column 3). None of these is significant in the regression, even when tested jointly, and the coefficient of *Treatment *Round after stress* also does not change so we conclude that there is no difference when it comes to gender. In Column 4 we show results when we add into the regression a set of observable characteristics that include *Age*, the "Big-Five" personality traits and *Conformity*. Coefficient of *Age* is significant and positive, which means that older subjects stated probability after a private signal larger than the younger ones. Personality traits are insignificant with the exception of Neuroticism which is significant on a 1% level and negative, which means that subjects that are more neurotic and emotionally unstable stated a probability smaller than other subjects. Further we test whether there was a difference in the stated probability after the first private signal in a round (column 5) when we restrict the observations to only the first signals each subject received in a given round to conclude that there was no difference. To summarize, even after the addition of all these control variables, the coefficient of *Treatment *Round after stress* does not change its size or significance.

Next we move to the analysis of the reaction to the public signal. Table 4-3 reveals that subjects again used the provided signals as the coefficient of *True* is significant in their updating process, but with a smaller weight since the magnitude is about a half of the coefficient in the regressions for the private signal. However, there is no difference between the treatment and the control groups either before or after the treatment procedure (coefficient of *Treatment *Round after stress*), with and without additional controls (Columns 2 to 4). Column 4 of Table 4-3 presents that gender-specific treatment effects are not present, and only the coefficient of variable *Female* is significant and negative. Column 6 of Table 4-3 shows the result of analysis when the observations were restricted only to the decision after the first public signal which serves as a check when we avoid any influence of the order that may change the value of the rest of the signals. Again, there is no statistical difference between the treatment and control groups and the personality characteristics behave similarly as in the analysis of private signals: Age is significant and positive and the personality trait Neuroticism is significant and negative. Additionally to that, the personality trait Agreeableness is also significant and negative, which means that more agreeable people tended to state the probability as smaller than the rest.

Table 4-2: Regression analysis, observations restricted only to decisions after private signals.

	(1)	(2)	(3)	(4)	(5)
			Private signals		
VARIABLES	Decision	Decision	Decision	Decision	Decision
True	0.653***	0.655***	0.656***	0.656***	0.626***
	(0.0317)	(0.0312)	(0.0316)	(0.0311)	(0.0396)
Treatment	0.926	0.928	-0.331	1.512	1.768
	(1.185)	(1.094)	(1.522)	(1.061)	(1.086)
Round after stress	0.0341	0.0302	0.0292	0.0293	-0.951
	(0.661)	(0.662)	(0.662)	(0.661)	(0.747)
Treatment *Round after stress	-0.919	-0.922	-1.026	-0.923	-1.160
	(0.811)	(0.812)	(0.926)	(0.814)	(0.903)
Female			-1.450	-0.335	1.295
			(1.564)	(1.158)	(1.297)
Age				0.576***	0.485**
				(0.212)	(0.214)
Openness to Experience				-0.136	-0.131
				(0.127)	(0.131)
Conscientiousness				0.0919	0.151*
				(0.0854)	(0.0898)
Extraversion				0.124	0.0969
				(0.0845)	(0.0893)
Agreeableness				-0.150	-0.153
				(0.100)	(0.109)
Neuroticism				-0.207***	-0.207***
				(0.0696)	(0.0701)
Conformity				-0.0557	-0.0308
				(0.0996)	(0.0999)
Treatment *Female			2.634		
			(2.214)		
Treatment *Female *Round after stress			0.213		
			(1.015)		
Constant	9.270***	8.496***	9.177***	6.549	4.533
	(1.044)	(2.933)	(3.144)	(9.264)	(8.802)
Observations	5,320	5,320	5,320	5,320	1,820
R-squared	0.493	0.509	0.511	0.524	0.400
Session FE	NO	YES	YES	YES	YES
F	118.4	44.31	38.69	35.84	23.12

Notes: Dependent variable *Decision*. Robust standard errors clustered on the individual level in the parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4-3: Regression analysis, observations restricted to decisions after public signals.

	(1)	(2)	(3)	(4)	(5)	(6)
				Public signals		
VARIABLES	Decision	Decision	Decision	Decision	Decision	Decision
True	0.330***	0.332***	0.332***	0.331***	0.332***	0.287***
	(0.0143)	(0.0147)	(0.0147)	(0.0146)	(0.0139)	(0.0162)
Treatment	0.832	0.832	0.832	-0.677	1.468	0.873
	(1.464)	(1.414)	(1.414)	(1.906)	(1.398)	(1.565)
Round after stress	0.981	0.974	0.974	0.977	0.976	0.524
	(0.907)	(0.908)	(0.908)	(0.908)	(0.909)	(1.059)
Treatment *Round after stress	-0.0206	-0.0203	-0.0203	0.164	-0.0203	0.616
	(1.092)	(1.093)	(1.093)	(1.250)	(1.094)	(1.309)
Age					0.606**	0.554**
					(0.253)	(0.269)
Female				-3.426*	-1.645	-1.313
				(1.846)	(1.408)	(1.530)
Openness to Experience					-0.105	-0.107
					(0.156)	(0.166)
Conscientiousness					-0.00219	0.0365
					(0.0992)	(0.111)
Extraversion					0.144	0.159
					(0.102)	(0.108)
Agreeableness					-0.276**	-0.283**
					(0.134)	(0.142)
Neuroticism					-0.226***	-0.223**
					(0.0860)	(0.0943)
Conformity					-0.0605	-0.124
					(0.129)	(0.137)
Treatment*Female				3.207		
				(2.868)		
Treatment*Female*Round after stress				-0.380		
				(1.212)		
Constant	17.20***	15.61***	15.61***	17.16***	20.49*	23.84**
	(1.104)	(3.401)	(3.401)	(3.545)	(10.90)	(11.41)
Observations	3,920	3,920	3,920	3,920	3,920	1,820
R-squared	0.236	0.251	0.251	0.256	0.273	0.213
Session FE	NO	YES	YES	YES	YES	YES
F	137.3	48.98	48.98	43.00	39.13	20.97

Notes: Dependent variable *Decision*. Robust standard errors clustered on the individual level in the parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4-4 presents results of the regression analysis when the observations include stated probability after both of the types of signals simultaneously which on the one hand increases the statistical power but on the other makes the interpretation rather difficult. Here we again confirm null treatment effect: first, the coefficient of the variable *Treatment *Round after stress* is not different from zero, which informs us that the general weight of either type of a signal was similar for both treatment and the control groups after the TSST-G procedure. Further we test whether the weight of public signals after the TSST-G procedure was different in the treatment and the control groups. To do this, we conduct the F-test of the linear combination of coefficients *Public*Treatment*Round after stress + Treatment *Round after stress + Treatment* which is not significantly different from zero in any of the tested models ($F = 0.31$, $p = 0.58$; $F = 0.33$, $p = 0{,}57$; $F = 1.21$, $p = 0.27$ for the columns 1, 2 and 3, respectively). The significant and positive coefficient of the indicator variable *Public* which equals one if the signal was from public sources informs us that the signal from public sources followed by 1.9 percentage points more than the private signal, which is actually inconsistent with the literature (Weizsäcker, 2010) where the typical finding is that people tend to rely more on private than on public information.

Precision of estimates

Another potential effect of stress was hypothesized to appear in the precision of individual estimates relative to the value predicted by the Bayes theorem. Using again the difference-in-differences approach we regress the variable *Difference* in an absolute value on the set of dummies while including the same set of controls as in the preceding sections. In Table 4-5 we show that for both types of the signal, we cannot reject that the precision of estimates is the same for both treatment and control groups since the coefficient of *Treatment *Round after stress* is not different from zero, even in the specifications including additional controls. The coefficient *Round after stress* is significant and negative for the decisions made after the public signal which shows that both treatment and control groups improved the precision of the estimates after the TSST-G procedure. The addition of personality controls (column 3) does not increase the coefficient of determination vastly, and the only significant predictor is the Openness to experience which is significant and negative. In column 6 *Female* is significant and positive which informs us that women tended to have smaller precision of estimates than men; and the negative coefficient *Conformity* means that subjects high in Conformity tended to have more precise estimates when they reacted to the signal from public sources.

Table 4-4: Regression analysis, all observations.

	(1)	(2)	(3)
		All observations	
VARIABLES	Decision	Decision	Decision
True	0.455***	0.458***	0.457***
	(0.0182)	(0.0184)	(0.0179)
Treatment	0.815	0.816	1.448
	(1.247)	(1.174)	(1.149)
Round after stress	0.362	0.358	0.358
	(0.648)	(0.649)	(0.648)
Treatment *Round after stress	-0.662	-0.664	-0.664
	(0.795)	(0.795)	(0.795)
Public	1.956***	1.951***	1.952***
	(0.476)	(0.476)	(0.475)
Public *Round after stress	0.283	0.282	0.282
	(0.628)	(0.629)	(0.629)
Public *Round after stress*Treatment	0.665	0.667	0.666
	(0.772)	(0.773)	(0.773)
Female			-0.961
			(1.230)
Openness to experience			-0.117
			(0.138)
Conscientiousness			0.0494
			(0.0885)
Extraversion			0.128
			(0.0904)
Agreeableness			-0.206*
			(0.111)
Neuroticism			-0.220***
			(0.0737)
Conformity			-0.0612
			(0.108)
Age			0.588***
			(0.224)
Constant	12.79***	11.55***	12.95
	(0.958)	(3.009)	(9.720)
Observations	9,240	9,240	9,240
R-squared	0.341	0.356	0.373
Session FE	NO	YES	YES
F	107.1	53.27	45.08

Notes: Dependent variable *Decision*. Variable *Public *Round after stress*Treatment* indicates the decision of the subjects in treatment group after public signals. Robust standard errors clustered on the individual level in the parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4-5: Precision of estimates – regression analysis.

	(1)	(2)	(3)	(4)	(5)	(6)
	Difference in absolute value					
Signal type:		Private			Public	
True	-0.116***	-0.112***	-0.107***	-0.350***	-0.349***	-0.347***
	(0.0315)	(0.0304)	(0.0300)	(0.0218)	(0.0216)	(0.0214)
Treatment	0.430	0.432	0.171	-0.278	-0.278	-0.265
	(0.908)	(0.879)	(0.894)	(0.747)	(0.731)	(0.721)
Round after stress	0.117	0.112	0.103	-1.742***	-1.743***	-1.748***
	(0.521)	(0.521)	(0.521)	(0.504)	(0.504)	(0.504)
Treatment *Round after stress	0.0448	0.0405	0.0339	0.698	0.698	0.698
	(0.631)	(0.632)	(0.635)	(0.681)	(0.682)	(0.683)
Female			1.037			1.070*
			(0.816)			(0.632)
Openness to experience			-0.183**			-0.0867
			(0.0864)			(0.0753)
Conscientiousness			0.0399			0.0256
			(0.0594)			(0.0501)
Extraversion			0.0610			0.00929
			(0.0609)			(0.0477)
Agreeableness			0.0185			0.00934
			(0.0684)			(0.0489)
Neuroticism			0.0409			-0.0577
			(0.0513)			(0.0397)
Conformity			-0.0947			-0.173***
			(0.0756)			(0.0603)
Age			0.157			-0.0575
			(0.202)			(0.154)
Constant	10.87***	14.13***	13.62*	24.65***	27.38***	36.55***
	(1.038)	(2.406)	(7.942)	(0.818)	(1.744)	(6.352)
Observations	5,320	5,320	5,320	3,920	3,920	3,920
R-squared	0.041	0.063	0.080	0.290	0.295	0.298
Session FE	NO	YES	YES	NO	YES	YES
F	4.174	2.101	2.308	78.24	28.61	21.40

Notes: Dependent variable: *Difference* in absolute values. Robust standard errors clustered at the individual level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Robustness checks

To investigate whether there were any different treatment effects with respect to the reactivity to stress, we also perform the difference-in-differences comparison of the stressed and non-stressed subjects, where we define that a subject is stressed as 1 if cortisol increased by at least 2.5 nmol/l between the baseline (sample 1) and the higher of the two samples taken after the treatment procedure (R. Miller et al., 2013).[51] We re-run all the regression models in Tables 4-2, 3, and 5 to conclude that our results are robust against this change of specification, which would reveal correlations between being stressed and a change in behavior (results in the Appendix, Table 4-8 and Table 4-9). We further check for a correlation between the cortisol increase and the variables of interest (*Decision* and *Difference* in absolute value) for the treatment group only to see that the interaction of the cortisol increase with *Round after stress* is not significant. We then substitute the increase in cortisol with the change in heart-rate during the procedure, change in mood in the good-bad and the calm-nervous dimensions to see again no effect on any of the two variables of interest.[52]

Variance analysis

To further check for possible differences in treatment effects we also conduct the analysis of the equality of variance between the treatment and control groups. The variance ratio test revealed no differences between the two groups in the variable *Decision*; either before (p = 0.94) or after (p = 0.77) the TSST-G procedure. The Kolmogorov-Smirnov test for the equality of distribution functions also showed no differences (corrected p-values: before, p = 0.18; after, p = 0.3).

When carried out for the variable *Difference* in absolute value, the Kolmogorov-Smirnov test revealed no difference before (corrected p-value=0.36), but after (p=0.013) the TSST-G procedure. When examined with the robust test for the equality of variances,[53] the differences disappear (Pr > F = 0.37 and above).

4.5 Discussion of results

The absence of finding the hypothesized relationships may be due to several reasons. Either our design was unable to correctly identify the proposed relationship, or the relationship is smaller than could be found with the statistical power in this design, or the relationship is indeed not there, or two opposing stress effects may have cancelled each other out. We cannot rule out the last possibility since for example the change in preferences and change in expectations may have yielded opposing effects: subjects may have been more likely to take into account the information from the public

[51] See Table 4-10 in the Appendix for the resulting distribution of the compliers in the treatment and control groups.

[52] Results available upon request.

[53] As implemented in Stata 12 in the command *robvar*, which uses the Levene's robust statistic. Since the distribution is highly skewed (p<0.001), a standard test of the equality of variances would deliver biased results.

signal due to a change in their preferences, but at the same time, since they knew others were also under stress and may have reacted to the new situations even more, they may have discounted their beliefs about the real value of public signal.

Next, to check the statistical power of our design we used G*POWER 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009) which revealed that with the sample size of 140 subjects and the power of 0.8 our design was able to detect already a relatively small effect size of 0.27 SD. Therefore it seems unlikely that the null result is due to insufficient power of the experimental design.

If stress causes changes in risk preferences, we should observe a systematic difference between the treatment and control groups after the treatment manipulation; i.e. the coefficient of the variable *Treatment*Round after stress* should be significantly different from zero.[54] However, we do not observe any such effect, even though the results from Chapter 3 suggest otherwise. Either the effect is too small to be identified in the regressions, or it is already captured in some of the control variables, or it is offset by a combination of other factors, such as differences in beliefs about others and about the riskiness of the signals. Another potential reason may be hidden in the opposing effects of an increased reward responsiveness under stress (Porcelli, Lewis, & Delgado, 2012) and increased risk aversion that cancel each other out.

Another possible explanation for our null result is that despite our design feature of constantly changing the setting of the parameters of the problem, the updating process in the task could have already been mastered in the rounds before the stress procedure. In such a case, the decision making process would be operated by the fast automatic, Type-I processes rather than by the slower Type-II, rational processes. Indeed, in a recent study Bayesian updating has been found to be governed rather by automatic processes than by rational thought (Achtziger & Alós-Ferrer, 2014). If a stress reaction affects the higher-cognitive functions operated in the PFC as is generally suggested in the literature (McEwen, 2007; Porcelli & Delgado, 2009), but does not impair habitual automatic behavior, our design was not able to capture the effects of stress on herding behavior initiated in the higher-order cognitive structures.

Even though we have no reason to suspect this, the null results may potentially be a due to an experimenter demand of showing the public information

[54] Because the treatment intervention could operate through cortisol and not only through the change in preferences, including it in the regression specification would pose a danger of endogeneity in the estimation. See a detailed discussion in the Appendix and the respective robustness check.

that interacts with treatment, i.e. that the induced demand effect on the weight of public information is of an opposite sign between the two groups and the effect of stress is therefore cancelled. An experimenter demand effect may be characterized as the change in behavior of subjects due to cues about what constitutes proper behavior of the experiment that is closely related to the beliefs about the experimental objectives (Zizzo, 2010). Since it stems from the beliefs of the subjects that may be rooted in the non-quantifiable uncertainty of the situation, it may be determined by the preferences for ambiguity aversion. Then, even though in the related literature ambiguity aversion was found not to change under stress, we cannot rule this out since we do not measure it (Buckert, Schwieren, et al., 2014).

In the related literature investigating the effects of stress on economic decision making, no effects were found on inter-temporal discounting (Haushofer et al., 2013), non-social risk-taking (von Dawans et al., 2012), or ambiguity aversion (Buckert, Schwieren, et al., 2014). Moreover, basically the effects of stress can vary by the stressor used (Haushofer & Jang, 2015) and the timing when the behavioral task was administered (Pabst et al., 2013a), which may also explain why we observe different results than Buckert, Oechssler, et al., (2014).

4.6 Conclusion

As a first study of this type in the literature, using an efficient stressor and a standard Bayesian updating task we provide evidence that there is no effect of acute stress on herding behavior. Using salivary cortisol levels, heart rate and changes in mood we demonstrate that unlike participants in the control group, participants in the treatment group were under considerable levels of stress. The use of information in the process of Bayesian updating as well as the precision of the subjective estimates does not differ for the participants who underwent a stress-inducing treatment procedure and the control participants, and this is true for both private and public signals they received. We further conduct several robustness checks to prove that this null result is not due to different reactions of stressed and non-stressed subjects in terms of cortisol increase, different gender reactions to stress, differences in personality, and due to subject-specific and session-specific effects. Our results thus suggest that despite the existing literature on the effects of acute stress on decision making (Starcke & Brand, 2012), individual-level herding behavior is not affected by mild psycho-social stress, though we cannot conclude the existence of effects of a more severe or a different type of stress (Haushofer & Jang, 2015).

If we assume that the daily routine behavior of decision makers, e.g. professional traders, is more a habitual than a higher cognitive activity, the results of our study imply that the observed real-world phenomena when people engage in herding behavior in stressful situations, such as bank-runs, herding in financial markets during increased volatility and panic in general, as well as the results of the related studies (Buckert, Oechssler, et al., 2014; Driskell & Salas, 1991), occur due to changes in a different dimension of human behavior than herding and information updating, with the likely candidates being risk preferences, beliefs about the behavior of others and the general adaptation to a new environment. The real underlying reasons of these phenomena should thus be investigated in the future research.

4.7 Appendix A

Table 4-6: Randomization check

		Total	Control	Treatment	p-value
Gender	Male (%)	52.1	52.9	51.4	0.87
	Female (%)	47.9	47.1	48.6	
	Count	140	70	70	
Age	Mean	22.3	22.6	22.1	0.51
	SD	2.4	2.8	1.8	
	Valid N	140	70	70	
Education	Elementary (%)	0.0	0.0	0.0	
	High school (%)	55.7	60.0	51.4	0.35
	University (%)	44.3	40.0	48.6	
	Count	140	70	70	
Openness to experience	Mean	36.8	37.1	36.5	0.26
	SD	5.3	5.6	5.0	
	Valid N	140	70	70	
Conscientiousness	Mean	33.6	34.0	33.2	0.38
	SD	6.2	6.6	5.9	
	Valid N	140	70	70	
Extraversion	Mean	33.2	32.1	34.3	0.08
	SD	7.7	7.9	7.4	
	Valid N	140	70	70	
Agreeableness	Mean	36.2	35.9	36.5	0.33
	SD	5.8	5.1	6.4	
	Valid N	140	70	70	
Neuroticism	Mean	30.2	29.0	31.4	0.08
	SD	7.8	8.1	7.4	
	Valid N	140	70	70	
Conformity	Mean	28.6	28.7	28.5	0.92
	SD	5.7	6.0	5.4	
	Valid N	140.0	70.0	70.0	

Note: p-value from the Wilcoxon rank-sum test.

Table 4-7: Manipulation check

		Control	Treatment	p-value z-value Cohen's	Male Control	Male Treatment	Female Control	Female Treatment
Cortisol 1 - Before treatment	Mean	7.76	8.21	0.83	6.81	8.45	8.80	7.95
	SD	3.89	4.39	-0.21	4.11	4.59	3.41	4.22
	Valid N	69	70	-0.1	36	36	33	34
Cortisol 2 - After treatment	Mean	6.97	16.79	0.00	7.02	19.27	6.92	14.17
	SD	4.16	11.96	-6.22	5.20	12.10	2.62	11.39
	Valid N	70	70	-1.1	37	36	33	34
Cortisol 3 - Before risk-task	Mean	7.07	16.13	0.00	7.07	17.99	7.06	14.09
	SD	4.24	11.64	-6.05	5.13	11.00	3.06	12.15
	Valid N	69	69	-1.04	36	36	33	33
Heart rate - Before treatment	Mean	80.68	82.43	0.44	79.91	78.89	81.63	86.09
	SD	12.77	12.53	-0.77	12.89	12.40	12.79	11.76
	Valid N	65	65	-0.14	36	33	29	32
Heart rate - During treatment	Mean	92.92	100.99	0.07	90.88	96.31	95.74	105.97
	SD	20.41	19.25	-1.84	14.95	16.08	26.25	21.27
	Valid N	62	64	-0.41	36	33	26	31
Heart rate - after treatment	Mean	79.87	81.70	0.32	76.22	79.06	84.43	84.41
	SD	16.01	12.88	-0.99	12.98	12.64	18.37	12.74
	Valid N	63	65	-0.12	35	33	28	32
MDM Good-Bad 1 - before Treatment	Mean	22.89	23.36	0.29	23.41	23.19	22.30	23.53
	SD	4.40	4.45	-1.05	4.75	4.70	3.97	4.23
	Valid N	70	70	-0.11	37	36	33	34
MDM Good-Bad 2 - after Treatment	Mean	21.31	17.79	0.00	22.00	18.31	20.55	17.24
	SD	4.57	5.71	3.60	4.76	5.83	4.30	5.62
	Valid N	70	70	0.68	37	36	33	34
MDM Awake-Tired 1 - before Treatment	Mean	20.41	20.44	0.83	21.14	21.60	19.61	19.24
	SD	5.53	4.83	-0.22	5.53	5.10	5.50	4.29
	Valid N	70	69	-0.001	37	35	33	34
MDM Awake-Tired 2 - after Treatment	Mean	18.83	19.91	0.11	19.54	20.81	18.00	18.97
	SD	5.15	5.36	-1.59	4.29	5.04	5.95	5.61
	Valid N	69	70	-0.1	37	36	32	34
MDM Calm-Nervous 1 - before Treatment	Mean	21.79	22.91	0.23	21.97	22.47	21.58	23.39
	SD	4.77	4.49	-1.20	4.91	4.10	4.68	4.89
	Valid N	70	69	-0.24	37	36	33	33
MDM Calm-Nervous 2 - after Treatment	Mean	20.10	17.22	0.00	20.87	18.00	19.24	16.36
	SD	4.70	4.85	3.44	4.76	4.52	4.54	5.13
	Valid N	70	69	0.61	37	36	33	33

Note: p-value from the Wilcoxon rank-sum test.

Table 4-8: Regression analysis: correlations.

	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Dependent var.:	Decision							
Observations:	Private signals				Public signals			
True	0.652***	0.654***	0.655***	0.654***	0.329***	0.331***	0.331***	0.332***
	(0.0318)	(0.0313)	(0.0317)	(0.0306)	(0.0142)	(0.0146)	(0.0146)	(0.0134)
Stressed	0.455	0.516	0.0290	1.478	1.873	2.127	2.127	2.457*
	(1.162)	(1.082)	(1.272)	(1.142)	(1.459)	(1.450)	(1.450)	(1.475)
Round after stress	-0.413	-0.419	-0.325	-0.418	1.269*	1.264*	1.264*	1.261*
	(0.594)	(0.596)	(0.629)	(0.592)	(0.688)	(0.688)	(0.688)	(0.689)
Stressed * Round after stress	-0.0252	-0.0248	0.0189	-0.0249	-0.727	-0.729	-0.729	-0.731
	(0.805)	(0.806)	(0.820)	(0.806)	(1.125)	(1.125)	(1.125)	(1.127)
Constant	9.559***	8.753***	8.903***	14.11	16.87***	15.14***	15.14***	26.60*
	(1.004)	(2.876)	(3.135)	(11.23)	(1.059)	(3.313)	(3.313)	(13.77)
Observations	5,320	5,320	5,320	5,320	3,920	3,920	3,920	3,920
R-squared	0.493	0.509	0.510	0.535	0.237	0.253	0.253	0.284
Session FE	NO	YES	YES	YES	NO	YES	YES	YES
Observables	NO	NO	NO	YES	NO	NO	NO	NO
Female specific	NO	NO	YES	NO	NO	NO	NO	NO
F	109.2	42.73	37.39	33.45	135.5	48.82	48.82	35.23

Note: Stressed defined as an individual who showed an increase of cortisol higher than 2.5 nmol/l. Dependent variable *Decision*. Robust standard errors clustered on the individual level in the parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4-9: Regression analysis: correlations.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent var.:	Difference, in absolute value					
Observations:	Private signals			Public signals		
True	-0.114***	-0.111***	-0.105***	-0.349***	-0.349***	-0.346***
	(0.0309)	(0.0296)	(0.0287)	(0.0217)	(0.0215)	(0.0212)
Stressed	-1.273	-1.322	-0.384	-0.927	-0.881	-0.235
	(0.871)	(0.870)	(0.903)	(0.734)	(0.738)	(0.672)
Round after stress	0.133	0.125	0.112	-1.516***	-1.517***	-1.524***
	(0.463)	(0.462)	(0.461)	(0.439)	(0.439)	(0.440)
Stressed* Round after_stress	0.00575	0.00632	0.00715	0.300	0.300	0.297
	(0.623)	(0.624)	(0.625)	(0.702)	(0.703)	(0.704)
Constant	11.58***	14.88***	18.82**	24.87***	27.60***	43.86***
	(1.010)	(2.293)	(8.617)	(0.739)	(1.679)	(6.748)
Observations	5,320	5,320	5,320	3,920	3,920	3,920
R-squared	0.045	0.067	0.096	0.290	0.295	0.303
Session FE	NO	YES	YES	NO	YES	YES
Observables	NO	NO	YES	NO	NO	YES
F	3.521	1.806	2.049	76.63	28.00	19.48

Note: Stressed defined as an individual who showed an increase of cortisol higher than 2.5 nmol/l. Dependent variable *Difference* in absolute value. Robust standard errors clustered on the individual level in the parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4-10: Classification of subjects whether they reacted to the treatment procedure according the increase in cortisol above 2.5 nmol/l above the baseline.

		Cortisol increase above 2.5nmol/l		
		No	Yes	Total
Group:	Control	60	10	70
	Treatment	23	47	70
	Total	83	57	140

Figure 4-8: Normal values of salivary cortisol during the day.

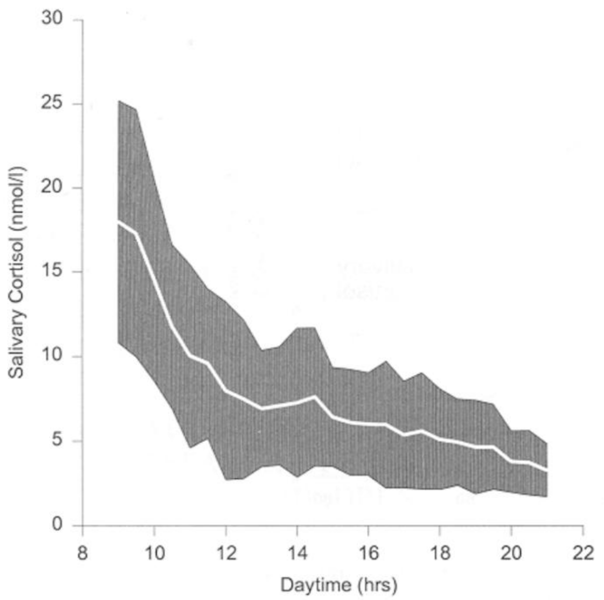


FIGURE 1 Normal values of salivary cortisol during the day (white line: mean levels; shaded area: means ±1 SD).

Note: Adapted from Kirschbaum & Hellhammer (2000), p. 381.

4.8 Appendix B - discussion of the role of risk-preferences

This part is devoted to the discussion of the influence of risk-preferences on the relative weight of the signals in the decision-making procedure. The subjects were paid according to the quadratic scoring rule which is incentive compatible only for risk-neutral preferences. In the measurement of risk-preferences (see Chapter 3) we obtained a wide variety of estimates of individual risk-aversion, which calls the employed payment scheme into question in terms of incentive compatibility. It is not clear whether this poses negative impact on the main results (treatment differences) since the procedure was constant across the two groups. A problem may arise when the risk-aversion interacts with treatment, which we show is the case and analyze in detail in Chapter 3. The subjects that become more risk-averse in treatment group may then face different incentives than the subjects in the control group: they should generally state their estimates of probability closer to the safe midpoint relative to the control group which would serve as a confounding factor. It is not clear though whether more risk-averse subjects should put more or less weight on the public signal relative to private, but generally this change in behavior due to change in risk-attitudes would be observed in the dif-in-dif regressions, though with no differences between reactions to public and private signals. We do not observe any significant differences in behavior between treatment and control groups in any of the steps of analysis, which may indicate either that the reaction to signals did not really depend on risk-preferences (maybe rather on ambiguity aversion) or there were two opposing forces: increased risk-aversion decreased the weight of both private and public signals while increased reward responsiveness under stress cancelled the effect on behavior mediated by the change in risk-attitudes (Porcelli et al., 2012). Even though we do dispose with the individual risk-parameters, we should not enter it as a control variable in the regression equation, because it is also determined by treatment and the concerns of potential bias stemming from the endogeneity. Having this limitation in mind, we perform another robustness check to examine the stability of the coefficient of interest when we add the variable *Certaintyequivalent* that represents the individual risk-attitudes into the three main regression specifications. The results are presented in Appendix Table 4-11 where it is evident that indeed the coefficients of interest are fairly stable in terms of magnitude as well as their significance.

Table 4-11: Robustness check with respect to risk-preferences

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Signals:	Private		Public		Private		Public	
Dependent variable	Decision				Difference in absolute values			
True	0.656***	0.655***	0.332***	0.328***	-0.107***	-0.109***	-0.347***	-0.350***
	(0.0311)	(0.0323)	(0.0139)	(0.0143)	(0.0300)	(0.0307)	(0.0214)	(0.0220)
Treatment	1.512	1.543	1.468	1.512	0.171	0.159	-0.265	-0.361
	(1.061)	(1.029)	(1.398)	(1.349)	(0.894)	(0.896)	(0.721)	(0.728)
Round after stress	0.0293	0.0878	0.976	1.179	0.103	0.100	-1.748***	-1.818***
	(0.661)	(0.697)	(0.909)	(0.947)	(0.521)	(0.548)	(0.504)	(0.532)
Treatment after stress	-0.923	-0.980	-0.0203	-0.214	0.0339	0.0430	0.698	0.776
	(0.814)	(0.842)	(1.094)	(1.127)	(0.635)	(0.657)	(0.683)	(0.704)
Female	-0.335	0.491	-1.645	-0.415	1.037	0.866	1.070*	1.023
	(1.158)	(1.176)	(1.408)	(1.391)	(0.816)	(0.837)	(0.632)	(0.651)
Age	0.576***	0.526**	0.606**	0.504**	0.157	0.198	-0.0575	-0.0258
	(0.212)	(0.215)	(0.253)	(0.246)	(0.202)	(0.203)	(0.154)	(0.160)
Openness to experience	-0.136	-0.156	-0.105	-0.131	-0.183**	-0.190**	-0.0867	-0.0972
	(0.127)	(0.120)	(0.156)	(0.146)	(0.0864)	(0.0877)	(0.0753)	(0.0774)
Conscientiousness	0.0919	0.133	-0.00219	0.0458	0.0399	0.0496	0.0256	0.0233
	(0.0854)	(0.0841)	(0.0992)	(0.0982)	(0.0594)	(0.0599)	(0.0501)	(0.0513)
Extraversion	0.124	0.143*	0.144	0.171*	0.0610	0.0649	0.00929	0.0110
	(0.0845)	(0.0790)	(0.102)	(0.0965)	(0.0609)	(0.0615)	(0.0477)	(0.0477)
Agreeableness	-0.150	-0.130	-0.276**	-0.238*	0.0185	0.00926	0.00934	0.00252
	(0.100)	(0.0944)	(0.134)	(0.134)	(0.0684)	(0.0682)	(0.0489)	(0.0488)
Neuroticism	-0.207***	-0.251***	-0.226***	-0.286***	0.0409	0.0380	-0.0577	-0.0579
	(0.0696)	(0.0722)	(0.0860)	(0.0890)	(0.0513)	(0.0518)	(0.0397)	(0.0408)
Conformity	-0.0557	-0.0306	-0.0605	-0.0347	-0.0947	-0.0677	-0.173***	-0.162***
	(0.0996)	(0.0966)	(0.129)	(0.129)	(0.0756)	(0.0779)	(0.0603)	(0.0615)
Certainty equivalent		0.0027***		0.0041***		-4.86e-05		-0.00037
		(0.00099)		(0.0011)		(0.00070)		(0.00057)
Constant	6.549	0.742	20.49*	12.72	13.62*	12.32	36.55***	37.02***
	(9.264)	(8.645)	(10.90)	(10.59)	(7.942)	(7.826)	(6.352)	(6.159)
Observations	5,320	5,168	3,920	3,808	5,320	5,168	3,920	3,808
R-squared	0.524	0.530	0.273	0.286	0.080	0.084	0.298	0.303
Session FE	YES	YES	YES	YES	YES	YES	YES	YES
F	35.84	33.53	39.13	34.81	2.308	2.265	21.40	23.14

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

5 References

Abeler, J., Falk, A., Goette, L., & Huffman, D. (2011). Reference Points and Effort Provision. *American Economic Review*, *101*(2), 470–492. doi:doi: 10.1257/aer.101.2.470

Achtziger, A., & Alós-Ferrer, C. (2014). Fast or Rational? A response-times study of Bayesian updating. *Management Science*, *60*(4), 923–938. doi:10.1287/mnsc.2013.1793

Aizer, A., & Currie, J. (2014). The intergenerational transmission of inequality: Maternal disadvantage and health at birth. *Science*, *344*(6186), 856–861. doi:10.1126/science.1251872

Allen, A. P., Kennedy, P. J., Cryan, J. F., Dinan, T. G., & Clarke, G. (2014). Biological and psychological markers of stress in humans: Focus on the Trier Social Stress Test. *Neuroscience and Biobehavioral Reviews*, *38*, 94–124. doi:10.1016/j.neubiorev.2013.11.005

Almlund, M., Duckworth, A. L., Heckman, J. J., & Kautz, T. D. (2011). Personality Psychology and Economics. *NBER WORKING PAPER SERIES*, (16822).

Andersen, S., Ertaç, S., Gneezy, U., Hoffman, M., & List, J. A. (2011). Stakes Matter in Ultimatum Games. *American Economic Review*, *101*(December), 3427–3439.

Andersen, S., Harrison, G. W., Lau, M. I., & Rutström, E. E. (2006). Elicitation using multiple price list formats. *Experimental Economics*, *9*(4), 383–405. doi:10.1007/s10683-006-7055-6

Anderson, L. R., & Holt, C. A. (1997). Information cascades in the laboratory. *The American Economic Review*, *87*(5), 847–862. Retrieved from http://www.jstor.org/stable/10.2307/2951328

Ariely, D., Gneezy, U., Loewenstein, G., & Mazar, N. (2009). Large Stakes and Big Mistakes. *Review of Economic Studies*, *76*(2), 451–469. doi:10.1111/j.1467-937X.2009.00534.x

Arnsten, A. (2009). Stress signalling pathways that impair prefrontal cortex structure and function. *Nature Reviews Neuroscience*, *10*(6), 410–22. doi:10.1038/nrn2648

Asch, S. E. (1951). Effects of group pressure upon the modification and distortion of judgments. In H. Guetzkow (Ed.), *Groups, Leadership, and Men* (pp. 177–190). Carnegie Press. doi:citeulike-article-id:975612

Avery, C. N., & Zemsky, P. (1998). Multidimensional Uncertainty and Herd Behavior in Financial Markets. *American Economic Review*, *88*(4), 724–748. Retrieved from http://econpapers.repec.org/RePEc:aea:aecrev:v:88:y:1998:i:4:p:724-48

Baddeley, M. (2010). Herding, social influence and economic decision-making:

socio-psychological and neuroscientific analyses. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *365*(1538), 281–90. doi:10.1098/rstb.2009.0169

Baddeley, M., Burke, C. J., Schultz, W., & Tobler, P. N. (2010). *Impacts of personality on herding in financial decision-making*. *Cambridge Working Papers in Economics* (Vol. No. 1006). Cambridge: Faculty of Economics, University of Cambridge. Retrieved from http://ideas.repec.org/p/cam/camdae/1006.html

Baddeley, M., Pillas, D., Christopoulos, Y., Schultz, W., & Tobler, P. N. (2007). Herding And Social Pressure In Trading Tasks: A Behavioural Analysis. *Cambridge Working Papers in Economics*, *No. 730*. Retrieved from http://econpapers.repec.org/RePEc:cam:camdae:0730

Banerjee, A. V. (1992). A Simple Model of Herd Behavior. *Quarterly Journal of Economics*, *107*(3), 797–817. Retrieved from <Go to ISI>://A1992JJ86300001

Baum, A., & Grunberg, N. E. (1997). Measuring Stress Hormones. In S. Cohen, R. C. Kessler, & L. U. Gordon (Eds.), *Measuring Stress: A Guide for Health and Social Scientists* (pp. 175–192). Oxford, UK: Oxford University Press.

Baum, A., Grunberg, N. E., & Singer, J. E. (1982). The use of psychological and neuroendocrinological measurements in the study of stress. *Health Psychology*, *1*(3), 217–236. doi:10.1037/0278-6133.1.3.217

Baur, D. G., & McDermott, T. K. (2010). Is gold a safe haven? International evidence. *Journal of Banking & Finance*, *34*(8), 1886–1898. doi:10.1016/j.jbankfin.2009.12.008

Becker, A., Deckers, T., Dohmen, T., Falk, A., & Kosse, F. (2012). The Relationship Between Economic Preferences and Psychological Personality Measures. *Annual Review of Economics*, *4*(1), 453–478. doi:10.1146/annurev-economics-080511-110922

Becker, G. M., DeGroot, M., & Marschak, J. (1964). Measuring utility by a single response sequential method. *Behavioral Science*, *9*(3), 226–232.

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition*, *50*, 7–15. doi:10.1016/0010-0277(94)90018-3

Bikhchandani, S., Hirshleifer, D. A., & Welch, I. (1992). A Theory of Fads, Fashion, Custom, and Cultural Change as Informational Cascades. *Journal of Political Economy*, *100*(5), 992–1026. Retrieved from <Go to ISI>://A1992JR33100005

Bikhchandani, S., Hirshleifer, D., & Welch, I. (1998). Learning from the Behavior of Others: Conformity, Fads, and Informational Cascades. *Journal of Economic Perspectives*, *12*(3), 151–170. Retrieved from http://econpapers.repec.org/RePEc:aea:jecper:v:12:y:1998:i:3:p:151-70

Bikhchandani, S., & Sharma, S. (2000). Herd behavior in financial markets. *IMF*

Staff Papers, 279–310.

Blair, C., Granger, D. A., Willoughby, M., Mills-Koonce, R., Cox, M., Greenberg, M. T., … Fortunato, C. K. (2011). Executive Functions in Early Childhood. *Child Development*, *82*(6), 1970–1984. doi:10.1111/j.1467-8624.2011.01643.x.Salivary

Blandini, F., Martignoni, E., Sances, E., Bono, G., & Nappi, G. (1995). Combined response of plasma and platelet catecholamines to different types of short-term stress. *Life Sciences*, *56*(13), 1113–1120.

Borghans, L., Duckworth, A. L., Heckman, J. J., & Weel, B. ter. (2008). The economics and psychology of personality traits. *Journal of Human Resources*, *43*(4), 972–1059. Retrieved from http://www.nber.org/papers/w13810.ack

Brand, M., Fujiwara, E., Borsutzky, S., Kalbe, E., Kessler, J., & Markowitsch, H. J. (2005). Decision-Making Deficits of Korsakoff Patients in a New Gambling Task With Explicit Rules: Associations With Executive Functions. *Neuropsychology*, *19*(3), 267–277. doi:10.1037/0894-4105.19.3.267

Brock, W. A., & Durlauf, S. N. (2001). Interactions-based models. *Handbook of Econometrics*, *5*, 3297–3380.

Buckert, M., Oechssler, J., & Schwieren, C. (2014). Imitation under stress. *University of Heidelberg Discussion Paper Series*, (556).

Buckert, M., Schwieren, C., Kudielka, B. M., & Fiebach, C. J. (2014). Acute stress affects risk taking but not ambiguity aversion. *Frontiers in Neuroscience*, *8*(May), 82. doi:10.3389/fnins.2014.00082

Burke, C. J., Tobler, P. N., Baddeley, M., & Schultz, W. (2010). Neural mechanisms of observational learning. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(32), 14431–6. doi:10.1073/pnas.1003111107

Cadsby, C., Song, F., & Tapon, F. (2009). The impact of risk aversion and stress on the incentive effect of performance pay. *Unpublished Paper, University of Guelph*. Retrieved from http://www.uoguelph.ca/economics/sites/uoguelph.ca.economics/files/2009_12.pdf

Callen, M., Long, J. D., & Sprenger, C. (2014). Violence and Risk Preference: Experimental Evidence. *American Economic Review*, *104*(1), 123–148. doi:10.1257/aer.104.1.123

Cameron, L., Erkal, N., Gangadharan, L., & Zhang, M. (2015). Cultural integration : Experimental evidence of convergence in immigrants ’ preferences. *Journal of Economic Behavior and Organization*, *111*, 38–58. doi:10.1016/j.jebo.2014.11.012

Cao, H. H., & Hirshleifer, D. A. (2000). Conversation, Observational Learning, and Informational Cascades. *Dice Center Working Paper, No. 2001-5*. doi:10.2139/ssrn.267770

Capra, C. M., Jiang, B., Engelmann, J. B., & Berns, G. S. (2013). Can personality type explain heterogeneity in probability distortions? *Journal of Neuroscience, Psychology, and Economics*, *6*(3), 151–166. doi:10.1037/a0033708

Cassar, A., Andrew, H., & von Kessler, C. (2011). Trust, risk, and time preferences after a natural disaster: experimental evidence from Thailand. *Mimeo*.

Clow, A. (2001). The physiology of stress. In F. Jones & J. Bright (Eds.), *Stress, myth, theory, and research* (pp. 47–61). Harlow: Pearson Education.

Coates, J. M., & Herbert, J. (2008). Endogenous steroids and financial risk taking on a London trading floor. *Proceedings of the National Academy of Sciences of the United States of America*, *105*(16), 6167–72. doi:10.1073/pnas.0704025105

Cohn, A., Engelmann, J., Fehr, E., & Maréchal, M. A. (2015). Evidence for Countercyclical Risk Aversion : An Experiment with Financial Professionals. *American Economic Review*, *105*(2), 860–885. doi:http://dx.doi.org/10.1257/aer.20131314

Cornelisse, S., van Ast, V. A., Haushofer, J., Seinstra, M. S., Kindt, M., & Joëls, M. (2013). Time-dependent effect of hydrocortisone administration on intertemporal choice. *Mimeo*. doi:http://dx.doi.org/10.2139/ssrn.2294189

Costa, J. P. T., & McCrae, R. R. (1992). Normal Personality Assessment in Clinical Practice: The NEO Personality Inventory. *Psychological Assessment*, *4*(1), 5–13. Retrieved from http://www.sciencedirect.com/science/article/B6WYX-46VD04F-2/2/430de88263303f8e481e3dac5a7a52b7

Cox, J. C., Sadiraj, V., & Schmidt, U. (2015). Paradoxes and mechanisms for choice under risk. *Experimental Economics*, *18*, 215–250. doi:10.1007/s11294-013-9452-x

Croson, R., & Gneezy, U. (2009). Gender differences in preferences. *Journal of Economic Literature*, *47*(2), 448–474. Retrieved from http://www.ingentaconnect.com/content/aea/jel/2009/00000047/00000002/art00003

Currie, J. (2011). Inequality at Birth: Some Causes and Consequences. *American Economic Review*, *101*(3), 1–22. doi:10.1257/aer.101.3.1

Deck, C., Lee, J., & Reyes, J. (2010). Personality and the Consistency of Risk Taking Behavior: Experimental Evidence. *Chapman Univesity Working Paper*, (10-17).

Deck, C., Lee, J., Reyes, J., & Rosen, C. (2012). Risk-Taking Behavior: An Experimental Analysis of Individuals and Dyads. *Southern Economic Journal*, *79*(2), 277–299. doi:10.4284/0038-4038-2010.026

Dedovic, K., Rexroth, M., Wolff, E., Duchesne, A., Scherling, C., Beaudry, T., … Pruessner, J. C. (2009). Neural correlates of processing stressful information: an event-related fMRI study. *Brain Research*, *1293*, 49–60.

Dickerson, S. S., & Kemeny, M. E. (2004). Acute Stressors and Cortisol Responses:

A Theoretical Integration and Synthesis of Laboratory Research. *Psychological Bulletin*, *130*(3), 355–391. Retrieved from http://www.sciencedirect.com/science/article/pii/S0033290904009451

Dohmen, T. (2008). Do professionals choke under pressure? *Journal of Economic Behavior and Organization*, *65*(3-4), 636–653. doi:10.1016/j.jebo.2005.12.004

Dohmen, T., & Falk, A. (2011). Performance pay and multidimensional sorting: Productivity, preferences, and gender. *The American Economic Review*, *101*(2), 556–590.

Dohmen, T., Falk, A., Huffman, D., & Sunde, U. (2010). Are risk aversion and impatience related to cognitive ability? *The American Economic Review*, *100*(3), 1238–1260. Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1146778

Dohmen, T., Falk, A., Huffman, D., Sunde, U., Schupp, J., & Wagner, G. G. (2011). Individual Risk Attitudes: Measurement, Determinants and Behavioral Consequences. *Journal of the European Economic Association*, *9*(3), 522–550. doi:10.1111/j.1542-4774.2011.01015.x

Driskell, J. E., & Salas, E. (1991). Group decision making under stress. *Journal of Applied Psychology*, *76*(3), 473–478. Retrieved from http://psycnet.apa.org/journals/apl/76/3/473/

Eckel, C. C., El-Gamal, M. A., & Wilson, R. K. (2009). Risk loving after the storm: A Bayesian-Network study of Hurricane Katrina evacuees. *Journal of Economic Behavior & Organization*, *69*(2), 110–124. doi:10.1016/j.jebo.2007.08.012

Elwér, S., Harryson, L., Bolin, M., & Hammarström, A. (2013). Patterns of gender equality at workplaces and psychological distress. *PloS One*, *8*(1), e53246. doi:10.1371/journal.pone.0053246

Engert, V., Efanov, S. I., Duchesne, A., Vogel, S., Corbo, V., & Pruessner, J. C. (2013). Differentiating anticipatory from reactive cortisol responses to psychosocial stress. *Psychoneuroendocrinology*, *38*(8), 1328–1337. doi:10.1016/j.psyneuen.2012.11.018

Engert, V., Plessow, F., Miller, R., Kirschbaum, C., & Singer, T. (2014). Cortisol increase in empathic stress is modulated by emotional closeness and observation modality. *Psychoneuroendocrinology*, *45*, 192–201. doi:10.1016/j.psyneuen.2014.04.005

Eurofound, & EU-OSHA. (2014). *Psychosocial risks in Europe Prevalence and strategies for prevention*. doi:10.2806/70971

Everly, G. S., & Lating, J. M. (2013a). *A Clinical Guide to the Treatment of the Human Stress Response*. New York, New York, USA: Springer. doi:10.1017/CBO9781107415324.004

Everly, G. S., & Lating, J. M. (2013b). The Anatomy and Physiology of the Human Stress Response. In *A Clinical Guide to the Treatment of the Human Stress*

Response (pp. 17–51). doi:10.1007/978-1-4614-5538-7

Falk, A., Menrath, Kupio, & Siegrist, M.-A. (2006). *Unfair pay and Stress*. *mimeo*. Bonn: University of Bonn.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149–60. doi:10.3758/BRM.41.4.1149

Feige, C. (2005). *Stress und Motivation : Die Auswirkung unfairer Behandlung am Arbeitsplatz*. University of Bonn.

Fischbacher, U. (2007). Z-TREE: Zurich toolbox for ready-made economic experiments. *Experimental Economics*, *10*(2), 171–178. Retrieved from http://econpapers.repec.org/RePEc:kap:expeco:v:10:y:2007:i:2:p:171-178

Fletcher, T. D., Major, D. A., & Davis, D. D. (2008). The interactive relationship of competitive climate and trait competitiveness with workplace attitudes, stress, and performance. *Journal of Organizational Behavior*, *29*(7), 899–922. doi:10.1002/job.503

Foley, P., & Kirschbaum, C. (2010). Human hypothalamus-pituitary-adrenal axis responses to acute psychosocial stress in laboratory settings. *Neuroscience & Biobehavioral Reviews*, *35*(1), 91–96. doi:10.1016/j.neubiorev.2010.01.010

Ganster, D. C., & Rosen, C. C. (2013). Work Stress and Employee Health: A Multidisciplinary Review. *Journal of Management*, *39*(5), 1085–1122. doi:10.1177/0149206313475815

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2008). *Cognitive Neuroscience: The Biology of the Mind*. New York: W. W. Norton & Company; Third Edition.

Gilbert, T., & Kogan, S. (2005). Learning From The Skills Of Others: Experimental Evidence. *GSIA Working Papers*. Retrieved from https://student-3k.tepper.cmu.edu/GSIADOC/WP/2006-E25.pdf

Goette, L., Bendahan, S., Thoresen, J., Hollis, F., & Sandi, C. (2015). Stress pulls us apart : Trait anxiety modulates self-confidence under stress. *Psychoneuroendocrinology*, *54*, 115–123. doi:10.1016/j.psyneuen.2015.01.019

Goh, J., Pfeffer, J., & Zenios, S. a. (2015). The Relationship Between Workplace Stressors and Mortality and Health Costs in the United States. *Management Science*. doi:http://dx.doi.org/10.1287/mnsc.2014.2115

Goldberg, L. R. (2010). International Personality Item Pool: A Scientific Collaboratory for the Development of Advanced Measures of Personality Traits and Other Individual Differences. Retrieved from http://ipip.ori.org/

Goldberg, L. R., Johnson, J. A., Eber, H. W., Hogan, R., Ashton, M. C., Cloninger, C. R., & Gough, H. G. (2006). The international personality item pool and the future of public-domain personality measures. *Journal of Research in Personality*, *40*(1), 84–96. doi:10.1016/j.jrp.2005.08.007

Goldstein, D. S., & McEwen, B. S. (2002). Allostasis, Homeostats, and the Nature of Stress. *Stress*, *5*(1), 55–58. doi:doi:10.1080/102538902900012345

Greene, W. H. (2003). *Econometric Analysis*. (P. Education, Ed.)*Journal of the American Statistical Association* (Vol. 97). Prentice Hall. doi:10.1198/jasa.2002.s458

Greiner, B. (2004). An online recruitment system for economic experiments. In K. Kremer & V. Macho (Eds.), *Forschung und wissenschaftliches Rechnen GWDG Bericht*. Göttingen: Gesellschaft fur Wissenschaftliche Datenverarbeitung.

Grether, D. M. (1980). Bayes' Rule as a Descriptive Model: The Representativeness Heuristic. *Quarterly Journal of Economics*, *95*(3), 537–557.

Guiso, L., & Paiella, M. (2008). Risk Aversion, Wealth, and Background Risk. *Journal of the European Economic Association*, *6*(6), 1109–1150.

Guiso, L., Sapienza, P., & Zingales, L. (2013). Time Varying Risk Aversion. *NBER Working Paper #19284*. doi:10.3386/w19284

Hartley, L. R., & Adams, R. G. (1974). Effect of noise on the Stroop test. *Journal of Experimental Psychology*, *102*, 62–66.

Haushofer, J., Cornelisse, S., Seinstra, M., Fehr, E., Joëls, M., & Kalenscher, T. (2013). No effects of psychosocial stress on intertemporal choice. *PloS One*, *8*(11), e78597. doi:10.1371/journal.pone.0078597

Haushofer, J., & Fehr, E. (2014). On the psychology of poverty. *Science*, *344*(6186), 862–867. doi:10.1126/science.1232491

Haushofer, J., & Jang, C. (2015). Stress and Temporal Discounting : Do Domains Matter? *Mimeo*.

Haushofer, J., & Shapiro, J. (2013). Household Response to Income Changes : Evidence from an Unconditional Cash Transfer Program in Kenya. *Massachusetts Institute of Technology*.

Heckman, J. J. (2011). Integrating personality psychology into economics. *National Bureau of Economic Research Working Paper Series*, *No. 17378*. Retrieved from http://www.nber.org/papers/w17378

Heinrichs, M., Baumgartner, T., Kirschbaum, C., & Ehlert, U. (2003). Social support and oxytocin interact to suppress cortisol and subjective responses to psychosocial stress. *Biological Psychiatry*, *54*(12), 1389–1398.

Hellhammer, D. H., Wüst, S., & Kudielka, B. M. (2009). Salivary cortisol as a biomarker in stress research. *Psychoneuroendocrinology*, *34*, 163–171. doi:10.1016/j.psyneuen.2008.10.026

Hines, E. A., & Brown, G. E. (1936). The cold pressor test for measuring the reactibility of the blood pressure: data concerning 571 normal and hypertensive subjects. *American Heart Journal*, *11*(1), 1–9.

Hirshleifer, D., & Hong Teoh, S. (2003). Herd Behaviour and Cascading in Capital Markets: a Review and Synthesis. *European Financial Management*, *9*(1), 25–66. doi:10.1111/1468-036x.00207

Hockey, G. R. J. (1970). Effect of loud noise on attentional selectivity. *Quarterly Journal of Experimental Psychology*, *22*, 28–36.

Hogan, R., & Hogan, J. (2007). *Hogan Personality Inventory Manual, Third Edition*. Tulsa, OK: Hogan Assessment Systems.

Holt, C. A., & Laury, S. K. (2002). Risk Aversion and Incentive Effects. *The American Economic Review*, *92*(5), 1644–1655. Retrieved from http://www.jstor.org/stable/3083270

Hott, C. (2009). Herding behavior in asset markets. *Journal of Financial Stability*, *5*(1), 35–56. doi:10.1016/j.jfs.2008.01.004

Huang, J.-H. J., & Chen, Y.-F. Y. (2006). Herding in online product choice. *Psychology and Marketing*, *23*(May 2006), 413–428. doi:10.1002/mar

Charness, G., & Gneezy, U. (2012). Strong Evidence for Gender Differences in Risk Taking. *Journal of Economic Behavior & Organization*, *83*(1), 50–58. doi:http://dx.doi.org/10.1016/j.jebo.2011.06.007

Charness, G., & Levin, D. (2005). When optimal choices feel wrong: A laboratory study of Bayesian updating, complexity, and affect. *American Economic Review*, *95*(4), 1300–1309.

Chemin, M., Laat, J. De, & Haushofer, J. (2013). Negative Rainfall Shocks Increase Levels of the Stress Hormone Cortisol Among Poor Farmers in Kenya. *Mimeo*.

Chen, M., Ma, Q., Li, M., & Wang, X. (2010). The Neural and Psychological Basis of Herding in Purchasing Books Online: An Event-Related Potential Study. *Cyberpsychology, Behavior, and Social Networking*, *13*(3), 7. doi:doi:10.1089/cyber.2009.0142

Choi, N., & Skiba, H. (2015). Institutional Herding in International Markets. *Journal of Banking & Finance*, *55*, 246–259. doi:10.1016/j.jbankfin.2015.02.002

Jackson, D. N. (1983). *JPI-R: Jackson Personality Inventory, Revised.* Sigma Assesment Systems, Incorporated.

Jennings, J., Bberg, W., Hutcheson, S., Obrist, P., Porges, S., & Turpin, G. (1981). Publication guidelines for heart rate studies in man. *Psychophysiology*, *18*(3), 226–231. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1469-8986.1981.tb03023.x/abstract

Joëls, M., & Baram, T. Z. (2009). The neuro-symphony of stress. *Nature Reviews Neuroscience*, *10*(6), 459–466.

Kahneman, D., & Tversky, A. (1973). On the psychology of prediction. *Psychological Review*, *80*(4), 237. Retrieved from http://psycnet.apa.org/journals/rev/80/4/237/

Kajantie, E., & Phillips, D. I. W. (2006). The effects of sex and hormonal status on the physiological response to acute psychosocial stress. *Psychoneuroendocrinology*, *31*(2), 151–178. doi:10.1016/j.psyneuen.2005.07.002

Kalia, M. (2002). Assessing the economic impact of stress--the modern day hidden epidemic. *Metabolism: Clinical and Experimental*, *51*(6 Suppl 1), 49–53. doi:10.1053/meta.2002.33193

Kandasamy, N., Hardy, B., Page, L., Schaffner, M., Graggaber, J., Powlson, A. S., … Coates, J. M. (2014). Cortisol shifts financial risk preferences. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(9), 3608–13. doi:10.1073/pnas.1317908111

Kaul, A., & Sapp, S. (2006). Y2K fears and safe haven trading of the U.S. dollar. *Journal of International Money and Finance*, *25*(5), 760–779. doi:10.1016/j.jimonfin.2006.04.003

Kemeny, M. E. (2003). The Psychobiology of Stress. *Current Directions in Psychological Science*, *12*(4), 124–129. doi:10.1111/1467-8721.01246

Kirschbaum, C., & Hellhammer, D. H. (1989). Salivary cortisol in psychobiological research: an overview. *Neuropsychobiologyy*, *22*(3), 150–169.

Kirschbaum, C., & Hellhammer, D. H. (2000). Salivary Cortisol. In *Encyclopedia of stress* (Vol. 3, pp. 379–383). Academia Press.

Kirschbaum, C., Kudielka, B. M., Gaab, J., Schommer, N. C., & Hellhammer, D. H. (1999). Impact of gender, menstrual cycle phase, and oral contraceptives on the activity of the hypothalamus-pituitary-adrenal axis. *Psychosomatic Medicine*, *61*(2), 154–62. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10204967

Kirschbaum, C., Pirke, K., & Hellhammer, D. H. (1993). The "Trier Social Stress Test" - A Tool for Investigating Psychobiological Stress Responses in a Laboratory Setting. *Neuropsychobiology*, *28*(1-2), 76–81. Retrieved from http://www.karger.com/DOI/10.1159/000119004

Klucharev, V., Hytönen, K., Rijpkema, M., Smidts, A., & Fernández, G. (2009). Reinforcement learning signal predicts social conformity. *Neuron*, *61*(1), 140–51. doi:10.1016/j.neuron.2008.11.027

Klucharev, V., Munneke, M. A. M., Smidts, A., & Fernández, G. (2011). Downregulation of the posterior medial frontal cortex prevents social conformity. *The Journal of Neuroscience*, *31*(33), 11934–11940.

Kocher, M. G., & Sutter, M. (2006). Time is money—Time pressure, incentives, and the quality of decision-making. *Journal of Economic Behavior & Organization*, *61*(3), 375–392.

Kudielka, B. M., Buske-Kirschbaum, A., Hellhammer, D. H., & Kirschbaum, C.

(2004). HPA axis responses to laboratory psychosocial stress in healthy elderly adults, younger adults, and children: impact of age and gender. *Psychoneuroendocrinology*, *29*(1), 83–98.

Kudielka, B. M., Hellhammer, D. H., & Wüst, S. (2009). Why do we respond so differently? Reviewing determinants of human salivary cortisol responses to challenge. *Psychoneuroendocrinology*, *34*(1), 2–18. doi:http://dx.doi.org/10.1016/j.psyneuen.2008.10.004

Leder, J., Häusser, J. A., & Mojzisch, A. (2013). Stress and strategic decision-making in the beauty contest game. *Psychoneuroendocrinology*, *38*(9), 1503–11. doi:10.1016/j.psyneuen.2012.12.016

Leder, J., Häusser, J. A., & Mojzisch, A. (2015). Exploring the underpinnings of impaired strategic decision-making under stress. *Journal of Economic Psychology*. doi:10.1016/j.joep.2015.05.006

Lejuez, C. W., Read, J. P., Kahler, C. W., Richards, J. B., Ramsey, S. E., Stuart, G. L., … Brown, R. a. (2002). Evaluation of a behavioral measure of risk taking: the Balloon Analogue Risk Task (BART). *Journal of Experimental Psychology. Applied*, *8*(2), 75–84. doi:10.1037/1076-898X.8.2.75

Lighthall, N. R., Mather, M., & Gorlick, M. a. (2009). Acute stress increases sex differences in risk seeking in the balloon analogue risk task. *PLoS One*, *4*(7), e6002. doi:10.1371/journal.pone.0006002

Lo, A. W., & Repin, D. V. (2002). The Psychophysiology of Real-Time Financial Risk Processing. *Journal of Cognitive Neuroscience*, *14*(3), 323–339. Retrieved from http://econpapers.repec.org/RePEc:nbr:nberwo:8508

Lundberg, U. (1993). On the Psychobiology of Stress and Health. (O. Svenson & A. J. Maule, Eds.)*Time Pressure and Stress in Human Judgement and Decision Making*. New York: Springer.

Malmendier, U., & Nagel, S. (2011). Depression Babies: Do Macroeconomic Experiences Affect Risk Taking? *The Quarterly Journal of Economics*, *126*(1), 373–416. doi:10.1093/qje/qjq004

Maule, J. A., & Edland, A. C. (2000). The Effects of time pressure on human judgment and decision making. In R. Ranyard, W. R. Crozier, & O. Svenson (Eds.), *Decision making: cognitive models and explanations*. London: Routledge.

McEwen, B. S. (2007). Physiology and neurobiology of stress and adaptation: central role of the brain. *Physiological Reviews*, *87*(3), 873–904. doi:10.1152/physrev.00041.2006

McEwen, B. S. (2012). Brain on stress: how the social environment gets under the skin. *Proceedings of the National Academy of Sciences of the United States of America*, *109 Suppl* , 17180–5. doi:10.1073/pnas.1121254109

Michl, T., Koellinger, P., & Picot, A. O. (2011). In the mood for risk? An experiment on moods and risk preferences. *Ludwig-Maximilians University Working Paper Series*.

Miller, E. K. (2000). The prefrontal cortex and cognitive control. *Nature Reviews Neuroscience*, *1*(1), 59–65.

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience*, *24*(1), 167–202. doi:10.1146/annurev.neuro.24.1.167

Miller, R., Plessow, F., Kirschbaum, C., & Stalder, T. (2013). Classification criteria for distinguishing cortisol responders from nonresponders to psychosocial stress: evaluation of salivary cortisol pulse detection in panel designs. *Psychosomatic Medicine*, *75*(10), 832–40. doi:10.1097/PSY.0000000000000002

Nguyen, Y., & Noussair, C. N. (2014). Risk Aversion and Emotions. *Pacific Economic Review*, *19*(3), 296–312. doi:10.2139/ssrn.2294859

Nicolson, N. (2007). Measurement of cortisol. In L. J. and G. Leucken L. C. (Ed.), *Handbook of physiological research methods in health psychology* (pp. 37–73). SAGE Publications.

Niederle, M., & Vesterlund, L. (2007). Do women shy away from competition? Do men compete too much? *Quarterly Journal of Economics*, *122*(August), 1067–1101. doi:10.1162/qjec.122.3.1067

Oberlechner, T., & Nimgade, A. (2005). Work stress and performance among financial traders. *Stress and Health*, *21*(5), 285–293. doi:10.1002/smi.1063

Pabst, S., Brand, M., & Wolf, O. T. (2013a). Stress and decision making: a few minutes make all the difference. *Behavioural Brain Research*, *250*, 39–45. doi:10.1016/j.bbr.2013.04.046

Pabst, S., Brand, M., & Wolf, O. T. (2013b). Stress effects on framed decisions: there are differences for gains and losses. *Frontiers in Behavioral Neuroscience*, *7*(142). doi:10.3389/fnbeh.2013.00142

Park, A., & Sabourian, H. (2011). Herding and contrarian behavior in financial markets. *Econometrica*, *79*(4), 973–1026. Retrieved from http://onlinelibrary.wiley.com/doi/10.3982/ECTA8602/abstract

Payne, J. W., Bettman, J. R., & Luce, M. F. (1996). When time is money: Decision behavior under opportunity-cost time pressure. *Organizational Behavior and Human Decision Processes*, *66*(2), 131–152. Retrieved from http://faculty.fuqua.duke.edu/~jrb12/bio/Jim/46.pdf

Petzold, A., Plessow, F., Goschke, T., & Kirschbaum, C. (2010). Stress reduces use of negative feedback in a feedback-based learning task. *Behavioral Neuroscience*, *124*(2), 248–55. doi:10.1037/a0018930

Porcelli, A. J., & Delgado, M. R. (2009). Acute Stress Modulates Risk Taking in Financial Decision Making. *Psychological Science*, *20*(3), 278–283.

Porcelli, A. J., Lewis, A. H., & Delgado, M. R. (2012). Acute stress influences neural circuits of reward processing. *Frontiers in Neuroscience*, *6*(November), 157. doi:10.3389/fnins.2012.00157

Putman, P., Antypa, N., & Crysovergi, P. (2010). Exogenous cortisol acutely influences motivated decision making in healthy young men. *Psychopharmacology*, *208*(2), 257–263. doi:10.1007/s00213-009-1725-y

Raafat, R. M., Chater, N., & Frith, C. (2009). Herding in humans. *Trends in Cognitive Sciences*, *13*(10), 420–428. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S1364661309001703

Rieskamp, J., & Hoffrage, U. (2008). Inferences under time pressure: How opportunity costs affect strategy selection. *Acta Psychologica*, *127*, 258–276.

Rogers, R. D., Owen, a M., Middleton, H. C., Williams, E. J., Pickard, J. D., Sahakian, B. J., & Robbins, T. W. (1999). Choosing between small, likely rewards and large, unlikely rewards activates inferior and orbital prefrontal cortex. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *19*(20), 9029–9038. doi:0270-6474/99/19209029-10$05.00/0

Roodman, D. (2012). CMP: Stata module to implement conditional (recursive) mixed process estimator. *Statistical Software Components*.

Salop, S. C. S. (1987). Evaluating uncertain evidence with Sir Thomas Bayes: A note for teachers. *The Journal of Economic Perspectives*, *1*(1), 155–159. Retrieved from http://www.jstor.org/stable/10.2307/1942953

Sanfey, A. G. (2007). Social decision-making: insights from game theory and neuroscience. *Science (New York, N.Y.)*, *318*(5850), 598–602. doi:10.1126/science.1142996

Sapolsky, R. M., Romero, L. M., & Munck, A. U. (2000). How Do Glucocorticoids Influence Stress Responses ? Preparative Actions. *Endocrine Reviews*, *21*(April), 55–89. doi:10.1210/er.21.1.55

Sharma, S., & Bikhchandani, S. (2000). *Herd Behavior in Financial Markets - A Review*. International Monetary Fund. Retrieved from http://econpapers.repec.org/RePEc:imf:imfwpa:00/48

Schipper, B. (2012). Sex hormones and choice under risk. *UC Davis Department of Economics Working Paper Series*, *12*(7).

Schwabe, L., Dalm, S., Schächinger, H., & Oitzl, M. S. (2008). Chronic stress modulates the use of spatial and stimulus-response learning strategies in mice and man. *Neurobiology of Learning and Memory*, *90*(3), 495–503. doi:10.1016/j.nlm.2008.07.015

Schwabe, L., & Wolf, O. T. (2009). Stress prompts habit behavior in humans. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *29*(22), 7191–7198. doi:10.1523/JNEUROSCI.0979-09.2009

Sinha, R. (2001). How does stress increase risk of drug abuse and relapse? *Psychopharmacology*, *158*(4), 343–359.

Sinha, R. (2008). Chronic Stress, Drug Use, and Vulnerability to Addiction. *Annals of the New York Academy of Sciences*, *1141*, 105–130. doi:10.1196/annals.1441.030.Chronic

Skořepa, M. (2010). *Decision making: a behavioral economic approach*. Palgrave Macmillan.

Starcke, K., & Brand, M. (2012). Decision making under stress: A selective review. *Neuroscience and Biobehavioral Reviews*, *36*(4), 1228–1248. doi:10.1016/j.neubiorev.2012.02.003

Starcke, K., Wolf, O. T., Markowitsch, H. J., & Brand, M. (2008). Anticipatory stress influences decision making under explicit risk conditions. *Behavioral Neuroscience*, *122*(6), 1352–1360. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19045954

Steyer, R., Schwenkmezger, P., Notz, P., & Eid, M. (1997). *MDBF-Mehrdimensionaler Befindlichkeitsfragebogen*. Göttingen: Hogrefe.

Svenson, O., & Benson, L. (1993). *On Experimental Instructions and the Inducement of Time Pressure Behavior*. (O. Svenson & A. J. Maule, Eds.)*Time pressure and stress in human judgement and decision making*. New York: Springer.

Taylor, S. E., Klein, L. C., Lewis, B. P., Gruenewald, T. L., Gurung, R. A. R., & Updegraff, J. A. (2000). Biobehavioral responses to stress in females: tend-and-befriend, not fight-or-flight. *Psychological Review*, *107*(3), 411.

Tinghög, G., Andersson, D., Bonn, C., Böttiger, H., Josephson, C., Lundgren, G., … Johannesson, M. (2013). Intuition and cooperation reconsidered. *Nature*, *498*(7452), E1–2; discussion E2–3. doi:10.1038/nature12194

Trautmann, S. T. (2014). Risk taking under stress: the role(s) of self-selection. A comment on Buckert et al. (2014). *Frontiers in Neuroscience*, *8*(July), 197. doi:10.3389/fnins.2014.00197

United Nations. (2015). *The Millennium Development Goals Report*. New York, New York, USA. Retrieved from https://visit.un.org/millenniumgoals/2008highlevel/pdf/MDG_Report_2008_Addendum.pdf

Upper, C. (2000). How Safe Was the "Safe Haven"? Financial Market Liquidity during the 1998 Turbulences. *Discussion Paper, Economic Research Group of the Deutsche Bundesbank*, *1*(February). Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=219132

van den Bos, R., Harteveld, M., & Stoop, H. (2009). Stress and decision-making in humans: performance is related to cortisol reactivity, albeit differently in men and women. *Psychoneuroendocrinology*, *34*(10), 1449–58. doi:10.1016/j.psyneuen.2009.04.016

Vieider, F. M., Lefebvre, M., Bouchouicha, R., Chmura, T., Hakimov, R., Krawczyk, M., & Martinsson, P. (2014). Common components of risk and uncertainty attitudes across contexts and domains: Evidence from 30 countries. *Journal of the European Economic Association*, 1–32. doi:10.1111/jeea.12102

Vinkers, C. H., Zorn, J. V, Cornelisse, S., Koot, S., Houtepen, L. C., Olivier, B., … Joëls, M. (2013). Time-dependent changes in altruistic punishment following stress. *Psychoneuroendocrinology*, *38*(9), 1467–75. doi:10.1016/j.psyneuen.2012.12.012

von Dawans, B., Fischbacher, U., Kirschbaum, C., Fehr, E., & Heinrichs, M. (2012). The social dimension of stress reactivity: acute stress increases prosocial behavior in humans. *Psychological Science*, *23*(6), 651–60. doi:10.1177/0956797611431576

von Dawans, B., Kirschbaum, C., & Heinrichs, M. (2011). The Trier Social Stress Test for Groups (TSST-G): A new research tool for controlled simultaneous social stress exposure in a group format. *Psychoneuroendocrinology*, *36*(4), 514–22. doi:10.1016/j.psyneuen.2010.08.004

Voors, M. J., Nillesen, E. E. M., Verwimp, P., Bulte, E. H., Lensink, R., & Soest, D. P. Van. (2012). Violent Conflict and Behavior: A Field Experiment in Burundi. *The American Economic Review*, *102*(2), 941–964. Retrieved from http://dx.doi.org/10.1257/aer.102.2.941

Weizsäcker, G. (2010). Do We Follow Others when We Should? A Simple Test of Rational Expectations. *American Economic Review*, *100*(5), 2340–2360. doi:10.1257/aer.100.5.2340

Welch, I. (1992). Sequential Sales, Learning and Cascades. *Journal of Finance*, *47*(2), 695–732.

Yesuf, M., & Bluffstone, R. A. (2009). Poverty, Risk Aversion, and Path Dependence in Low-Income Countries: Experimental Evidence from Ethiopia. *American Journal of Agricultural Economics*, *91*(4), 1022–1037. doi:10.1111/j.l467-8276.2009.01307.x

Young, E. a., Abelson, J., & Lightman, S. L. (2004). Cortisol pulsatility and its role in stress regulation and health. *Frontiers in Neuroendocrinology*, *25*, 69–76. doi:10.1016/j.yfrne.2004.07.001

Zafar, B. (2011). An experimental investigation of why individuals conform. *European Economic Review*, *55*(6), 774–798. doi:10.1016/j.euroecorev.2011.01.002

Zizzo, D. J. (2010). Experimenter demand effects in economic experiments. *Experimental Economics*, *13*(1), 75–98. doi:10.1007/s10683-009-9230-z

6 Response to Reviewers

Pre-defense report on manuscript "Essays on Decision Making under Stress" as of April 19.

I would like to express my deep thanks to the reviewers for their helpful comments on the pre-defense version of my dissertation thesis. Their often general comments will actually not only improve this thesis, but also help me in my future work. Below I present my responses.

Response to Dr. Levinský: I am grateful to Dr. Levínský for his thoughtful report on my thesis. His main comment is as follows: *"...using just TSST-G technique questions the robustness of the results. A family of experiments that would induce stress by various methods will give us a much broader picture of behaviour under stress. For instance, it would be interesting to see how different the results would be if the authors would employ more physiological instruments (as, e.g., glucose-clamp technique). However, it is understandable that such a manipulation could be easily beyond the technical capabilities of research institutions where the research project was developed.* "

Response: This comment is certainly valid and the possibility to do that would substantially improve the research value added of this thesis, but it addresses rather future lines of stress research than a possible improvement of the present form of this thesis. Employing this stressor is the current frontier in the literature and only very few papers have went beyond and addressed the robustness of behavioral changes across various types of stressors: the most recent (Haushofer & Chang, 2015) uses, unlike the previous studies, consistent methodology to show that the effects of three different types of stressor induce three different behavioral reactions, particularly in the domain of time-preferences. I consider my thesis as the first step in the direction of investigating the effects of a frequently experienced type of stress on risk preferences and herding behavior: I specifically chose this type of stressor since it resembles the situations that people in contemporary society face most frequently in their lives, as discussed in page 82, to maximize the external validity of the results. I add the following two paragraphs in the Introduction section where I specifically discuss the effects of different types of stressors.

The effects of stress may differ with respect to the type of stressor. Stress typically arises when an organism is threatened on life and its body is exposed to non-standard conditions. Such stress may thus be termed the *physical stress* with stressors being all sorts of life-threatening circumstances, including blood-loss, electric shocks, infection, pain, food and sleep deprivation, dental procedures, hyper or hypothermia and drug withdrawal states. *Psychological (mental) stressors* do not threaten the physical survival, but are connected with important goal in one's social, emotional or personal life. *Emotional* stressors then include interpersonal conflict, loss of relationship, death in family and loss of a child, while personal psychological stressors can be daily hassle, meeting deadlines, traffic jams or interpersonal conflicts (Sapolsky et al., 2000; Sinha, 2008). A prominent type of a psychological stressor is the *psycho-social stressor*. Since human is a social animal, it possesses also a "social-self", which reflects one's social value, esteem, status and is mostly based on individual perception of self-worth. Threat to preserving such social self has been shown to induce similar stress reaction as a threat to physical survival. Generally, the aforementioned types of stress differ in terms of physiological and psychological response. (Dickerson & Kemeny, 2004). Behaviorally, the effects may also differ: as noted below, Haushofer & Jang (2015) compare the effects of three different types of stressors on temporal discounting: social, physical and an economic game. They find opposing effects of the social stressor and the economic game, while the physical stressor has no effect.

Based on a meta-study of 208 laboratory studies, the Trier Social Stress Test (TSST; Kirschbaum et al., 1993; von Dawans et al., 2011) used in Chapter 2 and Chapter 3 has been considered the most efficient laboratory stressor in terms of the magnitude of cortisol increase it stimulates (Dickerson & Kemeny, 2004). Moreover, the type of stress it induces in subjects, acute psycho-social stress, is the most common type of stress experienced by the general public in the workplace (Ganster & Rosen, 2013; Goh et al., 2015) compared to other types of stressors. A different typical laboratory stressor that induces physical stress is the Cold Pressor Test: the procedure consists of putting the non-dominant hand or one foot into ice-cold water (0-4˘C) for a period of 5 minutes (Blandini et al., 1995; Hines & Brown, 1936; Schwabe et al., 2008). However, e.g. the result of Lighthall et al. (2009) show this procedure may be problematic: the male treated subjects did not have the cortisol change significantly different to the control group and the female subjects showed only a mild increase. Apart from the mentioned procedures, commonly used are also time pressure (Buckert, Oechssler, et al., 2014), information about future performing in TSST protocol (Engert et al., 2013), and mere watching other participant undergoing TSST (Engert et al., 2014). Also combinations of psychological and physical stressors have been used, e.g. Cold Pressor Test in combination with mental arithmetic task and social evaluation (Dickerson & Kemeny, 2004).

The current frontier in the stress research is to use one type of a stressor and study its effects on one type of behavior. The next steps will be to focus on the robustness of the behavioral results with respect to various changes in the protocol, such as the change of the type of stressor, the timing of the intervention and behavioral task, the age of the subjects, culturally specific reaction to stressors etc. In particular, the robustness of the behavioral results with respect to the type of stressor has been studied consistently only once, particularly in the domain of time-preferences (Haushofer & Jang 2015). Thus, investigating the effects of a wider variety of stressors on risk-preferences and herding behavior would certainly increase the scientific value and the external validity of this thesis, but it is not within its scope and rather suggested for future research.

Response to Dr. Skořepa: I am grateful to Dr. Skořepa for his thoughtful report on my thesis. He specifically mentions the following improvement: "*While the papers do not explicitly report the range of actual or possible payoffs, the average figure allows one to think that the difference in payoffs depending on a subject's behavior was perhaps not dramatically high, compared to what participants can earn outside the lab in real-life tasks of the nature being studied such as trading in security markets or investing. This is a well-known issue concerning "external validity" of the experimental research: in real life where the incentives are (possibly) stronger, human behavior may be different from what is observed in the lab. ... So one improvement that I can imagine is to devote some space in the thesis to this issue, including a suggestion that future research might study whether the effects of time pressure or stress increase when the incentives for subjects to give the correct response in the experimental task are higher*"

Response: The issue regarding the size of stakes is a legitimate concern and I have added the following paragraph in the Introduction section where I point out that this an important area for future research

Another issue worth discussing is the relative importance of the monetary stakes that subjects disposed with during the experiments in this thesis: the amounts were typical for the experiments in the area and not too much smaller than the stakes used in comparable experiment in other countries, when adjusted for the purchasing power parity. However, the intrinsic hardship of the situation created by the stress procedure may have prevailed over the extrinsic concern over money (Skořepa, 2010) and the subjects may have not cared about their decisions enough. Thus what we observe is probably only a lower bound of the effects of stress on the particular type of behavior, and it is an interesting area for a future research to assess the effects of stake size, as has been the case with other phenomena in behavioral economics (e.g. Ultimatum game; Andersen et al., 2011), since in many "choking-under-pressure" situations people get stressed because they deal with big amounts of money (Dohmen, 2008).

Response to prof. Servátka : I am very grateful for all the comments of prof. Servátka that he brought up in his report on my thesis. He specifically mentions the following improvements:

1. "*My main comment, which at this stage is relevant mostly for the third paper (but to some degree also applies to the two published papers), is the (lack of) motivation why propensity to herd should be influenced by stress. Although the paper mentions various scenarios where stress might matter, I think it would benefit from a more focused discussion that would dissect a particular example related to updating. Alternatively, it would be great to have a formal theory that explains how stress influences different domains of decision-making. Such theory would inform the experimental design as well as make it easier to justify the choice of task and implemented procedures. At the moment, one could always raise a comment that the null result is due to the experimental task not capturing the essential features of decision-making under stress or it is simply something that subjects do not care much about (despite the financial incentives).* "

   Response: This is a very important comment that I address by extending the discussion on page 84 where I discuss the hypothesized effects of stress on herding behavior and illustrate it on an example of traders in a stock-market.

To illustrate that reasoning in an example, consider traders in the stock market that suddenly experience a shock that induces a stress reaction. The first effect of stress (on the bounded-rational channel) may be that due to stress reaction their cognitive abilities deteriorate and in turn their response to new information is not optimal – they may simply have higher variance in their judgment. Second, the behavioral channel may be affected in the way that under stress, traders become more sensitive to the observed behavior of others and put more weight on what others do relative to what they should do; both directly due to physiological processes in brain caused by the stress reaction, and also indirectly through knowing about their deterioration of cognitive abilities. In the latter case, traders may be aware that others under stress may also suffer from the same cognitive decline and thus not change their behavior: this would however require traders to be sophisticated and know how they react to stress relative to others, or that others react similarly as they do. This may be the case in the real markets, but not in our experiment, where the subjects are anonymous to each other and have no prior knowledge of the reaction to stress of others.

2. "*is it possible that the measurement of, say, heart rate or saliva induced stress even in the baseline, which would explain the null result? Alternatively, is there a possibility of an interaction effect with treatments?*"

   Response: This is an interesting comment. To monitor the stress reaction we administered a proper control group and have three different measures of stress. We observe in the control group that their cortisol levels were stable declining over the time of the experiment, following the natural circadian rhythm. Similarly, heart-rate increased in the control group, but less than in the treatment group. Moreover, to check whether the measurement procedures induced stress per se, we compare the levels of cortisol and heart-rate in our control group with the typical values observed in similar literature as well as in the general population for this type of physical activity and part of the day to conclude they do not differ (Kirschbaum & Hellhammer, 1989). This type of measurement of both is generally the least obtrusive from the available methods of sampling for cortisol analysis / measurement of heart-rate. I summarize that in the footnote:

The procedure of saliva sampling as well as the administration of the heart-rate monitor chest belts may have been by some perceived as stressful, which would confound our baseline measurement and thus the control group would be also under the influence of stress. To capture this we for the sake of simplicity focus only on salivary cortisol and compare the levels in our control group (7.7 +/- 3.9 nmol/l) with the values observed in similar studies (cca 12 nmol/l, von Dawans, Fischbacher, Kirschbaum, Fehr, & Heinrichs, 2012, 7 nmol/l, von Dawans et al., 2011 and 9 nmol/l Kirschbaum et al., 1993) as well as in the general population for this type of physical activity and part of the day (refer to Appendix Figure 4-8). We conclude that the levels in our group were smaller or equal than those in the relevant literature and they do not substantially differ from the reference values for general population. This suggests that the subjects were not stressed already at the baseline. Moreover, the types of measurement used of both variables are considered to be the least obtrusive from all the available methods (Baum, Grunberg, & Singer, 1982).

Figure 4-8: Normal values of salivary cortisol during the day.

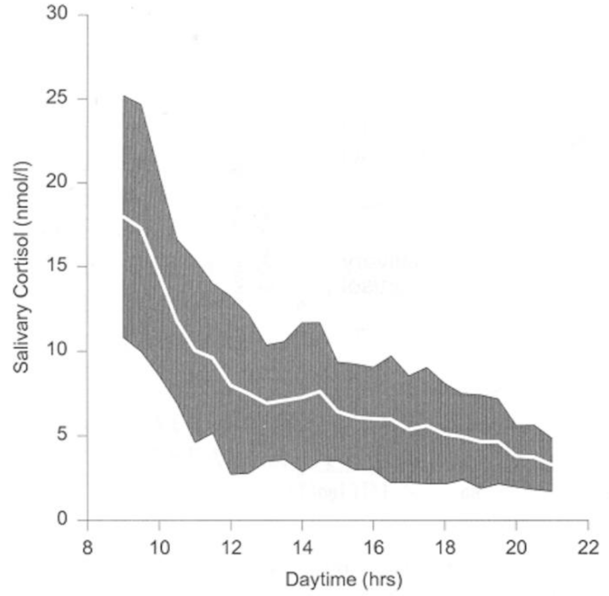


FIGURE 1 Normal values of salivary cortisol during the day (white line: mean levels; shaded area: means ±1 SD).

Note: Adapted from (Kirschbaum & Hellhammer, 2000), p. 381.

3. "*In the same vein, is it possible that informing subjects about decisions of others introduces an experimenter demand effect which then interacts with stress?*"

   Response: This is an interesting comment which can also be potentially contribute to the explanation of the null results. However I have no reason to suspect the differential experimenter demand effect for the treatment and the control groups. I add a paragraph where I discuss this possibility of inducing the demand effect on the weight of public signal that is of the opposite sign in the treatment group than in the control group due to possible change in ambiguity aversion.

Even though we have no reason to suspect this, the null results may potentially be a due to an experimenter demand of showing the public information that interacts with treatment, i.e. that the induced demand effect on the weight of public information is of an opposite sign between the two groups and the effect of stress is therefore cancelled. An experimenter demand effect may be characterized as the change in behavior of subjects due to cues about what constitutes proper behavior of the experiment that is closely related to the beliefs about the experimental objectives (Zizzo, 2010). Since it stems from the beliefs of the subjects that may be rooted in the non-quantifiable uncertainty of the situation, it may be determined by the preferences for ambiguity aversion. Then, even though in the related literature ambiguity aversion was found not to change under stress, we cannot rule this out since we do not measure it (Buckert, Schwieren, et al., 2014).

4. "*I would like to see a justification of some of the payment procedures, e.g. pay three decisions randomly in the third paper. This is very important given the recent evidence on various payment procedures (see Cox, Sadiraj & Schmidt, EE 2015 and Cox, Sadiraj & Schmidt, forthcoming in Int. Adv. Econ Res.) and should be discussed.* "

   Response: This comment raises concern about the payment method, since it has been shown that the method of paying subjects for a randomly chosen subsample of their decisions may induce changes in their responses due to the violation of isolation assumption when compared to other methods of payment, like pay all decisions sequentially or pay all independently. This is an interesting comment that is important for the general validity of my estimates of the behavior. However, the payment procedure is constant across treatments so if the bias introduced by the elicitation procedure is not interacting with the stress treatment, then in the comparison the bias induced by this technique should cancel out. I add a footnote where I address this.

The reason for using random incentive scheme is purely to minimize hedging of the subjects resulting from a wealth effect. We acknowledge that due to recent evidence on the differences in outcomes depending on different payment scheme, the elicited parameters may not be generally valid beyond this setting (Cox, Sadiraj, & Schmidt, 2015). However, the main purpose of this experiment is the dif-in-dif comparison of treatment and control groups only and not establishing the parameters as in the case of e.g. the experiments on trust, so the bias potentially induced by the payment method should be similar in both groups and cancel out.

5. "*Discussion of risk-preferences (footnote 39) is missing*"

   Response: I add the discussion in the Appendix as the section Appendix B:

This part is devoted to the discussion of the influence of risk-preferences on the relative weight of the signals in the decision-making procedure. The subjects were paid according to the quadratic scoring rule which is incentive compatible only for risk-neutral preferences. In the measurement of risk-preferences (see Chapter 3) we obtained a wide variety of estimates of individual risk-aversion, which calls the employed payment scheme into question in terms of incentive compatibility. It is not clear whether this poses negative impact on the main results (treatment differences) since the procedure was constant across the two groups. A problem may arise when the risk-aversion interacts with treatment, which we show is the case and analyze in detail in Chapter 3. The subjects that become more risk-averse in treatment group may then face different incentives than the subjects in the control group: they should generally state their estimates of probability closer to the safe midpoint relative to the control group which would serve as a confounding factor. It is not clear though whether more risk-averse subjects should put more or less weight on the public signal relative to private, but generally this change in behavior due to change in risk-attitudes would be observed in the dif-in-dif regressions, though with no differences between reactions to public and private signals. We do not observe any significant differences in behavior between treatment and control groups in any of the steps of analysis, which may indicate either that the reaction to signals did not really depend on risk-preferences (maybe rather on ambiguity aversion) or there were two opposing forces: increased risk-aversion decreased the weight of both private and public signals while increased reward responsiveness under stress cancelled the effect on behavior mediated by the change in risk-attitudes (Porcelli et al., 2012). Even though we do dispose with the individual risk-parameters, we should not enter it as a control variable in the regression equation, because it is also determined by treatment and the concerns of potential bias stemming from the endogeneity. Having this limitation in mind, we perform another robustness check to examine the stability of the coefficient of interest when we add the variable *Certaintyequivalent* that represents the individual risk-attitudes into the three main regression specifications. The results are presented in Appendix Table 4-6 where it is evident that indeed the coefficients of interest are fairly stable in terms of magnitude as well as their significance.

Table 4-6: Robustness check with respect to risk-preferences.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Signals:	Private		Public		Private		Public	
Dependent variable	Decision				Difference in absolute values			
True	0.656***	0.655***	0.332***	0.328***	-0.107***	-0.109***	-0.347***	-0.350***
	(0.0311)	(0.0323)	(0.0139)	(0.0143)	(0.0300)	(0.0307)	(0.0214)	(0.0220)
Treatment	1.512	1.543	1.468	1.512	0.171	0.159	-0.265	-0.361
	(1.061)	(1.029)	(1.398)	(1.349)	(0.894)	(0.896)	(0.721)	(0.728)
Round after stress	0.0293	0.0878	0.976	1.179	0.103	0.100	-1.748***	-1.818***
	(0.661)	(0.697)	(0.909)	(0.947)	(0.521)	(0.548)	(0.504)	(0.532)
Treatment after stress	-0.923	-0.980	-0.0203	-0.214	0.0339	0.0430	0.698	0.776
	(0.814)	(0.842)	(1.094)	(1.127)	(0.635)	(0.657)	(0.683)	(0.704)
Female	-0.335	0.491	-1.645	-0.415	1.037	0.866	1.070*	1.023
	(1.158)	(1.176)	(1.408)	(1.391)	(0.816)	(0.837)	(0.632)	(0.651)
Age	0.576***	0.526**	0.606**	0.504**	0.157	0.198	-0.0575	-0.0258
	(0.212)	(0.215)	(0.253)	(0.246)	(0.202)	(0.203)	(0.154)	(0.160)
Openness to experience	-0.136	-0.156	-0.105	-0.131	-0.183**	-0.190**	-0.0867	-0.0972
	(0.127)	(0.120)	(0.156)	(0.146)	(0.0864)	(0.0877)	(0.0753)	(0.0774)
Conscientiousness	0.0919	0.133	-0.00219	0.0458	0.0399	0.0496	0.0256	0.0233
	(0.0854)	(0.0841)	(0.0992)	(0.0982)	(0.0594)	(0.0599)	(0.0501)	(0.0513)
Extraversion	0.124	0.143*	0.144	0.171*	0.0610	0.0649	0.00929	0.0110
	(0.0845)	(0.0790)	(0.102)	(0.0965)	(0.0609)	(0.0615)	(0.0477)	(0.0477)
Agreeableness	-0.150	-0.130	-0.276**	-0.238*	0.0185	0.00926	0.00934	0.00252
	(0.100)	(0.0944)	(0.134)	(0.134)	(0.0684)	(0.0682)	(0.0489)	(0.0488)
Neuroticism	-0.207***	-0.251***	-0.226***	-0.286***	0.0409	0.0380	-0.0577	-0.0579
	(0.0696)	(0.0722)	(0.0860)	(0.0890)	(0.0513)	(0.0518)	(0.0397)	(0.0408)
Conformity	-0.0557	-0.0306	-0.0605	-0.0347	-0.0947	-0.0677	-0.173***	-0.162***
	(0.0996)	(0.0966)	(0.129)	(0.129)	(0.0756)	(0.0779)	(0.0603)	(0.0615)
Certainty equivalent		0.0027***		0.0041***		-4.86e-05		-0.00037
		(0.00099)		(0.00113)		(0.00073)		(0.0005)
Constant	6.549	0.742	20.49*	12.72	13.62*	12.32	36.55***	37.02***
	(9.264)	(8.645)	(10.90)	(10.59)	(7.942)	(7.826)	(6.352)	(6.159)
Observations	5,320	5,168	3,920	3,808	5,320	5,168	3,920	3,808
R-squared	0.524	0.530	0.273	0.286	0.080	0.084	0.298	0.303
Session FE	YES	YES	YES	YES	YES	YES	YES	YES
F	35.84	33.53	39.13	34.81	2.308	2.265	21.40	23.14

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1