Taking your chances: risk behavior and its relation to arousal, framing and motivation

Inaugural-Dissertation
zur Erlangung der Doktorwürde der
Philosophischen Fakultät II
der
Julius-Maximilians-Universität Würzburg

Vorgelegt von
Barbara Schmidt
aus München

Würzburg
2014

Erstgutachter:	Prof. Dr. Johannes Hewig
Zweitgutachter:	Prof. Dr. Matthias Wieser
Tag des Kolloquiums:	9. Dezember 2014

Es gibt nichts Gutes, außer man tut es.

Erich Kästner

Acknowledgements

First and foremost I want to thank my advisor, Johannes Hewig, who has been a great mentor. He always listened to me and appreciated all of my ideas. We had highly enriching discussions about scientific questions that led to very good results. He always encouraged me and arranged many contacts to outstanding researchers in our field of research. I am very thankful for his great support during my time in Würzburg. I am also grateful to Matthias Wieser for his willingness to complete my thesis committee.

Special thanks go to my coauthors, Patrick Mussel, Roman Osinsky, Björn Rasch and Stefan Debener. Patrick and Roman have always been great colleagues providing on-site help on issues like personality questionnaires and EEG recording. Björn inspired me to do experiments on ego-depletion and was always an encouraging mentor. Stefan offered me the opportunity to stay in Oldenburg for a week and learn ERP analysis techniques, donating me his time and great expertise.

I am especially grateful to the student assistants Johannes Rodrigues (who is now a colleague), Laura Ottermann, Larissa Fuchs and Meike Hellmer as well as my diploma student Carola Müller for help with data acquisition and analysis. It was a pleasure to work with these amazing persons who did a great job. Thank you. Many thanks go to Peter Lenz, who was always there to help with technical problems of any kind. I also want to thank our competent, supportive and friendly secretaries Anna Weisensel and Elke Hoffmann.

Further thanks go to the Volkswagen Stiftung who funded my research via a Schumpeter Fellowship to Johannes Hewig.

My colleagues at the department have made the last three years a lot of fun. Thank you. I am also very grateful about my friends that I got to know at the University of Arizona. We had many inspiring conversations and a great time together. I am always looking forward to our annual meetings at the SPR conference.

I also want to thank all my friends here in Germany who supported me in various ways. You are the colors of my life!

Last but not least, special thanks go to my parents for their constant support during my education.

Barbara Schmidt

Würzburg, September 2014

Zusammenfassung

Menschliches Risikoverhalten ist zunehmend Gegenstand psychologischer und ökonomischer Forschung. Eine zentrale Rolle spielt dabei der Einfluss psychologischer Variablen auf Risikoverhalten. Die in dieser Arbeit vorgestellten Studien untersuchen den Einfluss von physiologischer Erregung, Framing und Motivation auf Risikoverhalten.

Physiologische Erregung kann einerseits als zeitlich stabile Eigenschaft, andererseits als situationsabhängige Variable gesehen werden. Wir konnten zeigen, dass niedrige zeitlich stabile physiologische Erregung, die über die Ruhe-Herzrate gemessen wurde, riskantes Verhalten vorhersagte. Nach körperlichen Training war die physiologische Erregung der Versuchspersonen im Experiment kurzzeitig erhöht. Die Versuchspersonen tendierten dazu, nach diesem Training weniger riskant zu handeln. Zusammengenommen legen die Ergebnisse nahe, dass eine inverse Relation zwischen physiologischer Erregung und Risikoverhalten vorliegt.

Die meisten Studien, die sich mit Risikoverhalten befassen, verwenden die sogenannte pay-one Auszahlungsmethode: In Risikospielen, die aus vielen Durchgängen bestehen, wird nur ein Durchgang des gesamten Risikospiels ausbezahlt. Wir untersuchten den Effekt der Auszahlungsmethode auf das Risikoverhalten, indem wir sowohl die pay-one Methode als auch die pay-all Methode, bei der die Gewinne aller Durchgänge ausbezahlt werden, in einem Zwischensubjekt-Design verwendeten. Wir fanden heraus, dass die Versuchspersonen in der pay-one Bedingung etwa 10 % weniger riskant handelten, verglichen mit der pay-all Bedingung. Dieses Ergebnis legt nahe, dass die Risiko-Aversion in Paradigmen, die die pay-one Methode verwenden, überschätzt wird.

Nachdem wir an einer schwierigen Aufgabe gearbeitet haben, sehnen wir uns nach einer angenehmeren Aufgabe. Diese Beobachtung führte zu einer generellen Unterscheidung von want-to und have-to Aufgaben. Unser Körper strebt nach einem Gleichgewicht zwischen diesen beiden Aufgabentypen im Sinne einer Homöostase. Wir erfassten ereigniskorrelierte Potentiale (ERPs) durch das Elektroencephalogramm in einem Risikospiel, das wir als want-to Aufgabe verwendeten. Wenn Versuchspersonen vorher eine schwere Aufgabe bearbeitet hatten, waren die Amplituden der ERP-Komponenten im Risikospiel erhöht im Vergleich zu einer Bedingung, in der die Versuchspersonen vorher eine einfache Aufgabe bearbeitet hatten. Wir schlussfolgern, dass die Motivationsänderung nach einer have-to Aufgabe in Richtung einer want-to Aufgabe mit Hilfe von ERP Amplituden erfasst werden kann.

Zusammenfassend wurde gezeigt, dass physiologische Erregung, Framing und Motivation wichtige psychologische Variablen sind, die Risikoverhalten beeinflussen. Die spezifischen Wirkungsweisen dieser Einflüsse wurden untersucht und diskutiert.

Abstract

Human risk behavior is the subject of growing research in the field of psychology as well as economics. One central topic is the influence of psychological variables on risk behavior. Studies contained in this work investigated the impact of arousal, framing and motivation on risk behavior.

Arousal can on the one hand be a temporarily stable trait and on the other hand a situation-dependent variable. We showed that low trait arousal, measured via resting heart rate, predicted risky behavior. After physical exercise, state arousal was heightened in the experiment. Participants tended to act less risky after physical exercise. Taken together, the results suggest an inverse relation of arousal and risk behavior.

Most studies investigating risk behavior employ a payment method that we call pay-one method: although the gambles that are used consist of many trials, only one trial is paid out. We investigated the effect of the payment method on risk behavior by employing both the pay-one and a pay-all method, which pays out all trials, in a within-subjects design. We found that participants acted about 10 % less risky in the pay-one condition compared to the pay-all condition. This result suggests that risk-aversion is over-estimated in common risk paradigms that use the pay-one method.

When we worked on a hard task before, we like to engage in a more likable task afterwards. That observation led to the general classification of tasks in want-to and have-to tasks. Our body system strives towards a balance between those two task types in the sense of a homeostasis. We assessed event-related potentials (ERPs) in a risk game that we treated as a want-to task. When participants worked on a difficult have-to task before, amplitudes of the ERP-components in the risk game were raised compared to a condition where participants worked on an easy task before. We conclude that the motivation shift towards a want-to task after a have-to task can be assessed via ERP amplitudes.

In conclusion, it was shown that arousal, framing and motivation are important psychological variables that influence risk behavior. The specific mechanisms of these influences have been investigated and discussed.

Contents

Preface

When Caesar stood in front of the Rubicon river with his army in 49 BC, he had to decide: Do I cross the river, which means to declare war on the Roman Senate, or not? Crossing the river was the far riskier option compared to staying on this side of the river. As we know from history, Caesar decided to cross the Rubicon. That is when he said the famous words *alea iacta est* - the die is cast (Suetonus, *Divus Iulius*, 31f).

Decision making in risky situations is a topic that concerns many different areas of life. One bigger general question might be: Do we reduce our carbon dioxide emissions to prevent further climate changes and risk that other countries don't do the same so that we just have the financial costs of the reduction and no advantages for the environment? On the individual level, there are important decisions like: Do I concentrate on my career or do I have children and see how work and family can be combined? And also in our daily life, we have to make decisions like: Do I eat lunch in our well-known cafeteria or do I try a new restaurant that I heard of?

The common thing in all these more or less important decision scenarios is the presence of at least two alternatives that differ in the variability of their outcomes. One alternative is the riskier one with higher variability of outcomes (crossing the Rubicon) and the other alternative is the safer one with lower variability of outcomes (staying on this side of the Rubicon). For example, going to a new restaurant for lunch implies that I can either have a cheap excellent meal or I can be highly disappointed because of high prices and low quality of the food. In contrast, eating lunch in our well-known cafeteria means that I will get a meal of immediate quality and price for sure. Rothschild and Stiglitz (1970) provided a basic definition of risk that sums up: If there are two alternatives with identical expected values, the alternative with the higher variability of outcomes is the riskier alternative.

To visualize that basic concept, let's assume that we compare two dice games: In the first game, we have one 11-sided dice with sides 2-12. In the second game, we have two 6-sided dice that are thrown together, summing up their sides. In both games, you are paid out according to the value of the dice. Which one of the two games is the riskier one? To answer this question, we can plot the probabilities of each outcome for both games.

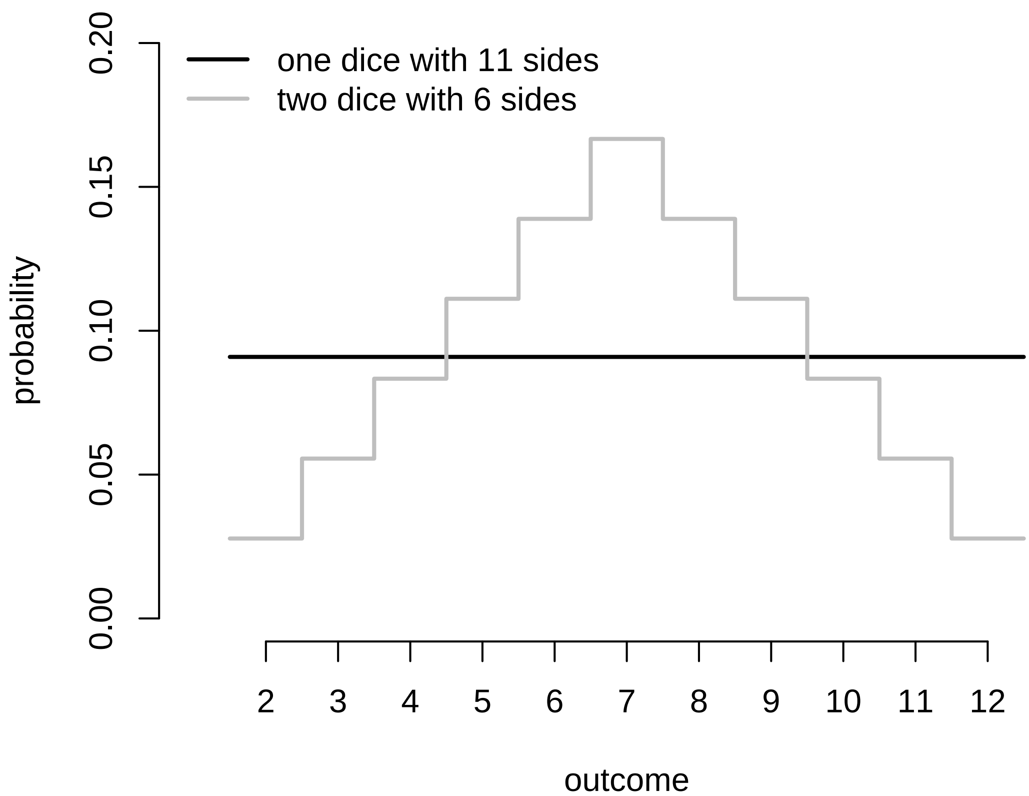

Figure 1: Distribution of outcomes in two dice games

As you can see in Figure 1, the mean outcomes and thus the expected values of both games are identical: both distributions center at an outcome of 7. But the variability of outcomes is different for the two games. If you throw the 11-sided dice, it is equally probable to get everything from the minimal outcome of 2 to the maximal outcome of 12, so we obtain an equal distribution in this game. But if we throw two 6-sided dice, it is much more likely to get an immediate outcome of 7 compared to all other possible outcomes as there are 6 combinations to get 7 with two dice: 1+6, 2+5, 3+4, 4+3, 5+2, 6+1. So we can be quite sure to go home with an immediate outcome of around 7. We conclude that the game with the two 6-sided dice is the safer game, whereas the game with the one 11-sided dice is the riskier game. Crossing the Rubicon would mean to choose the game with the one 11-sided dice, staying on this side of the river would mean to choose the game with the two 6-sided dice.

In the previous dice example, we see that it is important to have exact values for outcomes and probabilities to compare two alternatives concerning their riskiness. There are also situations where we don't have exact information about outcomes and probabilities. In this case, we would use the term ambiguity instead of risk, as there is lacking information concerning either the outcome or the probabilities or both (Camerer and Weber, 1992). In this dissertation, information about the exact values of outcomes and probabilities are always provided.

To investigate risk behavior, I developed a risk game consisting of many trials in which participants can choose between two options that differ concerning risk. Each of the two options represent an equally rational choice, as expected values of the two options are the same. That is very important as we did not want to assess rational behavior, asking the question: Is the participant able to choose the better option? Instead, we wanted to see if the participant chooses an option with higher or lower variability of outcomes, asking the question: Does the participant prefer the riskier or the less risky option? By computing the percentage of trials where the participant chose the riskier of the two options, we obtained an index of individual risk behavior with high values indicating risky behavior and low values indicating risk-averse behavior.

As a common topic of economics and psychology, there is growing interest about the factors influencing risky decision making. Back to the Caesar story, we might ask: Why did Caesar decide to cross the Rubicon? Was he a sensation-seeker? Or did he deliberate carefully all possible consequences and decided that it is the best option to cross the river? Today, we might be less interested in Caesar's decisions but more in investment bankers' decisions that cause financial crises. What are the psychological constructs that affect risky decision making? We used the risk game described above to gain further insights about the factors influencing risk behavior. In the following, I will give a brief overview over the empirical studies presented in this dissertation. All chapters are based on stand-alone co-authored papers and can be read separately.

According to the circumplex model of affect, all emotions can be seen as linear combinations of the two independent neurophysiological dimensions valence and arousal (Colibazzi et al., 2010). There are many studies investigating the impact of emotion on risk behavior, but there is no common conclusion yet (Isen and Patrick, 1983; Lee and Andrade, 2014; Leith and Baumeister, 1996). One reason for that might be the difficulty of inducing emotion in the laboratory (Westermann et al., 1996). We concluded that it might help to clarify the issue if we manipulate only one emotional dimension. So we assessed the impact of physiological arousal on risk behavior, leaving aside the valence dimension. We did that via physical exercise: participants cycled on an ergometer for ten minutes in the arousal condition and sat on the ergometer without cycling in the control condition. As we also assessed resting heart rate of the participants, we could distinguish state and trait arousal and its impact on risk behavior.

Another issue in risk research is the payment method employed in most paradigms. To be able to run many experimental trials with high stakes while not getting bankrupt, researchers usually pay participants according to one randomly selected trial (Levy et al., 2010). We assumed that this payment method, compared to a straightforward payment method that pays out every trial of the risk game, influences participants and leads to less risky behavior.

In the third empirical study, we assessed the electroencephalogram (EEG) of the participants. We used a study design that is usually employed in ego-depletion experiments: participants work on a first task that is difficult and exhausting, and after that, they are working on a second task which is the main dependent task (Hagger et al., 2010). According to a new theory by Inzlicht et al. (2014), tasks can be divided into want-to and have-to tasks. Our system is seeking for a balance between those two task types on the basis of a homeostatic principle. When you first worked on a difficult have-to task, you are motivated to work on a funny want-to task afterwards. As playing a risk game and getting paid for it is internally rewarding, we treated our risk game as a want-to task. We assumed that when participants worked on a have-to task before, motivation to play the risk game afterwards is increased. That in turn should result in more pronounced responses in the event-related potential of the EEG.

Taken together, we investigated the impact of arousal, framing and motivation on risk behavior.

Arousal and Risk Behavior

The following chapter is based on the publication

Schmidt, B., Mussel, P. & Hewig, J. (2013). I'm too calm - Let's take a risk! On the impact of state and trait arousal on risk taking. *Psychophysiology, 50*(5), 498-503.

Abstract

Theories of an optimal level of arousal suggest that underaroused humans seek stimulation to enhance their arousal. One way to increase arousal is risky behavior during gambling. In the current study, we show that the lower the participants' resting arousal, measured via resting heart rate, the riskier they acted in a gamble and the faster they responded, indicating less impulse control. Participants with low resting heart rate also perceived the risk options in the gamble as less arousing and less risky compared to participants with higher resting heart rate. Partial correlations show that resting heart rate, risk behavior, and ratings were interrelated. After physical exercise, participants tended to behave less risky in the gamble compared to a control condition without exercise. Thus, both trait and state arousal effects indicate an inverse relationship of arousal and risky behavior.

Introduction

The concept of an optimal level of arousal was already proposed by Hebb (1955). He stated that when arousal is at a low level, a response that produces increased stimulation and greater arousal will tend to be repeated. According to Hebb (1955), this concept explains the "positive attraction of risk taking or mild fear" (p. 250). In isolation, humans develop a high need for stimulation (Bexton et al., 1954). These results show that a state of very low stimulation is highly aversive and participants try to enhance their arousal in every way possible. Later on, Eysenck and Zuckerman developed theories of personality that are based upon the concept of an optimal level of arousal (Eysenck, 1967; Zuckerman, 1991). In particular, Eysenck relates extraversion to low chronic cortical arousal and low arousability, which causes extraverts to seek stimulation to compensate for this unpleasant psychological state (Eysenck and

Eysenck, 1985).

As an indicator of an individual's basic arousal, resting heart rate can be used (McNamara and Ballard, 1999). Several authors have provided evidence that heart rate is a reliable indicator of cognitive or emotional arousal and frequently used it to measure arousal in different contexts (e.g., Graham and Clifton, 1966; Lang et al., 1993; Wulfert et al., 2005; but see Lacey and Lacey, 1970, for an alternative interpretation of heart rate). Mean resting heart rate is at least partly heritable (Ditto, 1993). There is evidence that low resting heart rate is associated with certain personality characteristics such as pathological gambling (Meyer et al., 2000), impulsiveness (Mathias and Stanford, 2003), aggression (Mawson, 2009), intent to commit an assault (Armstrong and Boutwell, 2012), and antisocial behavior (Armstrong et al., 2009; Ortiz and Raine, 2004). These findings support the assumption that participants with low resting heart rate seek stimulation to approach their optimal level of arousal in manifold ways. Therefore, we can treat resting heart rate as an indicator of trait-like baseline arousal.

One possible way to increase arousal is risk taking during gambling. Correlates of autonomic arousal such as heart rate, galvanic skin response, and cortisol levels are elevated during gambling in humans (Krueger et al., 2005; Ladouceur et al., 2003; Meyer et al., 2000; Sharpe, 2004; Wulfert et al., 2005). This means that risk taking during gambling can bring an underaroused participant closer to his or her optimal level of arousal.

An interesting question in this respect is the effect of state arousal on risky behavior. If baseline arousal of an individual is heightened via physical exercise, the level of optimal arousal would already be quite close, and individuals may not intend to further increase their arousal by risky behavior. Therefore, we assumed that state arousal should influence risk behavior: Participants should act less risky when their arousal state is elevated after a few minutes of acute physical exercise compared to a resting state.

With respect to trait arousal, we hypothesized that participants whose arousal is low, indicated by low resting heart rate, will more likely act in a risky manner. In addition, if low resting heart rate is associated with impulsivity, participants with low resting heart rate should also respond faster. Response time can be treated as an indicator of impulsivity and response control (Edman et al., 1983; Pailing et al., 2002). Therefore, we expected a positive correlation of mean response time and resting heart rate of the participants.

Method

Participants

Data were collected from 40 participants (20 male, 20 female). Mean age of the participants was 24.9 years (range 19-42 years), and 90 % had a university entry degree or had already completed a graduate degree. The participants were paid according to their gain in the risk game. On average, they received 7 euros for two experimental sessions.

Apparatus

Heart rate was measured via a chest strap with electrodes and a wireless Polar heart rate transmitter, which transfers the signal directly to a computer where it is recorded (Polar Electro, Kempele, Finland). The time windows of heart rate assessments can be seen in Figure 2. Each analyzed time window was 5 min long, using the last 5 min of every event of interest, namely, cycling, resting, and the risk game in both conditions (see below).

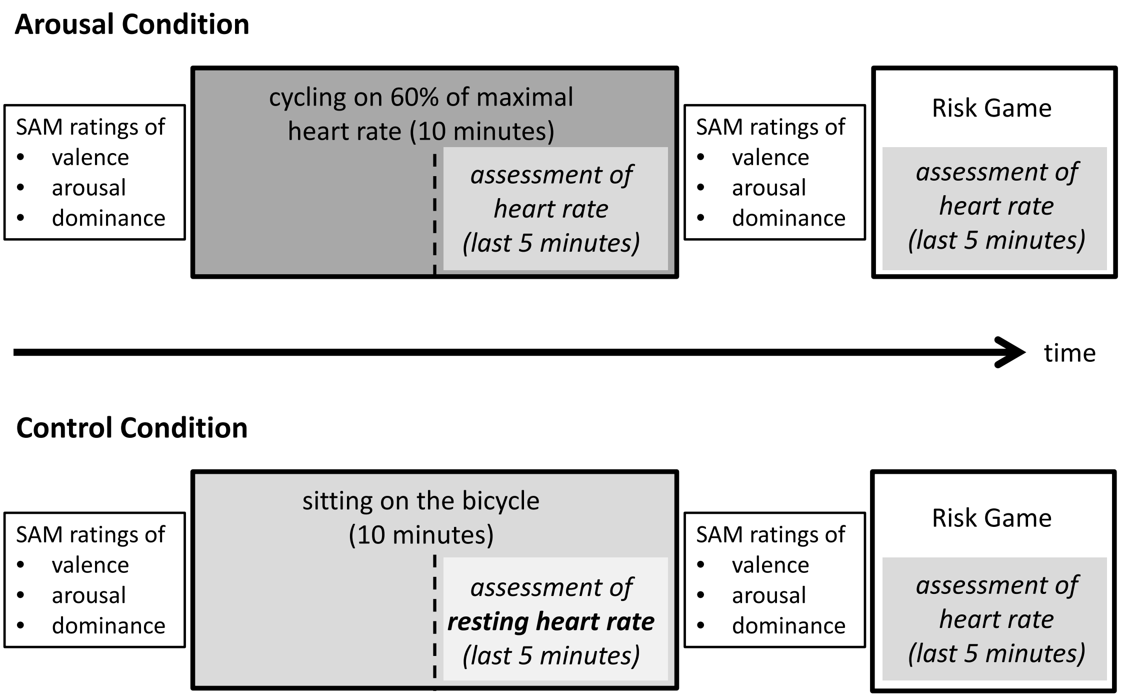

Figure 2: Design of the study

The raw data were interbeat intervals, indicating the time between two heart beats. These intervals were artifact-corrected via ARTiiFACT (Kaufmann et al., 2011) using cubic spline interpolation. The corrected data were analyzed with Kubios HRV software (Niskanen et al., 2004). Mean heart rate was averaged over the 5-min intervals of every event of interest.

The risk game was programmed and presented in PsychoPy (Peirce, 2008). Statistical analyses were computed with R (R Development Core Team, 2014). In analyses of variance (ANOVAs), p values were adjusted using the Huynh-Feldt correction when the Mauchly test indicated a violation of sphericity assumption. In such cases, uncorrected degrees of freedom are provided.

Procedure

Arousal Manipulation

The experiment was divided into two sessions for every participant. The sessions took place on two days at the same time of day, separated by maximally two weeks. At the beginning of the first experimental session, participants signed an informed consent statement. They were instructed to put on the chest strap for heart rate measurement, and the recording was started. Maximal heart rate of the participants was computed using the formula $(220 - age)$, which is a good predictor of maximal heart rate for the age range in the current study (Tanaka et al., 2001). In a meta-analysis, Tanaka and colleagues showed that maximal heart rate can be predicted by age alone and is independent of gender and physical activity status. The formula is a result of regression analyses. Before starting the training, participants filled in the self-assessment manikin (SAM) (Bradley and Lang, 1994) to get their current valence, arousal, and dominance ratings. Participants were asked to cycle on the ergometer and try to keep their heart rate at 60 % of their maximal heart rate during 10 min of training (arousal condition). During the second experimental session, participants were sitting on the bicycle ergometer for 10 min without cycling (control condition). The order of the cycling and resting condition was balanced over all participants and both sexes. Mean resting heart rate was assessed during the last 5 min of sitting on the ergometer without cycling. For an overview of the study design, see Figure 2.

Risk Game

After the ergometer part of the experiment, participants filled in the SAM again and then started to play a risk game consisting of 56 trials. At the beginning of one trial, a fixation dot was shown for a random interval between 300-700 ms (see Figure 3). Next, two options were shown. Each of these options consisted of two monetary rewards (e.g., 14 cents and 1 cent). The expected value of both options was 7.5 cent while the degree of riskiness differed (15 cents vs. 0 cents as the riskiest option and 8 cents vs. 7 cents as the safest option). All possible option combinations were used and presented in random order. Participants had to choose one of the options by pressing the up or down arrow key of the keyboard. After another random interval between 300-700 ms, two cards were shown. On the back of these cards were the signs for winning the higher (diamond) or lower (square) sum of money. Participants chose one of the cards by pressing the left or right arrow key of the keyboard. After another random interval between 300-700 ms, the drawn card was shown together with the feedback "You get XX cents!". This feedback was shown for 1,500 ms. Participants drew the diamond card and the square card that indicated higher or lower gains in exactly 50 % of trials, independent of their card choice. Feedback at the end of the risk game showed how much money the participant won during the whole game.

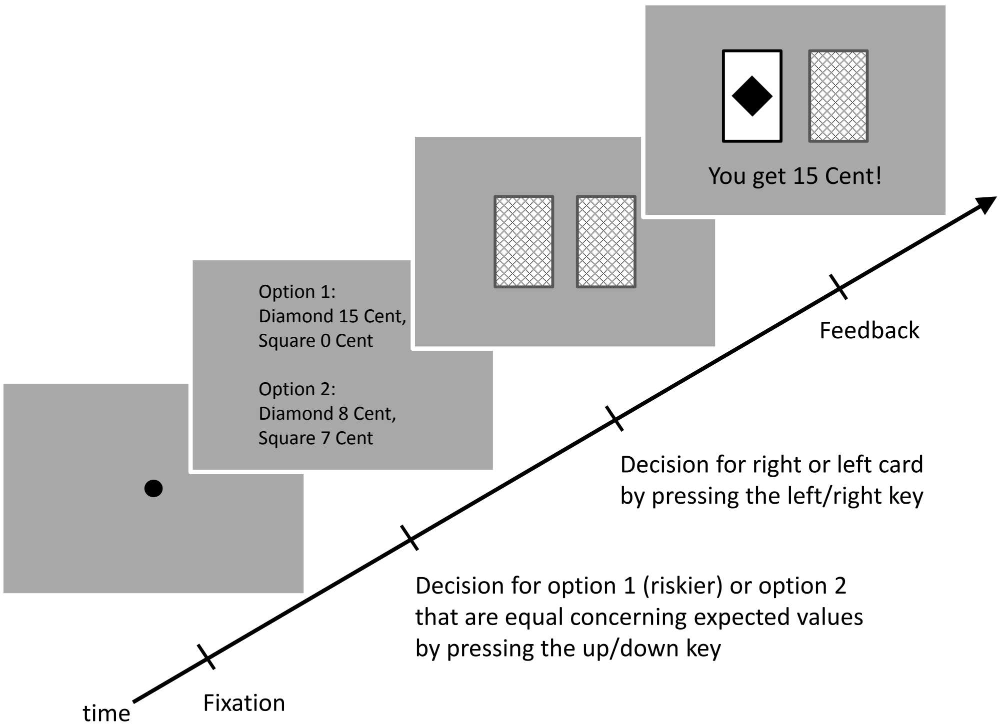

Figure 3: Time course of one trial of the risk game

Option Ratings

After the risk game, participants rated each option according to its valence, arousal, and riskiness on a 9-point rating scale.

Reliability of Resting Heart Rate

As we intend to treat mean resting heart rate like a trait, two correlations that indicate a higher and a lower estimate of reliability were computed. As mean resting heart rate was assessed in only one of two sessions, namely, during the control session (see Figure 2), we split the recording time of 5 min into two halves of 2.5 min and correlated mean resting heart rate during these two periods. As higher estimate of reliability, the within-session split-half reliability was $r = .97, p < .001$. As lower estimate of reliability, we correlated mean heart rates during the risk game in the arousal and in the control condition and found a retest reliability of $r = .69, p < .001$. Note that heart rate during the risk game in the arousal condition was significantly heightened by cycling compared to heart rate in the control condition, $t(39) = 6.0, p < .001$, one-tailed.

Resting Heart Rate and Impulsivity

We computed mean response times for every participant and correlated them with mean resting heart rates of the participants. There was a significant positive correlation of $r = .38, p = .02$, see Figure 4. The correlation indicates that lower resting heart rates were associated with faster responses.

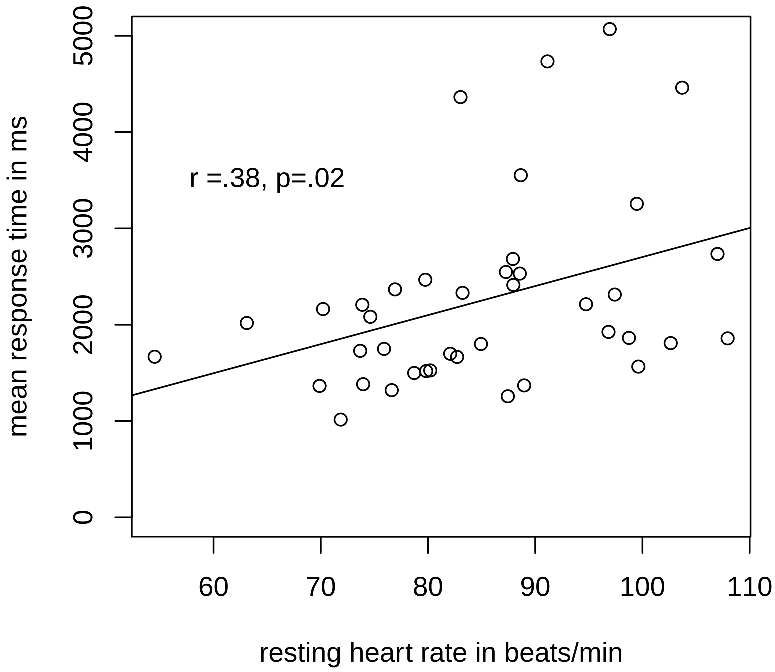

Figure 4: Positive correlation of resting heart rate and mean response time for every participant

Results

SAM Ratings

Ratings of valence, arousal, and dominance before and after the arousal manipulation were analyzed via separate ANOVAs with within-subject factors time (before/after arousal manipulation) and condition (arousal and control). For valence and dominance ratings, there were no significant effects (all $p's > .2$). Arousal ratings were generally higher in the arousal condition, $F(1, 39) = 5.7, p = .02$. Before the arousal manipulation, arousal ratings did not differ, whereas arousal ratings after the arousal manipulation were higher in the arousal condition, indicated by a significant interaction of condition and time, $F(1, 39) = 10.7, p = .002$.

Option Ratings

For valence, arousal, and riskiness ratings, separate ANOVAs were conducted with within-subject factors option (15/0, 14/1, 13/2, 12/3, 11/4, 10/5, 9/6, 8/7) and condition (arousal and control). Valence ratings of the risk options show that the riskier the presented option, the less pleasant the participants felt, indicating general risk aversion, $F(7, 273) = 28.3, p < .001$. Further, participants rated riskier options as more arousing, $F(7, 273) = 103.6, p < .001$, and more risky, $F(7, 273) = 242.0, p < .001$. None of the three ratings showed a condition effect or an interaction between condition and option (all $F's < 1$), indicating that the arousal manipulation did not have an influence on how the options were perceived. Ratings of arousal and riskiness were significantly correlated with risk behavior: The more arousing and risky that the participants rated the options, the fewer risky decisions they made in the game (arousal rating: $r = -.37, p = .02$, riskiness rating: $r = -.45, p = .004$). Arousal and riskiness ratings in turn were highly correlated ($r = .74, p < .001$).

Resting Heart Rate and Risk Behavior

The percentage of decisions for the riskier option in both experimental sessions was correlated with resting heart rate of the participants. A significant negative correlation ($r = -.38, p = .02$) indicates that participants with lower resting heart rate preferred the riskier option compared to participants with higher resting heart rate (see Figure 5A). This correlation was significant for both experimental conditions (arousal condition: $r = -.39, p = .01$, control condition: $r = -.34, p = .03$).

Resting heart rate was also significantly correlated with arousal ratings ($r = .38, p = .01$) and riskiness ratings of the options ($r = .37, p = .02$), but not with valence ratings ($r = -.24, p = .14$): Participants with lower resting heart rate perceived the options as less arousing and less risky compared to participants with higher resting

Table 1: Correlations and Partial Correlations of Resting Heart Rate, Risk Behavior, and Option Ratings

Variable A	Variable B	Controlled variable
Resting heart rate $r = -.38, p = .02$	% Riskier decision	Arousal ratings of options $r = -.28, p = .08$ Riskiness ratings of options $r = -.26, p = .10$
Resting heart rate $r = .38, p = .01$	Arousal ratings of options	% Riskier decision $r = .28, p = .07$
Resting heart rate $r = .37, p = .02$	Riskiness ratings of options	% Riskier decision $r = .24, p = .14$

heart rate. The correlation of resting heart rate and risk behavior that was controlled for arousal and riskiness ratings did not reach significance any more (partial correlations of resting heart rate and risk behavior, given arousal ratings: $r = -.28, p = .08$, and given riskiness ratings: $r = -.26, p = .10$). Also correlations of resting heart rate and ratings that were controlled for risk behavior were non-significant, revealing an interrelation of arousal and riskiness ratings, resting heart rate, and risk behavior (partial correlation of resting heart rate and arousal ratings, given risk behavior: $r = .28, p = .07$, partial correlation of resting heart rate and riskiness ratings, given risk behavior: $r = .24, p = .14$). For an overview of these correlations and partial correlations, see Table 1.

Resting heart rate did not differ depending on when it was assessed, during the first or the second of the two experimental sessions, $t(37) = 0.2, p = .86$, two-tailed). SAM ratings of basic arousal immediately after the assessment of resting heart rate did not correlate with resting heart rate ($r = .15, p = .35$) or risk behavior ($r = -.12, p = .47$), but did predict arousal ratings of the options ($r = .52, p < .001$).

Acute Physical Exercise and Risk Behavior

Mean heart rate was elevated during exercise and during the risk game in the arousal condition compared to the control condition (during exercise, heart rate was on average 34 beats/min faster than during rest: $t(39) = 18.7, p < .001$, one-tailed; during the risk game, heart rate was on average 8 beats/min faster after exercise than after rest: $t(39) = 6.0, p < .001$, one-tailed). Participants tended to choose the safer option during the arousal condition compared to the control condition, M (percent decisions for riskier option in arousal condition) $= 47\,\%$, M(percent decisions for riskier option in control condition) $= 50\,\%$, $t(39) = 1.4, p = .08$, one-tailed, $d = .12$, Figure 5B.

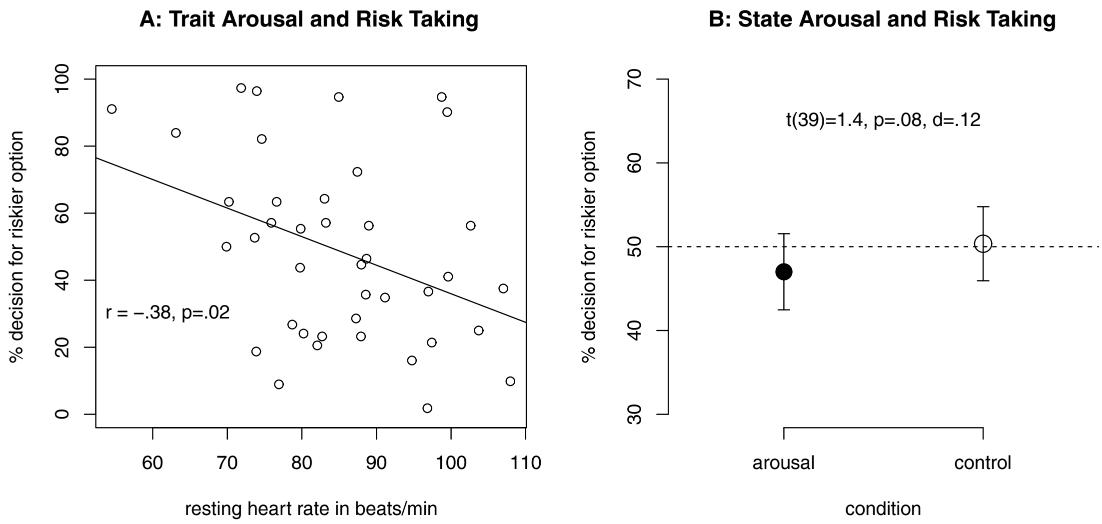

Figure 5: A: Negative correlation of resting heart rate and risky behavior. B: Less risky decisions in the arousal condition compared to the control condition

Resting heart rate did not account for the difference in risk behavior between the two experimental sessions, indicated by a non-significant correlation between resting heart rate and difference in risky behavior in the arousal-control condition ($r = .10, p = .52$). Further, when the effect of state arousal on risk behavior was controlled for trait arousal, measured via resting heart rate, the effect of state arousal did not change, and we did not observe an interaction of state and trait arousal on risk behavior. First, an ANOVA with the within-subject factor condition (arousal and control) was carried out. There was a main effect of condition of $F(1, 39) = 2.0, p = .16$ (note that the t-test we reported earlier was one-tailed, and therefore the p value was $p = .08$). To control for resting heart rate, we conducted an analysis of covariance with factor condition (arousal and control) and covariate resting heart rate, which has been normalized via z-transformation before, and received virtually the same effect of condition: $F(1, 38) = 2.0, p = .17$ and a significant effect of resting heart rate: $F(1, 38) = 6.4, p = .02$. There was no interaction of resting heart rate and condition ($F < 1$).

Discussion

The data of the current study show a strong influence of trait arousal, measured via resting heart rate, on risk behavior: Individuals with low resting heart rate chose the riskier option more often than individuals with high resting heart rate. The effect of state arousal on risk behavior further supports the relation of low arousal and high risk taking - after physical exercise, participants tended to choose the safer option compared to the control condition. These results are in line with the assumption of an optimal level of arousal and its impact on risk behavior. In addition, the effects of state and trait arousal on risk behavior seem to be independent of each other.

As estimates of reliability for resting heart rate were quite high, we assume that it is a relatively stable measure and can be treated like a trait. Furthermore, low resting heart rate was associated with faster responses, indicating that resting heart rate may reflect impulsive behavior. Results of Mathias and Stanford (2003) further support this association. In their study, they related resting heart rate to impulsiveness, measured via the Barratt Impulsiveness Scale. Resting heart rate of the high impulsive group was significantly lower than resting heart rate of the normal impulsive group (Mathias and Stanford, 2003).

Up to now, research concerning the relation of resting heart rate and risky behavior mainly focused on specific populations such as children and adolescents with antisocial personality disorder (Ortiz and Raine, 2004), pathological gamblers (Meyer et al., 2000), or chronically aggressive individuals (Mawson, 2009). However, there are two studies that investigated this relation in healthy participants. One was the already-mentioned study by Mathias and Stanford (2003), who related resting heart rate to impulsiveness in a healthy male sample. A second study asked a large healthy sample to rate their perceptions of costs and benefits of criminal behavior scenarios and linked these ratings to resting heart rate. The authors found that participants with low resting heart rate perceived a lower likelihood of sanction and were less likely to anticipate a sense of guilt/shame should they commit assault during a confrontation. Those with low resting heart rate were also more likely to indicate that they would commit the act described in the assault scenario (Armstrong and Boutwell, 2012).

Whereas the investigated variables in these two healthy sample studies were ratings of impulsiveness or ratings of expected costs or benefits of crime, we assessed overt risk behavior that led to real differences in monetary reward. Participants had to decide if they wanted to take a higher or a lower risk in order to win money. In addition, we assessed the subjective perception of the risky options, which enabled us to compare perception and behavior in risky situations.

Participants with lower resting heart rate and therefore lower basic arousal perceived the options as less arousing and less risky. These participants also preferred the riskier option. The negative relationship between risk perception and risk behavior is a quite common observation (e.g., Blais and Weber, 2006; Horvath and Zuckerman, 1993). Concerning the direction of the effect, there is evidence that risky behavior leads to the perception of that behavior as less risky (Horvath and Zuckerman, 1993). In our study, we observed an interrelation of resting heart rate, ratings, and risk behavior, which allows no causal interpretation.

Limitations

In this study, heart rate is used as a measure of arousal. Concerning the validity of heart rate as a direct index of arousal, there are conflicting results, which led to the alternative view that elevations in heart rate may produce a sort of stimulus barrier, and that decreases in heart rate may produce a more permeable stimulus barrier (Lacey and Lacey, 1970). In addition, Eysenck's arousal theory (Eysenck and Eysenck, 1985) mainly refers to cortical arousal, whereas heart rate reflects autonomic arousal. As Hagemann and colleagues (Hagemann et al., 2003) point out, measures of central and autonomic arousal are only weakly correlated.

Concerning the link between heart rate and personality characteristics, there are also contradictory findings. As Matthews and Gilliland (1999) state in their review, there was no effect of extraversion on resting heart rate in the majority of studies. Nevertheless, they conclude that extraversion is a weak predictor of tonic arousal measures. As a further limitation, we did not include any personality questionnaires in the study and, therefore, we are not able to investigate additional influences on risk behavior, such as anxiety or extraversion. We recommend that future studies should employ measures of personality.

Summary

In conclusion, we show that low resting heart rate is associated with lower ratings of arousal/ riskiness and riskier behavior. When state arousal was elevated via physical exercise, participants' ratings did not change but they tended to behave in a less risky manner. Both trait and state arousal indicate a negative relationship between autonomic arousal and risk behavior, which is in line with theories assuming an optimal level of arousal.

Framing and Risk Behavior

The following chapter is based on the submitted publication

Schmidt, B. & Hewig, J. (under review). Getting paid for one trial instead of all trials: How the standard payment method in economic research influences risk behavior

Abstract

To investigate risk behavior, economic researchers use gambles consisting of many trials. But participants usually do not receive the sum of all outcomes. Instead, participants are paid out according to one trial that is randomly selected in the end. As the payment method might influence risk behavior, we let participants play a gamble two times. In the pay-all condition, the outcome of every trial is paid out and in the pay-one condition, the outcome of one randomly selected trial, multiplied by the number of trials, is paid out. Results show that participants made 10 % more risky decisions in the pay-all compared to the pay-one condition. In an additional questionnaire with hypothetical risk choices, participants also showed substantially riskier behavior in the pay-all condition. Risk behavior was highly correlated in both conditions. The results suggest that the absolute level of risk choices is higher in pay-all paradigms than in pay-one paradigms.

Introduction

Imagine your colleague coming to your desk and ask you if you want to gamble. There is an equal chance to win $200 or to lose $100. Would you do it?

In the 1960s, the economist Paul Samuelson asked his colleague exactly this question (Samuelson, 1963). His colleague refused this gamble, but said that he would accept the gamble if he can play it 100 times. What is it that makes a gamble more attractive if you can play it multiple times? One explanation for this phenomenon is called risk aggregation. According to Read et al. (1999), a combination of several gambles is less risky than a single gamble because the whole gamble is perceived as a portfolio and not as independent single trials. If you lose in the first gamble, there is still a chance to win in one of the following gambles.

If a series of gambles is perceived as a portfolio or as independent single trials depends on the current framing: A narrow decision frame makes participants treat every trial in isolation, whereas a broad decision frame combines all trials to a portfolio (Kahneman and Lovallo, 1993). The framing in turn influences risk taking: A narrow decision frame leads to less risky behavior compared to a broad decision frame. That phenomenon is called myopic risk aversion (Thaler et al., 1997). But how do you induce a narrow or broad decision frame?

One way of inducing a narrow decision frame is to let participants play many trials of a gamble but paying out only one random trial that is selected in the end of the gamble (De Martino et al., 2010). That is exactly what many current studies on risk behavior do (De Martino et al., 2010; Hsu et al., 2005, 0; Levy et al., 2010; Smith et al., 2002; Tom et al., 2007). There are several reasons why this way of payment is used. In studies that want to connect risk behavior to any kind of biological correlate, many trials are necessary to get enough data to analyze. Experiments like this can get very expensive when participants are paid according to the sum of all outcomes. Furthermore, the stakes in every trial should be high enough to make sure that participants take the gamble seriously. The common solution to this problem is to let participants play many high-stake gambles and choose one of the trials in the end for payment. Many papers published in high impact journals use this payment method in their risk paradigms. It is the standard payment method in economic research (Levy et al., 2010).

As we mentioned before, paying out only one randomly selected trial in the end of the gamble induces narrow framing. We think that this should lead to less risky behavior in the sense of myopic risk aversion. But the effect of the payment method on risk behavior has not been directly tested yet.

Thus, we designed a risk game that was played two times: One time with the instruction that you get the outcome of every trial you play (pay-all condition) and another time with the instruction that we will randomly choose one trial in the end and multiply the outcome of that trial with the number of trials for payment (pay-one condition). Please note that we multiplied the outcome of the randomly selected trial in the pay-one condition in contrast to the studies cited before, keeping expected values equal in the two conditions. We had to do this to rule out the influence of different expected values which would make the pay-all condition more lucrative than the pay-one condition and therefore would have an impact on risk behavior.

As we wanted to assess differences in risk behavior depending on the payment method, we used a within-subjects design. Every participant played the two gambles, the order of conditions counterbalanced. So, if we find differences in risk behavior between the two payment conditions, they are not due to differences between groups. As broad evidence shows that individual differences in personality generally influence risk behavior (Zuckerman and Kuhlman, 2000), we also collected data on relevant personality traits like the Big Five, impulsivity, aggression and anxiety.

To be sure that changes in risk behavior are due to the payment method, we had to rule out a possible alternative explanation: Theoretically, participants could have the impression that stakes are raised in the pay-one condition, though they are not. The instruction says that the outcome of one randomly selected trial will be multiplied by the number of trials. There is evidence that raising the stakes results in more risk-averse behavior (Holt and Laury, 2002), but only if outcomes are actually paid out in cash.

To control for this effect, we designed an additional risk questionnaire referring to Kahneman and Tversky (1979). In this questionnaire, two hypothetical choices have to be made: One that represents the pay-all condition and one that represents the pay-one condition. The expected values of these choices are identical to the risk game conditions. Filling in this questionnaire, participants were able to look at both choices simultaneously. It was like playing each condition of the risk game by marking one option with a cross.

If the effect of payment methods on risk behavior is only present in the risk game, where outcomes are paid out in cash, and not in the risk questionnaire, where outcomes are hypothetical, the alternative explanation of the results is confirmed: Participants had the impression that stakes are raised in the pay-one condition. But if the effect of payment methods on risk behavior is present in both the risk game and the risk questionnaire, we can assume that the difference in risk behavior is due to the payment method.

Method

Participants

Data were collected from 40 participants (20 male, 20 female). Mean age of the participants was 22.9 years (range 16-37 years) and 93 % had a university entry degree or had already completed a graduate degree. Participants were paid according to their outcomes in the risk games. On average, they received 6.6 euros (range 3-10 euros).

This study was carried out in accordance with the provisions of the World Medical Association Declaration of Helsinki. For two minor participants (16 and 17 years old), we obtained written informed consent of their parents in addition to their own written informed consent. Participants were recruited via an announcement on a local website. People who were interested in participation wrote an e-mail to an e-mail address that was stated in the announcement. Identifying information of the participants was only obtained during the e-mail correspondence of the recruitment process and kept separately from the experimental data at all times. In the beginning of the experiment, we assigned a number to every participant and used this number as identifier during the whole experiment. For this study, we did not seek approval by the local ethics committee as potential risks or other negative effects of the study did not exceed daily sensitivities.

Apparatus

The risk game was programmed and presented in PsychoPy (Peirce, 2008). Statistical analyses were computed with R (R Development Core Team, 2014).

Procedure

In the beginning of the experiment, participants read a written instruction and signed an informed consent statement. Then, participants played two blocks of a risk game which was almost identical to a risk game we used in a former study (Schmidt et al., 2013). In one block, the gain of every trial was paid out to them (pay-all condition). In the other block, one trial was randomly selected in the end and the gain of this trial, multiplied by the number of trials, was paid out (pay-one condition). The order of the blocks was balanced over all participants and both sexes.

After the risk game, participants filled in several questionnaires: An additional questionnaire about risk behavior, the NEO-Five Factor Inventory (NEO-FFI) (McCrae and Costa, 2004), the German 15-item version of the Barratt-Impulsiveness Scale (BIS-15) (Meule et al., 2011), the Aggression Questionnaire (Buss and Perry, 1992), translated into German by Hewig et al. (2004) and the State-Trait Anxiety Inventory (STAI, trait version) (Spielberger et al., 1999).

Risk Game

Participants were told that the risk game will be divided into two blocks. Before each block, participants were instructed either for the pay-all condition ("The gain of every trial will be paid out") or the pay-one condition ("In the end of the block, one trial will be randomly selected and the outcome of this trial will be multiplied by the number of trials. That amount will be paid out"). To make sure that participants read the instruction, they had to look at it for at least ten seconds before they could continue. During each block, participants completed 60 trials of the risk game. In the beginning of one trial, a fixation dot was shown for a random interval between 300-700 ms (see Figure 6). After that, two options were shown that differed in riskiness. Each of these options consisted of two monetary rewards. The expected value of both options was 5.5 cents while the degree of riskiness differed (11 cents vs. 0 cents as the riskiest option and 6 cents vs. 5 cents as the safest option). Option combinations always consisted of the riskiest option (11 cents vs. 0 cents) and one of the other less risky options. The option combinations were presented in random order. Participants had to choose one of the options by pressing the up or down arrow key of the keyboard. After another random interval between 300-700 ms, two cards were shown. On the back of these cards were the signs for winning the higher (diamond) or lower (square) sum of money. Participants chose one of the cards by pressing the left or right arrow key of the keyboard. After another random interval between 300-700 ms, the drawn card was shown together with the feedback "You get XX cents!". This feedback was shown for 1500 ms. Participants drew the diamond card and the square card that indicated higher or lower gains in exactly 50 % of trials, independent of their card choice. A feedback screen in the end of each block showed how much money the participant won during the block.

Option Ratings

After both blocks of the risk game, participants rated each option according to its valence, arousal and riskiness on a 9-point rating scale. In the end of the experiment, participants got feedback about the total amount they won during the two risk game

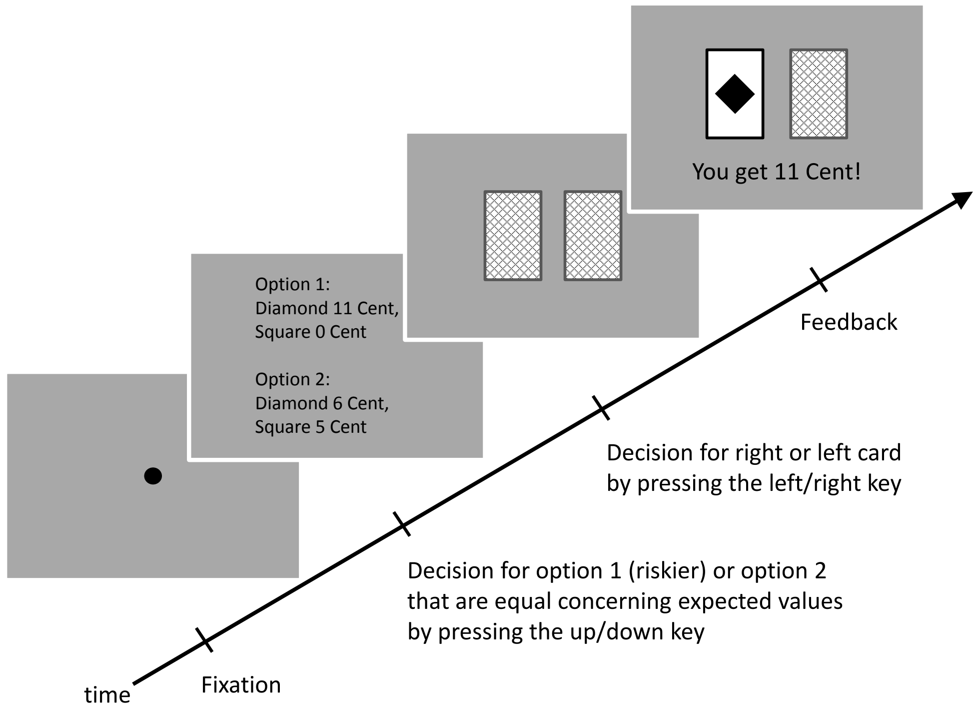

Figure 6: Time-course of one trial of the risk game

blocks.

Risk Questionnaire

We designed a questionnaire according to Kahneman and Tversky (1979). On page 264 of their paper, the authors describe how they measured risk behavior in their studies: "The respondents were presented with problems of the type illustrated below. Which of the following would you prefer? A: 50 % chance to win 1,000, 50 % chance to win nothing; B: 450 for sure.[...]The respondents were asked to imagine that they were actually faced with the choice described in the problem, and to indicate the decision they would have made in such a case.". To avoid order effects, Kahneman and Tversky (1979) presented the hypothetical choices in different orders and changed the left and right position of the options.

According to that, we asked participants to imagine that they are confronted with the following choices and to indicate which one of the options they would choose. Like in the game before, they would draw one of two cards afterwards and get their outcome accordingly. One choice represented the pay-all condition. Participants should imagine they are playing the following game 60 times: "win 11 cents with the diamond card and 0 cent with the square card" (riskier option) versus "win 6 cents with the diamond card and 5 cents with the square card". It was not specified if participants should choose one option for all following 60 trials or if they should just make one decision for one of the 60 trials. The other choice mirrored the pay-one condition: "win 660 cents with the diamond card and 0 cents with the square card" (riskier option) versus "win 360 cents with the diamond card and 300 cents with the square card". Please note that the two choices are identical concerning expected values but different concerning riskiness and exactly represent the two blocks of the risk game.

Results

Option Ratings

For valence, arousal and riskiness ratings, separate analyses of variance were conducted with within-subject factors option (11/0, 10/1, 9/2, 8/3, 7/4, 6/5) and condition (pay-all and pay-one). Valence ratings of the risk options show that the riskier the presented option, the less pleasant the participants felt ($F(5, 195) = 17.9, p < .001$). Further, participants rated riskier options as more arousing ($F(5, 195) = 52.4, p < .001$) and more risky ($F(5, 195) = 222.6, p < .001$). None of the three ratings showed a condition effect or an interaction between condition and option (all $p's > .2$).

Risk Behavior

The percentage of riskier decisions in the pay-all condition of the risk game was significantly higher than in the pay-one condition (M(% riskier choices in the pay-all condition)=49 %, M(% riskier choices in the pay-one condition)=39 %, $t(39) = 3.4, p < .001$ (one-tailed), $d = .5$). Risk behavior in both conditions was highly correlated ($r = .83, p < .001$).

Also in the risk questionnaire, participants chose the riskier option more often in the pay-all condition (M=43 %) than in the pay-one condition (M=18 %). A McNemar test revealed that this difference was significant ($\chi^2(1) = 6.8, p = .009, \phi = .4$). These results are shown in Figure 7.

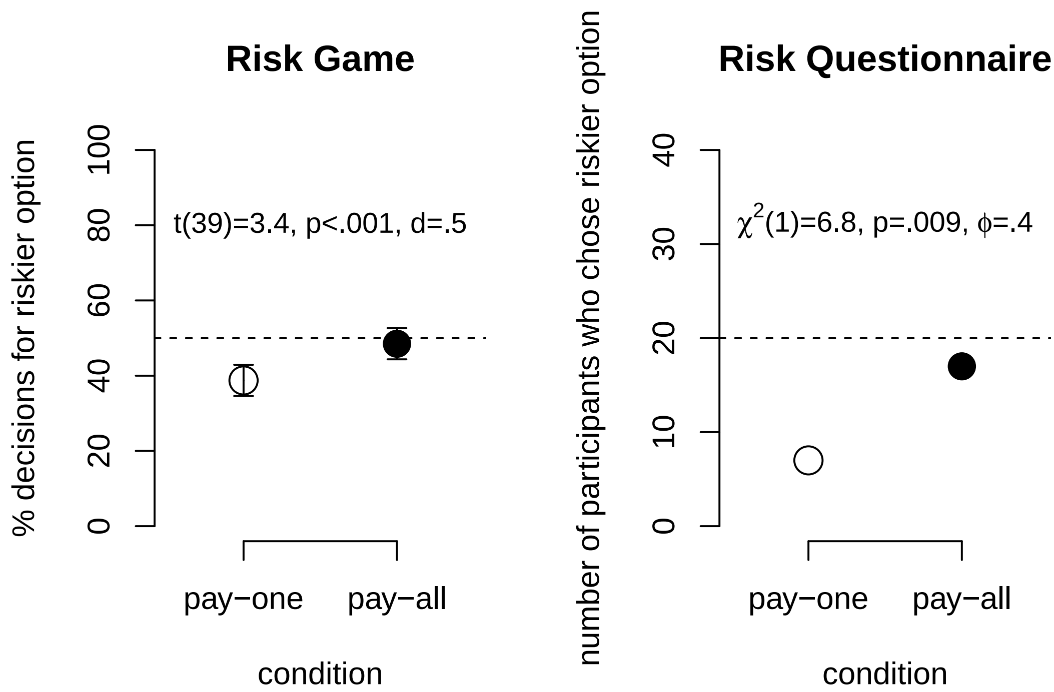

Figure 7: Direct comparison of risk behavior in the pay-one and the pay-all condition for the risk game and for the risk questionnaire

Risk Behavior and Personality

Participants who scored higher on the openness scale of the NEO-FFI chose the riskier option in the risk game more often ($r = .38, p = .02$). Impulsiveness, measured with the BIS-15, correlated marginally significant with risk behavior in the risk game ($r = .29, p = .07$): More impulsive participants tended to choose the riskier option. No other personality measures correlated significantly with risk behavior (all $p's > .1$).

Discussion

In this study, we show that participants act less risky when they get paid according to one randomly selected trial compared to when they get the money out of every trial. That was true for a risk game that was played once for each of the two payment conditions and for a risk questionnaire that assessed risk behavior in hypothetical choices. Please note that the expected values of both payment conditions were equal in the risk game and in the risk questionnaire.

When stakes are raised, participants usually behave less risky, but only if outcomes are actually paid out in cash, not in hypothetical risk choices (Holt and Laury, 2002). As the effect of payment method on risk behavior was significant not only in the risk game but also in the risk questionnaire, we can rule out the alternative explanation that participants had the impression stakes are raised in the pay-one condition.

Option ratings did not differ between conditions. This means that participants correctly realized that the isolated risk options were equal in both conditions. Despite this, participants acted 10 % less risky in the pay-one condition compared to the pay-all condition. Strikingly, participants behaved almost risk-neutral in the pay-all condition (on average 49 % choices for the riskier option). This result is in line with expected utility theory, which predicts risk-neutrality when stakes are small (Rabin, 2000). As

Rabin and Thaler (2001) point out, narrow framing might be the reason why risk aversion is observed at small stakes. So we conclude that pay-one paradigms may induce a narrow frame that causes less risky behavior (Thaler et al., 1997).

This is the first study that directly compares the straightforward pay-all payment method with the pay-one payment method. The results question the unchecked usage of the pay-one payment method which is the "standard payoff mechanism employed in behavioral and experimental economics" (Levy et al., 2010). The current data suggest that studies using the pay-one method (this method is also called "random lottery method" in some studies) may overestimate risk aversion.

Risk behavior was highly correlated in both conditions, though. That means, the underlying trait of risk aversion stayed the same, while the riskier pay-one paradigm led to less risky behavior (higher estimates of risk aversion) and the less risky pay-all paradigm led to riskier behavior (lower estimates of risk aversion). We conclude that both payment conditions are similarly able to assess individual differences in risk aversion, while estimates of risk aversion will be higher in pay-one paradigms compared to pay-all paradigms.

Please note that the order of the two payment conditions was balanced over all participants and sexes. Therefore, a systematic order effect of the two conditions cannot be the reason for the results obtained. We admit that the studies we refer to in the introduction never used a within subjects design with different payment conditions. It might be that the participants in the present study were more aware of payment methods compared to the cited studies, as they had to learn about the difference between the two payment conditions and run both of them one after the other. On the other hand, the within-subjects design we employed enabled us to compare risk behavior of the very same participants in different conditions without the problem of group effects and enabled us to check whether individual differences are affected by the payment methods or not. On the individual level, the personality traits openness and impulsiveness were positively associated with risk behavior, so the within-subjects design was an advantage for the interpretation of the effect of payment method on risk behavior. In a between-subjects design, groups may differ in terms of personality characteristics and thus handicap the interpretation of the results.

The present study can only be the beginning of a more profound investigation of the effects of payment methods on risk behavior. It would be interesting, for example, to see how behavior differs in mixed gambles with gains and losses or in gambles in the loss domain. Further, the effect of paying out one or all trials could be demonstrated using the very same paradigms of the studies we cited in the introduction section.

Nevertheless, we consider the issue of payment effects on risk behavior an important one. We want to point out that the generalized interpretation of risk aversion should always reflect the framing induced in the paradigm which has an important impact on risk behavior.

Motivation and Risk Behavior

The following chapter is based on the submitted publication

Schmidt, B., Mussel, P., Osinsky, R., Rasch, B., Debener, S. & Hewig, J. (under review). First work, then play: Prior task difficulty increases motivation-related ERPs in a risk game

Abstract

The motivation to engage in a certain task depends on what task was performed before. A recent theoretical view differentiates between want-to and have-to tasks: tasks that we like to do and tasks that we have to do. According to the theory, our organism is striving for a balance between those two task types: after a have-to task, motivation shifts towards a want-to task. We measured this shift of motivation via event-related potential (ERP) amplitudes in a within-subjects design. Participants worked on a Stroop task (have-to task) or an easier version of the Stroop task as a control condition and played a risk game afterwards (want-to task). After fulfilling the difficult Stroop task, ERP responses to risk decisions and gains in the risk game were stronger compared to ERP responses after the easy control task. The differences in ERP amplitudes were observed for an error-related negativity ERP component following the decision to take more or less risk and to the feedback-related negativity and P300 ERP components following the feedback about the financial outcome. We conclude that this pattern of ERP amplitude effects reflects the shift of motivation after a have-to task towards a want-to task.

Introduction

Imagine you did something that you have to do but what is not really fun like solving a problem on your PC. Afterwards, you may feel the urge to do something that is more fun like checking your private mail account or eating chocolate. You may even feel to have the right to reward yourself for the hard work you have just completed.

A recent theory addresses this shift of motivation towards a rewarding want-to task after an initial difficult have-to task. According to this model, people have a natural tendency to strive for an optimal balance of externally rewarded labor and intrinsically rewarding leisure (Inzlicht et al., 2014). Time is limited, and so it is adaptive to maximize the potential outcome in the sense of reward, which can be extrinsic or intrinsic. Of course it is important to engage in a difficult task like fixing a problem on your PC in order to gather external rewards and resources, but it is also important to be able to disengage from this have-to task and seek for activities that may also be gratifying like reading a private message from a friend or eat your favorite kind of chocolate. Motivation is seen as the driving force that makes us gravitate towards a want-to task after a have-to task.

But how does this shift of motivation manifest on the neuronal level? To address that topic in our study, we first had to choose appropriate tasks. As the want-to task, a risk game developed in our lab was chosen (Schmidt et al., 2013) (see Figure 8). In every trial of this task, participants decide if they want to play a riskier or less risky gamble. Then they choose one of two turned cards (one win and one loss card) and finally receive feedback about the amount of money they win in the current trial. The total outcome of the game is paid out to the participants in cash. Money is an intrinsically gratifying want-to goal (Hofmann et al., 2012). In addition, research on gambling motivation found out that the two main reasons to gamble are winning money and having fun (Neighbors et al., 2002). Therefore, we suggest that the risk game is a good example for a want-to task. As there might be individual differences concerning the general motivation to gamble in the risk game, we included several personality questionnaires that are associated with risk behavior.

To assess the hypothesized shift of motivation towards the want-to task, it is crucial to quantify motivation. One way to do this is to look at the impact of motivation on event-related potential (ERP) components. Recent electrophysiological results suggest that motivation affects ERP components like the error-related negativity (ERN; Hajcak and Foti, 2008; Pailing and Segalowitz, 2004), the feedback-related negativity (FRN; Masaki et al., 2006) and the P300 (Nieuwenhuis et al., 2005). The ERN was first observed after erroneous responses (Falkenstein et al., 1991; Gehring et al., 1993) and is sensitive to risky decisions (Hewig et al., 2007; Martin and Potts, 2009; Yu and Zhou, 2009). Gehring et al. (1993) also showed that participants who were motivated to answer correctly had larger ERN amplitudes. Source localization techniques suggest that the neural generator of the ERN is located in the anterior cingulate cortex (ACC), a brain region associated with the monitoring of motivation (Bush et al., 2000). Taken together, it can be suggested that increased motivation leads to larger ERN amplitudes.

The FRN is a component that is observed after feedback (Miltner et al., 1997) and differentiates between good and bad outcomes, especially between winning and losing money (Gehring and Willoughby, 2002). Further results show that FRN amplitudes were larger after surprising unexpected feedback that was either negative or positive (Pfabigan et al., 2011). Surprising feedback also implies motivational salience. Therefore, we conclude that increased motivation could be mirrored in larger FRN amplitudes.

The P300 is evoked in response to task-relevant and/or rare events (Polich, 2007). In risk games, the P300 was found to be more pronounced in riskier trials (Goyer et al., 2008; Wu and Zhou, 2009). As Nieuwenhuis et al. (2005) report in their review, the P300 is highly sensitive to motivational significance. Thus, higher motivation should result in higher P300 amplitudes.

The risk game developed in our lab and employed here was designed to assess each of these ERP components: the ERN after the decision for the riskier or less risky option and the FRN and P300 after the feedback concerning the financial outcome. So, if a have-to task which is performed before a want-to task leads to a shift in motivation, there should be an observable effect in the ERP results of the risk game.

As appropriate have-to task, a task that is known to deplete self-control was chosen (Hagger et al., 2010). When a dominant response has to be overridden, self-control is required (Baumeister et al., 2007). The exertion of self-control leads to ego depletion (Baumeister et al., 2007), as cognitive resources are demanded. There is a general bias to avoid cognitive demand (Kool et al., 2010). Therefore, depleting tasks can be treated as have-to tasks. We decided to employ a Stroop task as the have-to task in our study and adapted the task design used by Silvestrini and Rainville (2013). In this Stroop task, participants have to indicate the number of numerals presented on the screen (e.g. two two two; correct response is three) while suppressing the dominant response of reading the words (i.e. two). In this interference task, parallel processing and suppression of irrelevant information challenges attentional resources (MacLeod, 1991). As a control task, we used an easier version of the Stroop task with low interference. Here, the presented words were animal names instead of numerals and the task will be referred to as Animal task.

The typical depletion experiments are conducted as between-subjects designs (Hagger et al., 2010). To control for group effects, we decided to employ a within-subjects design to see if the ERP results of the participants differed depending on the task that was carried out before.

To sum up, participants came to the lab twice: once, they worked on the difficult Stroop task before they played the risk game and once they worked on the easier Animal task before they played the risk game. We predicted that ERP responses in the risk game after the difficult Stroop task reflect the shift of motivation towards the risk game: when you worked hard before, you want to play afterwards. Higher motivation in the risk game should lead to stronger electrophysiological responses in the ERP components ERN, FRN and P300.

Method

Participants

Data were collected from 20 participants (10 female). Mean age of the participants was 27.6 years (range 20-56 years). Ninety-five percent had a university entry degree or had already completed a graduate degree. Participants were paid according to their gain in the two risk games. On average, they got 6.6 euros for the risk games. As participants performed several additional tasks with monetary outcomes after the risk game, participants earned on average 23.5 euros for participation. The study was carried out in accordance to the Declaration of Helsinki.

Apparatus

All experimental tasks were programmed and presented in PsychoPy (Peirce, 2008). Statistical analyses were computed with R (R Development Core Team, 2014).

Procedure

In the beginning of the experiment, participants read a written instruction and signed an informed consent statement. Then, the electrode cap for EEG measurement was placed on their head. Participants were seated in a dimly lit room on a comfortable chair. A computer monitor was placed at a distance of approximately 100 cm in front of the participants. The participants worked on two tasks: first a high interference Stroop task or an easier, low interference control version of the Stroop task (Animal task), second a risk game. Participants came to the lab twice to undergo both the experimental and the control condition: In the experimental condition, the task before the risk game was the Stroop task, in the control condition, it was the Animal task.

Both sessions were separated by about one week and took place at the same time of day to control for arousal effects. The order of the conditions was balanced over all participants and both sexes.

Stroop/Animal task

The Stroop and Animal task consisted of 240 experimental trials and four practice trials which were not included in the analyses. In each trial, one to four identical words were presented on the screen. In both tasks, participants were instructed to indicate the number of words presented on the screen by pressing one of four different answer buttons on a button box. In the Stroop task, the presented words were four German numerals (one, two, three, four; in German: eins, zwei, drei, vier) whereas in the Animal task, the presented words were German animal names (dog, mouse, rabbit, duck; in German: hund, maus, hase, ente). Each of the presented words consisted of four uncapitalized characters. In the Stroop task, half of the trials (120) were congruent (number of words = numeral) and half of the trials incongruent (number of words $\neq$ numeral). A very similar version of these tasks was used as a depletion manipulation by Silvestrini and Rainville (2013).

Before the start of the task, participants were instructed to respond as accurately and quickly as possible and not to blur the words on the screen to make the task easier. Each trial started with a fixation dot that was shown during a random time interval between 300 and 700 ms. Then, the stimulus was presented, consisting of one to four identical words written below each other. The visual angle of the stimuli was about 2° times 2°. The stimuli remained on the screen until the participant pressed one of four answer buttons. During the four test trials, participants got feedback concerning their performance after each trial ("right!" or "wrong!") but not during the experimental trials. After the completion of all 240 trials, participants got feedback about the percentage of correct responses and their mean response time.

Participants answered the following questions after the Stroop/Animal task as manipulation check: 1. How difficult was the task? 2. How difficult was it for you to work on the task? 3. Did you try to answer as correctly and rapidly as possible until the end of the task? 4. How important was it for you to achieve the task successfully? 5. How do you feel at the moment? (one scale for valence and one scale for arousal). These questions were answered by choosing a value from 0 to 10 on a rating scale presented on the screen, with high values indicating high difficulty ratings, high engagement and importance, positive valence and high arousal, respectively.

Risk game

After completing the Stroop/Animal task, participants played a risk game which was almost identical to a risk game we successfully used in a former study (Schmidt et al., 2013). The risk game consisted of 60 trials. In the beginning of one trial, a fixation dot was shown for a random interval between 300-700 ms (see Figure 8). After that, two options were shown that differed in riskiness. Each of these options consisted of two monetary rewards. The expected value of both options was 5.5 cent while the degree of riskiness differed (11 cent vs. 0 cent as the riskiest option and 6 cent vs. 5 cent as the safest option). Option combinations always consisted of the riskiest option (11 cent vs. 0 cent) and one of the other less risky options. The option combinations were presented in random order. Participants had to choose one of the options by pressing one of two buttons. After another random interval between 300-700 ms, two cards were shown. On the back of these cards were the signs for winning the higher (diamond) or lower (square) sum of money. Participants chose one of the cards by pressing one of two buttons. After another random interval between 300-700 ms, the drawn card was shown together with the feedback “You get XX cent!”. This feedback was shown for 1500 ms. All stimuli in the risk game occupied about 6° of visual angle horizontally and 4° vertically. Participants drew the diamond card and the square card that indicated higher or lower gains in exactly 50 % of trials, independent of their card choice. A feedback in the end of the risk game showed how much money the participant won during the game.

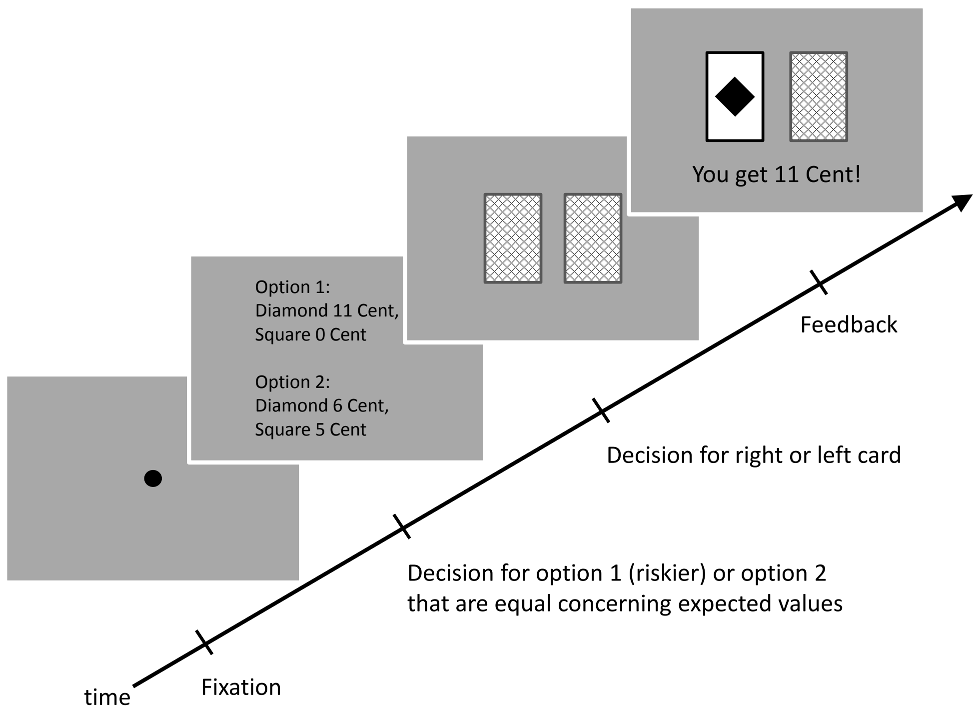

Figure 8: Time-course of one trial of the risk game

Option ratings and questionnaires

After the risk game, participants rated each risk option according to its valence, arousal and riskiness on a 9-point rating scale, while high values indicated positive valence, high arousal and high riskiness. At the end of the whole experiment, participants filled in several questionnaires: After the first session, they filled in the UPPS (Whiteside and Lynam, 2001) in its German version according to Keye et al. (2009), measuring impulsivity with its four facets urgency, premeditation, perseverance and sensation seeking and the Self-Control Scale (Tangney et al., 2004) in its brief German version according to Bertrams and Dickhäuser (2009). After the second session, participants filled in a greed questionnaire that was designed by our group and is currently under validation. This questionnaire contains 30 items and measures greed as well as its two sub-dimensions materialism and ruthlessness.

EEG recording and ERP quantification

The electroencephalogram of the participants was recorded from 31 scalp electrodes that were placed on their heads according to the 10-20 system (Fp1, Fp2, F9, F7, F3, Fz, F4, F8, F10, FC5, FC1, FCz, FC2, FC6, T7, C3, C4, T8, TP9, CP1, CP2, TP10, P7, P3, Pz, P4, P8, PO9, O1, O2 and PO10) and one electrode under the left eye, using Ag/AgCl electrodes and a BrainAmp DC amplifier (Brain Products GmbH, Gilching, Germany). Impedances were kept below 10 kΩ and electrodes were referenced to the vertex (Cz). The data were analog band-pass filtered during recording from 0.02 Hz to 80 Hz and the sampling rate was 250 Hz. For offline data processing, EEGLAB (Delorme and Makeig, 2004) running under the MATLAB environment (The MathWorks, Inc.) was used.
For artifact correction, independent component analysis (ICA) was used as proposed by Debener et al. (2010). Eye-related artifact components and heartbeat artifact components were removed by back-projection of all remaining components. The artifact-corrected data were then re-referenced to the mean of electrodes TP9 and TP10. For ERP analysis, we filtered the data with a high-pass filter of 0.2 Hz and a low-pass filter of 20 Hz. The EEG was then segmented into epochs around the events of interest with the time limits [-200 ms; 800 ms] and baseline-corrected [-200 ms; 0 ms]. Epochs with residual artifacts were removed. To quantify ERP responses to the risk game, we computed grand averages and identified the suitable time windows for our ERP components: For the ERN, we chose a time-window of [8 ms; 52 ms] after the button press for the risk decision centering around the peak of this component (30 ms). For the FRN, we selected two time-windows for the P2 and N2, respectively: the first was [204 ms;

252 ms] (center: 228 ms) after feedback presentation (P2) and the second was [240 ms; 340 ms] (center: 290 ms) after feedback presentation (N2). The P300 time window was [300 ms; 400 ms] (center: 350 ms) after feedback presentation. The amplitudes were computed as the average amplitude of the electrode of interest in the selected time windows. The FRN was quantified as peak-to-peak measure, so we subtracted the average amplitudes of window 1 (P2) from the average amplitudes of window 2 (N2). The electrodes of interest were identified by an across-conditions topographical plot and confirmed the well-known ERP topographies of the ERP components of interest. Accordingly, and in agreement with the literature, for the ERN and the FRN electrode, FCz was selected for parameterization and the P300 was quantified at electrode Pz.

Results

Stroop/Animal task

To test the prediction that the Stroop task was more difficult than the Animal task, several statistical analyses were conducted: within-subjects t-tests revealed that participants needed more time to respond in the Stroop task compared to the Animal task (M(Stroop)=656 ms, M(Animals)=580 ms; $t(19) = 4.2, p < .001$) but performance (percentage of correct responses) did not differ between the two tasks ($p > .5$). Participants responded correctly in on average 96 % of trials in the Animal task and in the Stroop task.

Ratings after the Animal/Stroop task showed that the Stroop task was more difficult than the Animal task ($t(19) = 2.3, p = .02$, one-tailed) and also more difficult to work on ($t(19) = 2.5, p = .01$, one-tailed). Also the arousal-ratings after the tasks differed: participants were more aroused after the Stroop task than after the Animal task ($t(19) = 3.6, p = .001$, one-tailed). Ratings concerning the engagement and importance of the two tasks as well as the subjective feeling (positive/negative) after the tasks did not differ between the tasks (all $p's > .5$).

Option ratings

To control that the risk game worked as intended, separate repeated-measures analyses of variance were conducted for valence, arousal and riskiness ratings with within-subject factors option (11/0, 10/1, 9/2, 8/3, 7/4, 6/5) and condition (Stroop or Animal task before). Valence ratings of the risk options showed that the riskier the presented option, the less pleasant the participants felt ($F(5, 95) = 6.1, p < .001$). Further, participants rated riskier options as more arousing ($F(5, 95) = 21.2, p < .001$). Also the interaction of option and condition was significant for arousal ratings ($F(5, 95) = 2.3, p = .05$): the most risky option 11/0 was rated as more arousing when the Stroop task was performed before ($t(19) = 2.3, p = .04$). Arousal ratings of all other options did not differ significantly for the two conditions (all $p's > .2$). Concerning the riskiness ratings of the options, participants rated riskier options as more risky ($F(5, 195) = 61.9, p < .001$). All other main effects and interactions did not reach significance (all $p's > .2$).

Risk behavior

Participants chose the riskier option in 44 % of trials. The percentage of riskier decisions after the Stroop task did not differ from the percentage of riskier decisions after the Animal task ($p = .6$). Risk behavior in the first and second session was highly correlated, indicating high retest reliability of the risk game we employed ($r = .85, p < .001$).

For the interpretation of the ERP results, it was important to test if one of the events "riskier decision" (44 %) or "less risky decision" (56 %) was more frequent. The frequency of both events did not differ significantly ($t(19) = 1.1, p = .3$). Therefore, a frequency interpretation of the ERP results, whereby rare events evoke larger ERP amplitudes, can be ruled out. Concerning personality questionnaires and risk behavior, a positive correlation between sensation seeking and risk behavior was found: participants that scored higher on sensation seeking chose the riskier option more often ($r = .59, p = .006$).

The evaluation of the risk options was also correlated with risk behavior: the more arousing participants rated the risk options, the less often they chose the riskier option ($r = -.58, p = .007$). In addition, a trend suggested that the riskier the participants rated the options, the less often they chose the riskier option ($r = -.42, p = .07$).

ERP components

Three subjects had to be excluded from the ERP analysis, as they either almost always or never chose the riskier option and therefore, not enough trials remained for all necessary condition combinations. There were two events of interest in the risk game: The first event was the time when participants pressed the button to choose the riskier or less risky option. We call this event risk decision. The second event of interest was the presentation of feedback about winning or losing. Please note that there were no real losses in the gamble: loss meant to win less than you would have won if you drew the diamond card.

ERN

The ERN was maximal at FCz and peaked 30 ms after the risk decision, indicated by the button press of the participants. The ERN was larger after the Stroop task than after the Animal task, indicated by higher negative amplitudes ($t(16) = 1.7, p = .05$, one-tailed, $d = .4$, see Figure 9). Further, the ERN was significantly larger in amplitude for riskier decisions compared to less risky decisions ($t(16) = 2.2, p = .02$, one-tailed, $d = .5$). A significant correlation between sensation seeking and ERN amplitudes revealed that participants scoring higher on sensation seeking had higher ERNs (i.e. more negative amplitudes): $r = -.45, p = .04$, one-tailed.

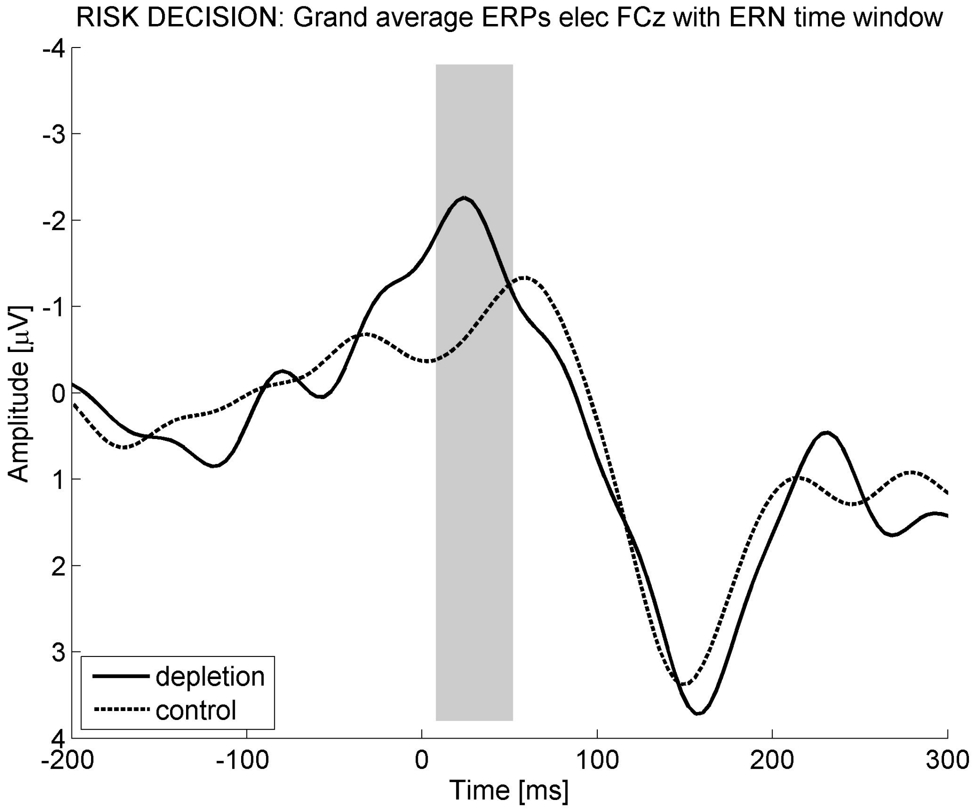

Figure 9: ERN amplitude after the Stroop task (depletion) and after the Animal task (control)

FRN

The FRN was also maximal at FCz and peaked 290 ms after feedback presentation. Again, the FRN was higher after the Stroop task than after the Animal task, indicated by higher negative amplitudes ($t(16) = 1.7, p = .05$, one-tailed, $d = .4$, see Figure 10). This effect was driven by higher negative amplitudes after the Stroop task than after the Animal task in win trials (M(FRN Stroop, win) = -0.9 μV, M(FRN Animal, win)

$= 0.9\,\mu$V). In the loss condition, there was no difference between the Stroop and Animal condition (M(FRN Stroop, loss) = -1.4 μV, M(FRN Animal, loss) = -1.5 μV). This observation also resulted in a significant interaction between the within-subject factors task history (Stroop/Animal) and feedback (win/loss): ($F(1, 16) = 8.9, p = .009$). Further, the FRN was higher after less risky decisions than after riskier decisions ($t(16) = 3.6, p = .003, d = .9$). After negative feedback (loss), the FRN was higher compared to positive feedback (win) ($t(16) = 3.0, p = .004$, one-tailed, $d = .7$). The difference between FRN amplitudes of (loss-win), which indicates the magnitude of the feedback effect on the FRN for every participant, was associated with risk behavior ($r = -.51, p = .04$) and decision time ($r = .49, p = .04$). The riskier the participants behaved and the faster they decided, the bigger was the FRN feedback effect (indicated by higher negative amplitudes). The FRN feedback effect was also correlated with sensation seeking measured via the UPPS ($r = -.65, p = .004$): the higher the participants scored on sensation seeking, the bigger was the FRN feedback effect.

P300

The P300 was maximal at Pz and peaked 350 ms after feedback presentation. Like the ERN and the FRN, the P300 was higher after the Stroop task than after the Animal task, indicated by higher positive amplitudes ($t(16) = 1.7, p = .05$, one-tailed, $d = .4$, see Figure 11). This effect was quantified for every participant via the difference of (Stroop-Animal) task history. The size of the effect was associated with premeditation, measured via the UPPS: participants who tend to think over their decisions before acting (the definition of premeditation) showed a bigger effect ($r = .51, p = .04$). The P300 was also higher in trials where participants chose the riskier option compared to trials where participants chose the less risky option ($t(16) = 6.3, p < .001$, one-tailed, $d = 1.5$). A significant correlation between greed,

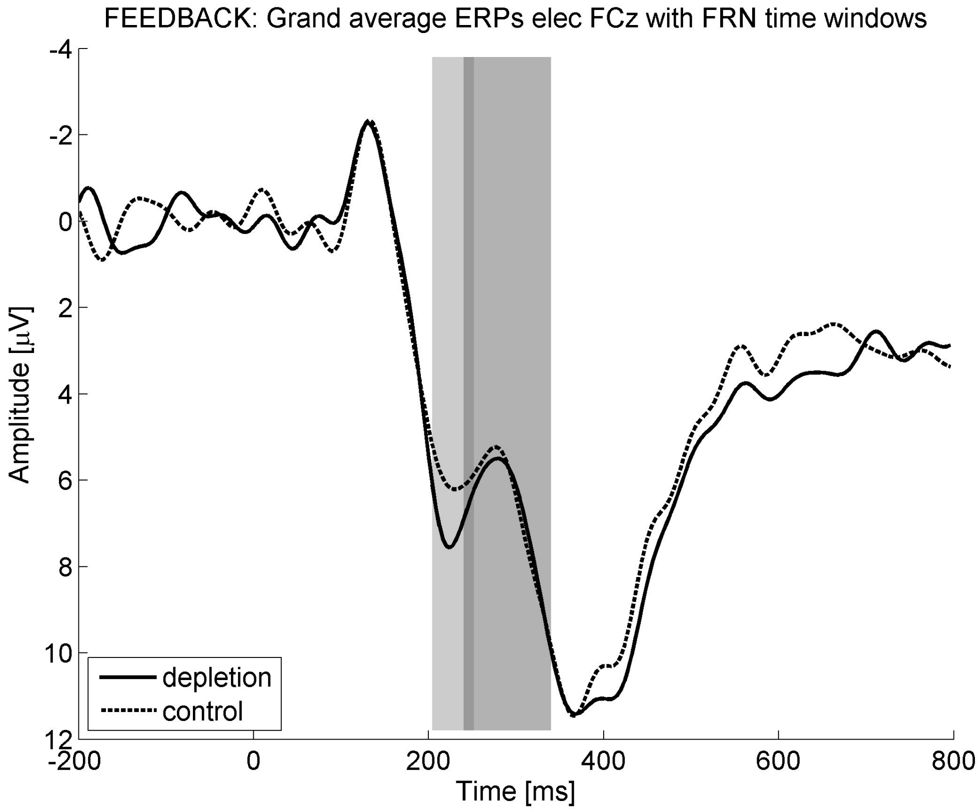

Figure 10: FRN amplitude after the Stroop task (depletion) and after the Animal task (control)

measured via the greed questionnaire, and P300 amplitudes indicated that participants who scored higher on greed had generally higher P300 amplitudes ($r = .46, p = .03$, one-tailed). Materialism, a sub-dimension of greed, was also significantly associated with P300 amplitudes ($r = .49, p = .02$, one-tailed): more materialistic participants showed higher P300 amplitudes.

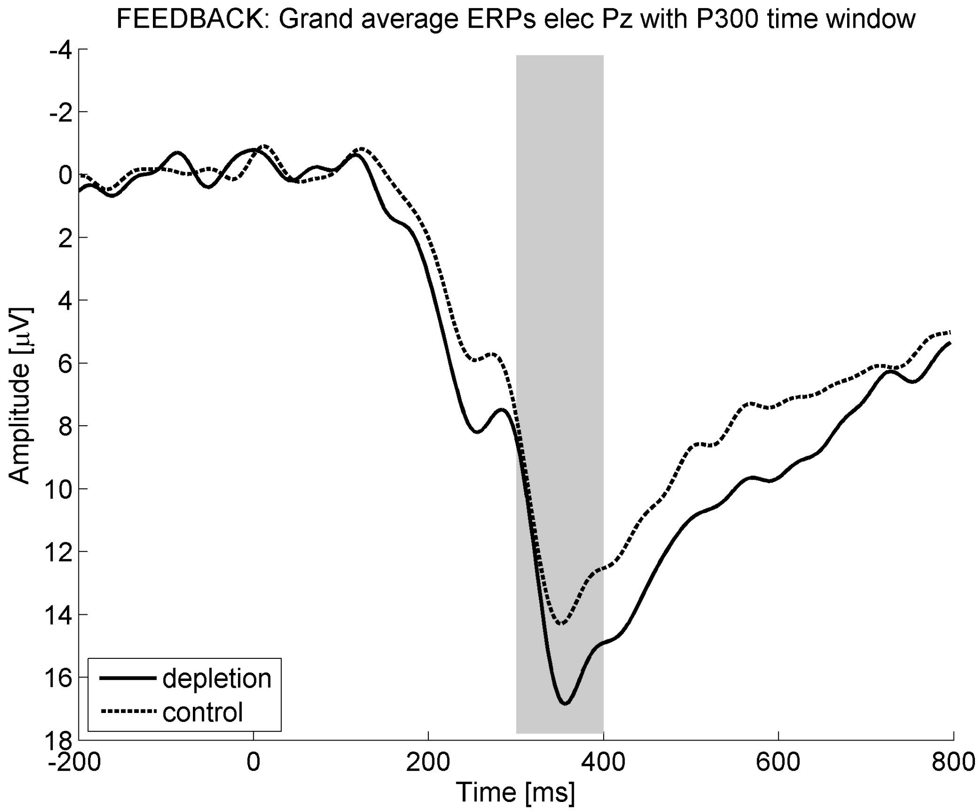

Figure 11: P300 amplitude after the Stroop task (depletion) and after the Animal task (control)

Discussion

This study aimed to assess the motivation shift after an initial have-to task towards a more pleasurable want-to task via ERP amplitude changes. Two have-to tasks were used in our within-subjects design: a harder one and an easier one. Longer response times and higher task ratings showed that the Stroop task was more difficult than the Animal task. ERP amplitudes of the ERN, FRN and P300 were more pronounced after the difficult Stroop task than after the easier Animal task. This pattern of ERP amplitude changes indicates a shift of motivation as postulated by Inzlicht et al. (2014): after the hard have-to task (Stroop), participants' motivation gravitates towards an inherently rewarding want-to task (risk game).

To the best of our knowledge, only two previous studies investigated brain responses after an initial have-to task (Friese et al., 2013; Inzlicht and Gutsell, 2007). In these two studies, participants first had to suppress their emotional responses to an emotional movie or to emotional pictures and then performed a Stroop task. Brain responses to the Stroop task were diminished after the emotion suppression task in both studies. According to the new model of Inzlicht et al. (2014), the emotion suppression task and the Stroop task are both have-to tasks as self-control has to be exerted (Baumeister et al., 2007). As a consequence, the theory predicts diminished motivation if one works on a second have-to task (Stroop) after the initial have-to task (emotion suppression). In our study, the task after the initial have-to task was a want-to task instead of another have-to task. So we expected brain responses to be more pronounced after the Stroop task and confirmed this hypothesis. Taken together, the empirical evidence provided here supports the new model of Inzlicht et al. (2014): after an initial have-to task, participants are less motivated to work on another have-to task but are instead more motivated to work on a subsequent want-to task to achieve a balance between have-to and want-to activities.

In the current study, we also assessed several personality traits to check for individual differences in the motivation to gamble in the risk game. We found that participants scoring higher on sensation seeking played riskier in the game. As a complementary result, participants who rated the risk options generally as more arousing and risky played less risky, replicating previous findings by Schmidt et al. (2013). Evidently, behavior in the risk game was influenced by individual preferences. Besides the fact that winning money is intrinsically rewarding, this result further justifies the consideration of the risk game as a want-to task.

The ERN was more pronounced after risky decisions than after less risky decisions. Similar observations were made before by Hewig et al. (2007); Martin and Potts (2009); Yu and Zhou (2009). The ERN is assumed to mirror a very fast process that evaluates the current decision. Sensation seeking was not only correlated with risk behavior, but also with the ERN amplitude: The higher participants scored on sensation seeking, the higher was their ERN (higher negative amplitudes). Keeping in mind that sensation seekers made more risky decisions in the risk game and that the ERN was greater after risky decisions, it is plausible that sensation seekers also had higher ERNs. Yet this finding also suggests that the ERN did not reflect immediate regret of a risky choice but rather an evaluation process that highlights the degree of riskiness without judging risky choices per se as negative. We speculate that for sensation seekers it might be more important to evaluate a decision as riskier or less risky which could be reflected in their heightened ERNs.

After negative feedback that indicated winning the lower amount of money, the FRN was more pronounced than after positive feedback. This is in line with a vast amount of studies stating that the FRN differentiates between good and bad outcomes (Foti et al., 2011; Gehring and Willoughby, 2002; Goyer et al., 2008; Hajcak et al., 2006; Hewig et al., 2007; Kreussel et al., 2012; Osinsky et al., 2012; Yeung and Sanfey, 2004). Correlations with risk behavior and response times in the risk game revealed that riskier participants and participants that responded faster exhibited a greater FRN-effect (FRN(loss)- FRN(win)). Further, participants that scored high on sensation seeking had a greater FRN-effect. Taken together, this pattern of results suggests that more impulsive participants especially emphasize the discrimination between wins and losses.

The non-intuitive observation that the FRN was stronger after less risky decisions in our study was already made before (Goyer et al., 2008; Wu and Zhou, 2009), but these studies offered no conceptual explanation for it. One reason for this result could be the close temporal proximity of the FRN and the P300, a problem that has been identified before, although a solution to it is lacking (Foti et al., 2011).

The P300 component was more pronounced in risky trials compared to less risky trials as it was also shown by Goyer et al. (2008); Wu and Zhou (2009). To rule out the explanation that risky trials were just less frequent than less risky trials and that this effect is therefore just an oddball-effect, we compared the frequency of the two trial types. There was no significant difference between the frequency of risky and less risky trials, so we think that the observed feedback effect is due to the higher importance or relevance of risky trials. In risky trials, the feedback about winning or losing is more important as the variance of outcomes is greater (winning either zero or eleven cent) than in less risky trials. As Yeung and Sanfey (2004) have argued, P300 amplitudes might vary simply because participants pay more attention to outcomes of larger monetary gambles. There is also evidence from non-monetary paradigms that the P300 is higher in amplitude when the stimulus is more relevant and is therefore especially attended (Gray et al., 2004). One further argument for the interpretation that the P300 effect is due to heightened attention in risky trials is the fact that participants who scored higher on greed and materialism generally had larger P300 amplitudes. For greedy and materialistic participants, it might be especially important to evaluate the outcomes in the risk game and consequently, they might pay more attention to the outcomes, resulting in higher P300 amplitudes.

Concerning the effect of the difficult Stroop task on the P300 amplitude, we found that for participants scoring high on premeditation (the tendency to think before you act), the effect was more pronounced. In the context of the ideas put forward by Inzlicht et al. (2014), it seems as if the premeditating participants are the ones who show the strongest shift of motivation towards the want-to task. It is possible that these individuals pay more attention to the outcomes in the risk game and therefore, the pronouncing effect of the previous task is observed in the P300 amplitude, which is known to mirror increased attention.

In summary, we found that ERP responses to a risk game were markedly increased after an initial have-to task. We interpret this finding as a shift of motivation after an initial have-to task towards a subsequent want-to task. Importantly, this shift of motivation was associated with personality: participants who tend to think over their actions showed a more pronounced motivation shift, mirrored by higher P300 amplitudes in the risk game.

So, the urge to do something pleasurable after working hard is also reflected in increased brain responses. That may be the reason why playing is much more fun when you worked hard before.

Conclusion

The studies presented in this dissertation investigated the impact of arousal, framing and motivation on risk behavior. These three psychological variables play important roles in psychological research as they are assumed to be key concepts underlying human attitudes and behavior.

Arousal as an independent dimension of emotion (Colibazzi et al., 2010) can be seen as the amplifier of emotion. The higher your arousal, the more intensive is your emotion. Famous historical psychological experiments show that arousal is easily misattributed if you are not aware of the true source of it (Cantor et al., 1975; Schachter and Singer, 1962). Walking over a dangerous suspension bridge for example heightens physiological arousal. If you meet an attractive person in the middle of that bridge, you will perceive that person as highly sexual attractive (Dutton and Aron, 1974) compared to a rendezvous on solid ground.

In the presented study concerning the impact of arousal on risk behavior, we overtly manipulated arousal via physical exercise, so we interpret our results in terms of an optimal level of arousal (Hebb, 1955) instead of misattribution (Cantor et al., 1975; Schachter and Singer, 1962). Reconsidering the example of Caesar standing at the Rubicon river, we could ask: Was Caesar under-aroused, seeking for new adventures and thus accepting the high risk of crossing the Rubicon? If that is the case, we can ask further: Was Caesar generally under-aroused, which could have been assessed by measuring his resting heart rate? Or did he just miss his daily training that would have put him into a state of higher physiological arousal?

Our result that low arousal is associated with high risk seems to contradict the finding that high sexual arousal is associated with high sexual risk (Ariely and Loewenstein, 2006). In their study, Ariely and Loewenstein (2006) let male participants masturbate until a sub-orgasmic level of sexual arousal. Then, the participants had to rate the attractiveness of different sexual activities, indicate what they are willing to do in order to obtain sexual gratification and answer questions about their attitude towards sexual risks in the heat of passion. Results show that sexually aroused males rated sexual activities as more attractive, were more willing to engage in morally questionable behavior in order to obtain sexual gratification and had a more positive attitude towards unsafe sex compared to a control condition. The authors interpret their results in line with the view that sexual arousal serves as an amplifier: neutral activities become sexually attractive and already sexual attractive activities become even more attractive under sexual arousal. But the authors also point out that sexual arousal implies a very specific motivation to have sex compared to other goals like behaving morally or avoiding pregnancy.

Comparing the results of Ariely and Loewenstein (2006) with our results, the distinction between physiological arousal and sexual arousal is crucial. Sexual arousal is strongly associated with the very specific motivation to have sex while physiological arousal is rather unspecific concerning motivation. It would be interesting to compare the impact of sexual and physiological arousal on risk behavior in the sexual domain as well as in the financial domain. Further, it would be important to include not only male participants, but also female participants to see whether there are sex difference concerning sexual arousal effects, as the male sex drive is more intense than the female sex drive (Ariely and Loewenstein, 2006).

The concept of framing on the other hand is a topic that is primarily addressed by researchers in the field of economics, using psychological methods to see how heuristics influence decision making (Tversky and Kahneman, 1981). In our study, we addressed one very specific case of framing. We noticed that in many neuroeconomic experiments that use gambles, participants are not paid out according to all trials they play. Instead, one trial of the gamble is randomly selected in the end and the outcome of this trial is paid out. The reasons for this payment method are that first, stakes should be high enough to be taken seriously by the participants. Second, experiments should not get too expensive. And third, participants should treat every trial as independent, not like a portfolio. That is why the pay-one method is the standard method in economic research (Levy et al., 2010). As studies using this method currently do not discuss their results in terms of their payment method, we wanted to assess whether the payment method influences risk behavior. We found that the pay-one method led to significantly less risky behavior compared to the pay-all method. We consider this result as very important for research on risk behavior, as risk-aversion might be over-estimated by pay-one paradigms. As we employed a very specific risk game, the effect of the payment method should be replicated in other gambling paradigms. Further, risk behavior in both payment conditions was highly correlated, indicating that individual differences in risk behavior can be assessed with both payment methods. But the finding that paying out only one trial of a gamble leads to risk-averse behavior should cause researchers to pay special attention to the interpretation of risk behavior in pay-one paradigms. Up to date, there is no doubt concerning the employment of the pay-one method in economic paradigms.

The third psychological variable that we addressed was motivation. Motivation is the driving force of our daily life: it fuels our actions by setting goals that are to be reached (Kaplan et al., 2012). There are things that we like to do and other things that we have to do. So, a recent theory differentiates between those two types of tasks: want-to and have-to tasks (Inzlicht et al., 2014). Motivation is seen as the force that strives for a balance between want-to and have-to tasks in the sense of homeostasis. When we worked a lot on have-to tasks, our motivation directs us towards a want-to task afterwards. The saying "first work, then play" might base on the observation that we like to engage in delightful tasks even more when we fulfilled our duties before. We addressed this topic by assessing event-related potentials (ERPs) of the EEG in the want-to task that was played after a difficult have-to task. We compared the amplitudes of the ERP components in the want-to task after a difficult have-to task with amplitudes of the ERP components after an easier control task. Results showed that the increased motivation to play the want-to task after the difficult have-to task was mirrored in higher ERP amplitudes. Thus, we showed that the shift of motivation after hard work towards leisure activities is measurable in our EEG. This result also implies that researchers should keep in mind their participants' task history. When participants arrive at the laboratory, they might be in very different motivational states. Some may be motivated to engage in difficult laboratory tasks as they are relaxed because they had lots of leisure, others may be worn out by their exhausting studies and thus not motivated to engage in an additional have-to task in the laboratory. In addition, the results provide further evidence for the appropriateness of ERP measures for the assessment of motivation. That is important as it gets more and more important in psychological research to look at concepts like motivation and emotion with the means of psychophysiological measures like EEG.

Let's focus on the concept of risk in a final consideration. In our study investigating the impact of motivation on risk behavior, we used the risk game as a want-to task. Playing a gamble and getting money is intrinsically rewarding (Hofmann et al., 2012; Neighbors et al., 2002). But what about risk per se? Does risk itself have a specific valence? For one last time, let's go back to the historic Caesar story. After Caesar decided to take the riskier option to cross the Rubicon instead of staying on his side of the river, he said *alea iacta est* (Suetonus, *Divus Iulius*, 31f). That is the moment of risk: The dice are thrown in the air, but it is unclear yet what the outcome will be. For

Caesar, that must have been a thrilling moment. If he was a sensation seeker, as we suggested earlier, he might have liked the moment and it was intrinsically rewarding for him. In general, risk per se has no specific valence. Risk is a naturally occurring feature of decisions that we have to make in life. And even though we don't have exact values of the probabilities that we have to deal with, we have developed a feeling of risk (Loewenstein et al., 2001). In many decision situations, we will therefore rely on our gut feeling. But knowing about influences from arousal, framing and motivation, we may be able to deal better with our feelings concerning a decision that has to be made. Maybe we know that we are generally risk seeking, which may result from low trait arousal, and keep that in mind. Or we are aware of the influence of framing and try to see the decision from different point of views. Finally, we should always ask ourselves about our motivation: Why do we prefer one alternative over the other?

Caesar chose the riskier option to cross the Rubicon and accepted its higher variability of outcomes, compared with the safer option to stay on this side of the river. From today's perspective, we know about the extreme outcomes of this decision. On the one hand, Caesar was appointed *dictator perpetuo*, eliminating any timely restrictions from his dictatorship. This was the summit of his political career that he strove for during his whole life. On the other hand, he was assassinated in a very cruel way during a session of the Senate in the Ides of March 44 BC, only a few months after he was officially appointed *dictator perpetuo* (Suetonus, *Divus Iulius*, 81f). So, the decision for the riskier option to cross the river Rubicon resulted in an extremely positive outcome (being *dictator perpetuo*), followed by an extremely negative outcome (being assassinated). Like in the dice example described in the preface, the risky decision to throw one 11-sided dice results with equal probability in both immediate and extreme outcomes.

Transferred to decisions that are important today, we have to calculate the risk of the possible options. When we decide to reduce our carbon dioxide emissions, we can either prevent further climate change that harms our planet or it turns out that we invested the money in vain as we were the only ones reducing carbon dioxide emissions while other important countries refused to follow us. As we don't know the exact probabilities of outcomes, we can never be sure if we made the right decision. But we should keep in mind that in the end, we will be responsible for our decisions and their consequences. To make a risky choice can be dangerous, but it may pay out in the end. So, if we have good reasons for a risky decision, we should take our chances.

References

Ariely, D. and Loewenstein, G. (2006). The heat of the moment: The effect of sexual arousal on sexual decision making. *Journal of Behavioral Decision Making*, 19(2):87–98.

Armstrong, T. and Boutwell, B. (2012). Low resting heart rate and rational choice: Integrating biological correlates of crime in criminological theories. *Journal of Criminal Justice*, 40(1):31–39.

Armstrong, T., Keller, S., Franklin, T., and MacMillan, S. (2009). Low resting heart rate and antisocial behavior. *Criminal Justice and Behavior*, 36(11):1125–1140.

Baumeister, R. F., Vohs, K. D., and Tice, D. M. (2007). The strength model of self-control. *Current Directions in Psychological Science*, 16(6):351–355.

Bertrams, A. and Dickhäuser, O. (2009). Messung dispositioneller Selbstkontroll-Kapazität. *Diagnostica*, 55(1):2–10.

Bexton, W., Heron, W., and Scott, T. (1954). Effects of decreased variation in the sensory environment. *Canadian Journal of Psychology*, 8(2):70–76.

Blais, A. and Weber, E. (2006). A domain-specific risk-taking (dospert) scale for adult populations. *Judgment and Decision Making*, 1(1):33–47.

Bradley, M. and Lang, P. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry*, 25(1):49–59.

Bush, G., Luu, P., and Posner, M. I. (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends in Cognitive Sciences*, 4(6):215–222.

Buss, A. H. and Perry, M. (1992). The aggression questionnaire. *Journal of Personality and Social Psychology*, 63(3):452–459.

Camerer, C. and Weber, M. (1992). Recent developments in modeling preferences: Uncertainty and ambiguity. *Journal of Risk and Uncertainty*, 5(4):325–370.

Cantor, J. R., Zillmann, D., and Bryant, J. (1975). Enhancement of experienced sexual arousal in response to erotic stimuli through misattribution of unrelated residual excitation. *Journal of Personality and Social Psychology*, 32(1):69–75.

Colibazzi, T., Posner, J., Wang, Z., Gorman, D., Gerber, A., Yu, S., Zhu, H., Kangarlu, A., Duan, Y., Russell, J. A., and Peterson, B. S. (2010). Neural systems subserving valence and arousal during the experience of induced emotions. *Emotion*, 10(3):377–389.

De Martino, B., Camerer, C. F., and Adolphs, R. (2010). Amygdala damage eliminates monetary loss aversion. *Proceedings of the National Academy of Sciences*, 107(8):3788–3792.

Debener, S., Thorne, J., Schneider, T. R., and Viola, F. C. (2010). Using ICA for the analysis of multi-channel EEG data. In Ullsperger, M. and Debener, S., editors, *Simultaneous EEG and fMRI: recording, analysis and application*. Oxford: Oxford University Press.

Delorme, A. and Makeig, S. (2004). EEGLAB: An open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods*, 134(1):9–21.

Ditto, B. (1993). Familial influences on heart rate, blood pressure, and self-report anxiety responses to stress: Results from 100 twin pairs. *Psychophysiology*, 30(6):635–645.

Dutton, D. G. and Aron, A. P. (1974). Some evidence for heightened sexual attraction under conditions of high anxiety. *Journal of Personality and Social Psychology*, 30(4):510–517.

Edman, G., Schalling, D., and Levander, S. (1983). Impulsivity and speed and errors in a reaction time task: A contribution to the construct validity of the concept of impulsivity. *Acta Psychologica*, 53(1):1–8.

Eysenck, H. (1967). *The biological basis of personality.* American lecture series. Thomas, Springfield, Illinois.

Eysenck, H. and Eysenck, M. (1985). *Personality and individual differences.* Plenum Press, New York.

Falkenstein, M., Hohnsbein, J., Hoormann, J., and Blanke, L. (1991). Effects of crossmodal divided attention on late ERP components. II. Error processing in choice reaction tasks. *Electroencephalography and Clinical Neurophysiology*, 78(6):447–455.

Foti, D., Weinberg, A., Dien, J., and Hajcak, G. (2011). Event-related potential activity in the basal ganglia differentiates rewards from nonrewards: Temporospatial principal components analysis and source localization of the feedback negativity. *Human Brain Mapping*, 32(12):2207–2216.

Friese, M., Binder, J., Luechinger, R., Boesiger, P., and Rasch, B. (2013). Suppressing emotions impairs subsequent stroop performance and reduces prefrontal brain activation. *PloS one*, 8(4):e60385.

Gehring, W. J., Goss, B., Coles, M. G., Meyer, D. E., and Donchin, E. (1993). A neural system for error detection and compensation. *Psychological Science*, 4(6):385–390.

Gehring, W. J. and Willoughby, A. R. (2002). The medial frontal cortex and the rapid processing of monetary gains and losses. *Science*, 295(5563):2279–2282.

Goyer, J. P., Woldorff, M. G., and Huettel, S. A. (2008). Rapid electrophysiological brain responses are influenced by both valence and magnitude of monetary rewards. *Journal of Cognitive Neuroscience*, 20(11):2058–2069.

Graham, F. K. and Clifton, R. K. (1966). Heart-rate change as a component of the orienting response. *Psychological Bulletin*, 65(5):305–320.

Gray, H. M., Ambady, N., Lowenthal, W. T., and Deldin, P. (2004). P300 as an index of attention to self-relevant stimuli. *Journal of Experimental Social Psychology*, 40(2):216–224.

Hagemann, D., Waldstein, S. R., and Thayer, J. F. (2003). Central and autonomic nervous system integration in emotion. *Brain and Cognition*, 52(1):79–87.

Hagger, M. S., Wood, C., Stiff, C., and Chatzisarantis, N. L. (2010). Ego depletion and the strength model of self-control: A meta-analysis. *Psychological Bulletin*, 136(4):495–525.

Hajcak, G. and Foti, D. (2008). Errors are aversive: Defensive motivation and the error-related negativity. *Psychological Science*, 19(2):103–108.

Hajcak, G., Moser, J. S., Holroyd, C. B., and Simons, R. F. (2006). The feedback-related negativity reflects the binary evaluation of good versus bad outcomes. *Biological psychology*, 71(2):148–154.

Hebb, D. (1955). Drives and the CNS (conceptual nervous system). *Psychological Review*, 62(4):243–254.

Hewig, J., Hagemann, D., Seifert, J., Naumann, E., and Bartussek, D. (2004). On the selective relation of frontal cortical asymmetry and anger-out versus anger-control. *Journal of Personality and Social Psychology*, 87(6):926–939.

Hewig, J., Trippe, R., Hecht, H., Coles, M. G., Holroyd, C. B., and Miltner, W. H. (2007). Decision-making in blackjack: An electrophysiological analysis. *Cerebral Cortex*, 17(4):865–877.

Hofmann, W., Vohs, K. D., and Baumeister, R. F. (2012). What people desire, feel conflicted about, and try to resist in everyday life. *Psychological Science*, 23(6):582–588.

Holt, C. A. and Laury, S. K. (2002). Risk aversion and incentive effects. *American*

Economic Review, 92(5):1644–1655.

Horvath, P. and Zuckerman, M. (1993). Sensation seeking, risk appraisal, and risky behavior. *Personality and Individual Differences*, 14(1):41–52.

Hsu, M., Bhatt, M., Adolphs, R., Tranel, D., and Camerer, C. F. (2005). Neural systems responding to degrees of uncertainty in human decision-making. *Science*, 310(5754):1680–1683.

Hsu, M., Krajbich, I., Zhao, C., and Camerer, C. F. (2009). Neural response to reward anticipation under risk is nonlinear in probabilities. *The Journal of Neuroscience*, 29(7):2231–2237.

Inzlicht, M. and Gutsell, J. N. (2007). Running on empty: Neural signals for self-control failure. *Psychological Science*, 18(11):933–937.

Inzlicht, M., Schmeichel, B. J., and Macrae, C. N. (2014). Why self-control seems (but may not be) limited. *Trends in cognitive sciences*, 18(3):127–133.

Isen, A. M. and Patrick, R. (1983). The effect of positive feelings on risk taking: When the chips are down. *Organizational Behavior and Human Performance*, 31(2):194–202.

Kahneman, D. and Lovallo, D. (1993). Timid choices and bold forecasts: A cognitive perspective on risk taking. *Management Science*, 39(1):17–31.

Kahneman, D. and Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, pages 263–291.

Kaplan, R. L., Van Damme, I., and Levine, L. J. (2012). Motivation matters: Differing effects of pre-goal and post-goal emotions on attention and memory. *Frontiers in Psychology*, 3:1–9.

Kaufmann, T., Sütterlin, S., Schulz, S. M., and Vögele, C. (2011). ARTiiFACT: A tool for heart rate artifact processing and heart rate variability analysis. *Behavior Research Methods*, 43(4):1161–1170.

Keye, D., Wilhelm, O., and Oberauer, K. (2009). Structure and correlates of the

German version of the brief UPPS impulsive behavior scales. *European Journal of Psychological Assessment*, 25(3):175–185.

Kool, W., McGuire, J. T., Rosen, Z. B., and Botvinick, M. M. (2010). Decision making and the avoidance of cognitive demand. *Journal of Experimental Psychology: General*, 139(4):665–682.

Kreussel, L., Hewig, J., Kretschmer, N., Hecht, H., Coles, M. G., and Miltner, W. H. (2012). The influence of the magnitude, probability, and valence of potential wins and losses on the amplitude of the feedback negativity. *Psychophysiology*, 49(2):207–219.

Krueger, T., Schedlowski, M., and Meyer, G. (2005). Cortisol and heart rate measures during casino gambling in relation to impulsivity. *Neuropsychobiology*, 52(4):206–211.

Lacey, J. I. and Lacey, B. C. (1970). Some autonomic-central nervous system interrelationships. In Black, P., editor, *Physiological correlates of emotion*. Academic Press, New York, NY.

Ladouceur, R., Sévigny, S., Blaszczynski, A., O'Connor, K., and Lavoie, M. (2003). Video lottery: Winning expectancies and arousal. *Addiction*, 98(6):733–738.

Lang, P., Greenwald, M., Bradley, M., and Hamm, A. (1993). Looking at pictures: Affective, facial, visceral, and behavioral reactions. *Psychophysiology*, 30(3):261–273.

Lee, C. J. and Andrade, E. B. (2014). Fear, excitement, and financial risk-taking. *Cognition & Emotion*, pages 1–10.

Leith, K. P. and Baumeister, R. F. (1996). Why do bad moods increase self-defeating behavior? Emotion, risk tasking, and self-regulation. *Journal of Personality and Social Psychology*, 71(6):1250–1267.

Levy, I., Snell, J., Nelson, A. J., Rustichini, A., and Glimcher, P. W. (2010). Neural representation of subjective value under risk and ambiguity. *Journal of Neuro-*

physiology, 103(2):1036–1047.

Loewenstein, G. F., Weber, E. U., Hsee, C. K., and Welch, N. (2001). Risk as feelings. *Psychological Bulletin*, 127(2):267–286.

MacLeod, C. M. (1991). Half a century of research on the stroop effect: An integrative review. *Psychological Bulletin*, 109(2):163–203.

Martin, L. E. and Potts, G. F. (2009). Impulsivity in decision-making: An event-related potential investigation. *Personality and Individual Differences*, 46(3):303–308.

Masaki, H., Takeuchi, S., Gehring, W. J., Takasawa, N., and Yamazaki, K. (2006). Affective-motivational influences on feedback-related ERPs in a gambling task. *Brain Research*, 1105(1):110–121.

Mathias, C. and Stanford, M. (2003). Impulsiveness and arousal: Heart rate under conditions of rest and challenge in healthy males. *Personality and Individual Differences*, 35(2):355–371.

Matthews, G. and Gilliland, K. (1999). The personality theories of H. J. Eysenck and J. A. Gray: A comparative review. *Personality and Individual differences*, 26(4):583–626.

Mawson, A. (2009). On the association between low resting heart rate and chronic aggression: Retinoid toxicity hypothesis. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, 33(2):205–213.

McCrae, R. R. and Costa, P. T. (2004). A contemplated revision of the NEO Five-Factor Inventory. *Personality and Individual Differences*, 36(3):587–596.

McNamara, L. and Ballard, M. E. (1999). Resting arousal, sensation seeking, and music preference. *Genetic, Social, and General Psychology Monographs*, 125(3):229–250.

Meule, A., Vögele, C., and Kübler, A. (2011). Psychometrische Evaluation der deutschen Barratt Impulsiveness Scale–Kurzversion (BIS-15). *Diagnostica*, 57(3):126–133.

Meyer, G., Hauffa, B., Schedlowski, M., Pawlak, C., Stadler, M., and Exton, M. (2000). Casino gambling increases heart rate and salivary cortisol in regular gamblers. *Biological Psychiatry*, 48(9):948–953.

Miltner, W. H., Braun, C. H., and Coles, M. G. (1997). Event-related brain potentials following incorrect feedback in a time-estimation task: Evidence for a "generic" neural system for error detection. *Journal of Cognitive Neuroscience*, 9(6):788–798.

Neighbors, C., Lostutter, T. W., Cronce, J. M., and Larimer, M. E. (2002). Exploring college student gambling motivation. *Journal of Gambling Studies*, 18(4):361–370.

Nieuwenhuis, S., Aston-Jones, G., and Cohen, J. D. (2005). Decision making, the P3, and the locus coeruleus-norepinephrine system. *Psychological Bulletin*, 131(4):510–532.

Niskanen, J.-P., Tarvainen, M. P., Ranta-Aho, P. O., and Karjalainen, P. A. (2004). Software for advanced HRV analysis. *Computer Methods and Programs in Biomedicine*, 76(1):73–81.

Ortiz, J. and Raine, A. (2004). Heart rate level and antisocial behavior in children and adolescents: A meta-analysis. *Journal of the American Academy of Child & Adolescent Psychiatry*, 43(2):154–162.

Osinsky, R., Mussel, P., and Hewig, J. (2012). Feedback-related potentials are sensitive to sequential order of decision outcomes in a gambling task. *Psychophysiology*, 49(12):1579–1589.

Pailing, P. E. and Segalowitz, S. J. (2004). The error-related negativity as a state and trait measure: Motivation, personality, and ERPs in response to errors. *Psychophysiology*, 41(1):84–95.

Pailing, P. E., Segalowitz, S. J., Dywan, J., and Davies, P. L. (2002). Error negativity and response control. *Psychophysiology*, 39(2):198–206.

Peirce, J. (2008). Generating stimuli for neuroscience using psychopy. *Frontiers in Neuroinformatics*, 2.

Pfabigan, D. M., Alexopoulos, J., Bauer, H., and Sailer, U. (2011). Manipulation of feedback expectancy and valence induces negative and positive reward prediction error signals manifest in event-related brain potentials. *Psychophysiology*, 48(5):656–664.

Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology*, 118(10):2128–2148.

R Development Core Team (2014). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0.

Rabin, M. (2000). Risk aversion and expected-utility theory: A calibration theorem. *Econometrica*, 68(5):1281–1292.

Rabin, M. and Thaler, R. H. (2001). Anomalies: Risk aversion. *Journal of Economic Perspectives*, pages 219–232.

Read, D., Loewenstein, G., and Rabin, M. (1999). Choice bracketing. *Journal of Risk and Uncertainty*, pages 171–197.

Rothschild, M. and Stiglitz, J. E. (1970). Increasing risk: I. A definition. *Journal of Economic Theory*, 2(3):225–243.

Samuelson, P. A. (1963). Risk and uncertainty: A fallacy of large numbers. *Scientia*, 98:108–113.

Schachter, S. and Singer, J. (1962). Cognitive, social, and physiological determinants of emotional state. *Psychological Review*, 69(5):379–399.

Schmidt, B., Mussel, P., and Hewig, J. (2013). I'm too calm - Let's take a risk! On the impact of state and trait arousal on risk taking. *Psychophysiology*, 50(5):498–503.

Sharpe, L. (2004). Patterns of autonomic arousal in imaginal situations of winning and losing in problem gambling. *Journal of Gambling Studies*, 20(1):95–104.

Silvestrini, N. and Rainville, P. (2013). After-effects of cognitive control on pain. *European Journal of Pain*, 17(8):1225–1233.

Smith, K., Dickhaut, J., McCabe, K., and Pardo, J. V. (2002). Neuronal substrates for choice under ambiguity, risk, gains, and losses. *Management Science*, 48(6):711–718.

Spielberger, C. D., Sydeman, S. J., Owen, A. E., and Marsh, B. J. (1999). Measuring anxiety and anger with the State-Trait Anxiety Inventory (STAI) and the State-Trait Anger Expression Inventory (STAXI). In Maruish, M. E., editor, *The use of psychological testing for treatment planning and outcomes assessment*, pages 993–1021. Erlbaum, Mahwah, NJ, US, 2 edition.

Tanaka, H., Monahan, K., and Seals, D. (2001). Age-predicted maximal heart rate revisited. *Journal of the American College of Cardiology*, 37(1):153.

Tangney, J. P., Baumeister, R. F., and Boone, A. L. (2004). High self-control predicts good adjustment, less pathology, better grades, and interpersonal success. *Journal of Personality*, 72(2):271–324.

Thaler, R. H., Tversky, A., Kahneman, D., and Schwartz, A. (1997). The effect of myopia and loss aversion on risk taking: An experimental test. *The Quarterly Journal of Economics*, pages 647–661.

Tom, S. M., Fox, C. R., Trepel, C., and Poldrack, R. A. (2007). The neural basis of loss aversion in decision-making under risk. *Science*, 315(5811):515–518.

Tversky, A. and Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science*, 211(4481):453–458.

Westermann, R., Spies, K., Stahl, G., and Hesse, F. W. (1996). Relative effectiveness and validity of mood induction procedures: A meta-analysis. *European Journal of Social Psychology*, 26(4):557–580.

Whiteside, S. P. and Lynam, D. R. (2001). The five factor model and impulsivity: Using a structural model of personality to understand impulsivity. *Personality and Individual Differences*, 30(4):669–689.

Wu, Y. and Zhou, X. (2009). The P300 and reward valence, magnitude, and expectancy in outcome evaluation. *Brain Research*, 1286:114–122.

Wulfert, E., Roland, B., Hartley, J., Wang, N., and Franco, C. (2005). Heart rate arousal and excitement in gambling: Winners versus losers. *Psychology of Addictive Behaviors*, 19(3):311–316.

Yeung, N. and Sanfey, A. G. (2004). Independent coding of reward magnitude and valence in the human brain. *The Journal of Neuroscience*, 24(28):6258–6264.

Yu, R. and Zhou, X. (2009). To bet or not to bet? The error negativity or error-related negativity associated with risk-taking choices. *Journal of Cognitive Neuroscience*, 21(4):684–696.

Zuckerman, M. (1991). *Psychobiology of personality.* Cambridge University Press, Cambridge, New York.

Zuckerman, M. and Kuhlman, M. D. (2000). Personality and risk-taking: Common biosocial factors. *Journal of Personality*, 68(6):999–1029.

Curriculum Vitae

Oktober 2011 – November 2014	Wissenschaftliche Mitarbeiterin Lehrstuhl für Differentielle Psychologie und Diagnostik Julius-Maximilians-Universität Würzburg
Mai 2011 – Juli 2011	Forschungsaufenthalt bei Professor John J.B. Allen an der University of Arizona in Tucson (USA)
Oktober 2005 – März 2011	Studium der Psychologie Albertus-Magnus-Universität Regensburg Eberhard-Karls-Universität Tübingen Abschluss: Diplom
Juni 2005	Abitur Staatliches Gymnasium Pullach
Oktober 1985	Geboren am 23. Oktober 1985 in München

Würzburg, 15. Dezember 2014

Barbara Schmidt