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The role of psychological and physiological factors in decision making under risk and in a dilemma

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Abstract

We study the difference in the result of two different risk elicitation methods by linking estimates of risk attitudes to gender, age, personality traits, a decision in a dilemma situation, and physiological states measured by heart rate variability (HRV). Our results indicate that differences between the methods can partly be explained by gender, but not by personality traits. Furthermore, HRV is linked to risk-taking in the experiment for at least one of the methods, indicating that more stressed individuals display more risk aversion. Finally, we find that risk attitudes are not predictive of the ability to decide in a dilemma, but personality traits are. Surprisingly, there is also no apparent relationship between the physiological state during the dilemma situation and the ability to make a decision.

Keywords risk preferences · elicitation methods · physiological measures · personality traits · dilemma decision

JEL classification D08 · D81 · D87

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1 Introduction

The commonly used concept of risk aversion in economics is mainly based on a theoretical framework, although much of its intuition is also based on the daily observation that people avoid or are at least hesitant when taking risks. Both the theoretical as well as common sense understanding of risk aversion is based on the idea that a (stable) underlying element reflects that some individuals make more risky choices than others.¹ Besides providing interesting theoretical insights, risk attitudes also have clear implications for choices in daily life; hence understanding decision making under risk is of central importance for individuals, businesses and policy makers. However, it seems nontrivial to clearly measure risk attitudes of individuals in an experimental laboratory environment, which makes it difficult to use experimental findings for informing individuals, institutions and managers and raises the question of sources determining risk attitudes.

In contrast to economists' intuition, a large number of studies document individual-level inconsistencies in experimentally measured risk attitudes (e.g. Isaac and James, 2000; Berg et al., 2005; Hey et al., 2009; Dave et al., 2010): Measures obtained from different methods used to infer risk attitudes provide conflicting results and can even differ within one method over time (Harrison et al., 2005). However, the drivers of these instabilities or inconsistencies just as the general determinants of risk attitudes are often unclear.

Starting from these observations, we link theory-motivated risk aversion measures, demographics (age and gender) and personality traits, the physiological state of individuals and a stressful trade-off decision when presented with a dilemma. We use elicitation methods by Holt and Laury (HL, 2002,

¹The term *risk aversion* was originally coined with an expected utility (EUT) paradigm in mind, where the curvature of the utility function can be understood as a measure of risk aversion. We will keep our main lines of argument in this EUT world, although more advanced theories exist that are usually descriptively better in explaining observed decisions, such as prospect theory (PT) or rank-dependent utility theory (RDU; see Wakker, 2010, for a detailed discussion of more advanced theories). Under these theories, the understanding of risk attitudes can be more complicated (potentially *richer*) than under EUT; these theories often need richer data to be analysed. Furthermore, large parts of the literature looking at numerous aspects of risk attitudes in experiments, are still based on an EUT intuition. We follow this literature and address the connection of results with more sophisticated theories only if our data allows us to and keep these details in footnotes for interested readers.

2005) and Andreoni and Harbaugh (AH, 2009) to gather information about individual risk attitudes. Personality traits are elicited using a questionnaire. In the dilemma situation participants have to decide to save one of two swimmers from drowning after watching a video describing this situation.

To get physiological information of our experimental participants, throughout the experiment we monitor the electrocardiogram (ECG) during the decision making process. We focus on the heart rate variability (HRV) as a physiological measure, which has been linked to the processing of information in the brain (Critchley et al., 2003); using HRV is an interesting research frontier when trying to understand economic decision making as it reflects an individual's sympatho-vagal balance during the decision making process. In the economic literature HRV has been used to study decision making in the context of gambling (Meyer et al., 2000; Wulfert et al., 2005), on perceptions of unfair pay (Falk et al., 2011), on stress when being made accountable for decisions (Brandts and Garofalo, 2011) and has been connected to time preferences (Daly et al., 2009). Dulleck et al. (2011b) provide general guidelines on linking economic experiments and HRV data. Using the physiological data we aim to add to the understanding of factors underlying risk attitudes observable in individual choices, complementing studies using neuroimaging (e.g. Hsu et al., 2005; Huettel et al., 2006; Kuhnen and Knutson, 2005; Platt and Huettel, 2008; Polezzi et al., 2010; Preuschoff et al., 2008), genetic information (e.g. Carpenter et al., 2011; Dreber et al., 2011; Zhong et al., 2009) or studies on animal behavior (e.g. McCoy and Platt, 2005).

We find that the two elicitation methods provide with differing results, which is partly due to the different gender effect between the methods, while personality traits explain only relatively little of risk attitudes and of the difference between methods. We also find that risk taking and the physiological state are related at least for one of the methods, indicating that more stressed individuals are more risk averse in the experiment. Finally, we find evidence that personality traits have an influence on whether individuals made a decision in the dilemma situation but there was no connection to risk attitudes, and also the physiological state did not serve as an indicator for the ability to make a decision in the dilemma.

2 Background and Hypotheses

The use of most elicitation methods to measure risk attitudes of individuals builds on the idea that these are stable individual-specific characteristics. But what are determinants of risk attitudes and can they explain differences in the results of different risk elicitation methods? For example, gender and age effects, which have been found to vary with risk attitudes, might be more or less pronounced between methods.² Furthermore, different methods could reflect risk attitudes of *risk domains* (for example, one method might elicit primarily financial risk taking, another method risk taking in a health and safety context). Thinking of domain-specific risk taking is common in psychological research (Weber et al., 2002), while economists usually have the notion of a more general (underlying) risk attitude, which is nevertheless related to domain-specific risk taking (see Dohmen et al., 2011). Personality traits could have a varying influence on risk attitudes in different domains (Soane and Chmiel, 2005) and if different elicitation methods give more weight to measuring certain domains, personality traits could explain differences between elicitation methods.

We therefore link our two laboratory-based risk elicitation methods and personality traits, which we measure based on the so-called *Big Five* personality classification system (Goldberg, 1981)³. Based on results by Nicholson et al. (2005), who study the connection between personality traits and domain-specific and general risk attitudes, we expect that experimentally elicited risk taking will be positively related to extraversion and openness and negatively related to neuroticism, agreeableness and conscientiousness. Furthermore, we expect the results from our two risk elicitation methods to be different, but correlated (based on Dulleck et al., 2011a). We hypothesize that gender and personality traits are one source for explaining differences between the two methods.

Throughout the experiment we measure the physiological state of participants, reflected in their HRV (please see section below for more detail).

²See, for example Hartog et al. (2002) who connect risk attitudes with individual demographics; they find that gender and age are related to risk attitudes. Similar results are also included in Halek and Eisenhauer (2001). The experimental economic literature also suggests that, females display more risk aversion, although this results is not always significant (see Eckel and Grossman, 2008, for an overview). Another example is included in Harrison and Rutström (2008).

³Also see John et al. (2008) for developments in research using the *Big Five*.

We do not hypothesize that these measures are related to decisions in a way that they are able to explain behavior; rather, they are correlates reflecting mental states. Using *reverse inference*, we interpret the fact that decisions and changes in the physiological state occur at the same time such that they are causally related (for the potentially causal link between HRV and mental states see below).⁴ Using this approach, we analyze in how far risk taking as well as the ability to decide in the dilemma are connected to the physiological state of individuals. We conjecture that greater risk taking is related to higher excitement, or stress. However, if individuals are able to make excitement-optimal risk choices, a weak relationship between the riskiness of a choice and HRV measures is also reasonable. In this case we might, however, still observe differences across individuals in risk taking indicating if generally more or less excited individuals take higher risks.

Our hypothesis with respect to timely decision-making in the dilemma is that it depends on personality traits as well as on risk attitudes as both are potentially connected to how hesitant individuals are in their decision making. We expect more risk averse individuals to be more hesitant in their decision making, more extrovert individuals to make a decision and more conscientious and neurotic individuals to hesitate. We further expect that physiologically more excited individuals, once controlling for personality traits are more likely to make the decision of saving one of the drowning swimmers, as it helps them to overcome the tendency to hesitate.

3 Heart rate variability measurement

We use information on heart activity of participants to understand their physiological state during the decision making process. Our measurement devices, portable ECG recorders (AR12) with 3 electrodes attached to a participant's chest, collect data on the temporal succession of heart beats. From the recorded ECG we calculate the heart rate variability for a given period. HRV as a physiological indicator is mainly used in medical research (Camm et al., 1996) as a link to psychological, emotional and mental states.

Interpretations of HRV measures mainly rest on the understanding that the autonomous nervous system (ANS) is influenced by the sympathetic and parasympathetic systems and that the influence of the two systems

⁴Using reverse inference in neuroeconomic research is common, but not unproblematic (see e.g. Phelps, 2009, for a discussion).

is reflected in the heart rate.⁵ The sympathetic system is responsible for fight-or-flight responses, using sympathetic nerves and hormones (particularly adrenaline). The parasympathetic system controls rest and relaxation through specific pacemaker cells. Both systems are constantly active parallel to each other, but the degree to which one of the systems controls the heart rate in a given period varies. The two systems operate at different speeds. Changes in the heart rate due to increased sympathetic activity have a longer time horizon compared to parasympathetic activity.⁶ This allows for a decomposition of the heart rate into different frequencies, with varying importance of sympathetic and parasympathetic activity.

Practically, this is done in estimation procedures using waves of different lengths (or frequencies). Using decompositions into frequencies and studying their relative influence (power) at a given time allows to identify the effect of the sympathetic and the parasympathetic system and mediates some of the individual heterogeneity in heart rate data.⁷ The ratio of the low frequency (LF, .033-.15 Hz) to the high frequency (HF, .15-.4 Hz) mirrors the activity of sympathetic to parasympathetic activity (see Malik, 2007) and the (HRV) ratio $\frac{LF}{HF}$ serves as an indicator of psychologically induced physiological stress (see Appelhans and Luecken, 2006, who also include more detail on how HRV is measured). In the absence of major physical activity (such as walking, running, eating etc.) as in a laboratory environment this indicator conveys information about psychological states (Berntson and Cacioppo, 2008); for example, a higher ratio of sympathetic to parasympathetic activity has been connected to increased mental stress (Berntson et al., 1994).

We use heart rate measurements of our participants over the course of the experiment to determine their HRV, giving us a succession of 5 second intervals, which we averaged over the decision time we investigated for our analysis (the time between entering and leaving a decision screen). Due to unreadable measurements and instances in which participants made decisions in less than 5 seconds, data can be missing for some choices.

⁵Other systems are active alongside, regulating e.g. respiration, body temperature and blood pressure; the influence of these other systems is eliminated in our HRV data .

⁶Increases in sympathetic activity have their strongest effect after more, increases in parasympathetic activity after less than 5 seconds.

⁷More information on the estimation procedures is available upon request.

4 Experimental procedures

We ran our experiment in a computer lab over several sessions on two days with a total of 75 participants. We recruited participants from an online pool of about 2000 students using ORSEE (Greiner, 2004). Participants were on average 21.8 (*s.d.* .5) years old, in about equal shares of gender (51% were male) and were mostly enrolled in various business degrees. Our invitation included information about the length of the experiment and information that the heart rate of participants would be measured during the experiment. Upon arrival at the lab, participants were welcomed and asked to put on the heart rate monitor, led to a computer and asked to go through the experiment at their own pace; most participants needed about 30 minutes to do so. When participants had finished the experiment, they were given their payment and returned the heart rate monitor. Participants were paid a show-up fee of five Australian dollars for participating in the experiment plus a second amount according to their decisions in the risk elicitation task (on average, about 30 Australian dollars).

Our computer-based experiment, which used a custom-made java-based software, continued through five major stages. In the first stage participants were asked personality-related questions of the Big Five Inventory (BFI, John et al., 1991) and some other personality-related questions. The second stage of the experiment consisted of a relaxation phase during which participants were shown a picture of the ocean and heard background sound of the sea rushing on headphones. Participants were asked to close their eyes, take a sea shell from the table into one of their hands,⁸ to listen and relax. The relaxation phase lasted for five minutes and aimed to get participants down to an undisturbed baseline heart rate.

4.1 Risk elicitation methods

The experiment continued with the two risk elicitation methods. For both methods, participants were first presented with instructions and had to answer two test questions before advancing to the first round of decisions. Participants played both elicitation methods over two rounds, whereas the method by HL was played first in each round and the method by AH second.⁹

⁸The Purpose of the sea shell was to prevent participants from crossing their arms and distorting the heart rate measurement by interfering with the electrodes on their chest.

⁹There should be no order effect between the methods, see Dulleck et al. (2011a).

For final payments one of the two rounds was randomly selected and from this round one randomly selected choice of each method was determined for final payments to avoid wealth and portfolio-building effects.

In the risk elicitation method by HL, individuals choose between pairs of lotteries. Each pair consists of two lotteries between two options, with a higher and a lower payoff, whereas both lotteries have the same probabilities for the low and high option, but differing dispersion between the outcomes. Participants were presented with a table of 9 pairs of lotteries and had to decide for each of these pairs if they prefer the option with more or the one with less dispersion. Going down the table of these 9 lottery pairs, the risk premium of choosing the safer lottery (the one with smaller dispersion) increases with every row further down (see HL for further insights on the design of this method and appendix B2 for an illustration).

The method by AH elicits risk attitudes by letting participants allocate a (convex risk) budget (CRB) between their probability of winning (*prob*) and the amount ω received in case of winning. Each extra percentage point of winning costs the decision maker a certain price (*price*); hence, participants chose their preferred $prob^*$ such that their winning amount will be $\omega^* = \mu - prob^* \cdot price$ with μ being the maximum gain, or his budget, that can be won with corresponding $prob_\mu = 0$. As in this method participants face a direct trade-off between allocating their budget μ to either the probability of winning or the winning amount, given a simple CRRA utility function, a risk aversion parameter can be inferred for each of the 18 decisions taken in this method. In our experiment, participants were informed about the *price* on the top of the computer screen and were able to choose $prob^*$ by moving a slider. At the same time they were provided in writing with the corresponding pair of the gain ω^k in case of winning and the selected $prob^k$. They were also shown a picture of the winning probability represented in a pie chart and a bar chart that illustrated the gain when winning. We again refer to the original description of the method in AH and appendix B3 for instructions, more illustration and an example of this method.

4.2 Dilemma decision

After having finished the risk elicitation tasks, participants advanced to the fourth stage that included a short video of about one minute length. The video showed a life saver walking to the beach and then two people drowning in the water which was supplemented by a voice asking participants to

imagine being in the role of the life saver and having to make a decision of saving one of the two drowning swimmers. Furthermore, information was included saying that only one of the two could be saved (“you will only be able to save one of them”). At the end of the video, participants automatically advanced to a decision screen that asked them to save either the person on the left or on the right from the video they had just seen. Snapshots of the video showing a hand coming out of the water were included with the choice options. Furthermore, a button for “more information” was included; clicking on this option led to a screen describing more hypothetical options to contemplate about required time after which both swimmers would have drowned. An option to see even more information (which said that there was no more information) and the option to return to the decision screen were also included.¹⁰

Participants were given 20 seconds after entering the decision screen to make a choice and save one of the two swimmers. However, participants were not informed about this time limit and didn’t see any clock ticking down. The reason for this was that we wanted to identify those individuals who were able to understand the urgency of the situation and make a decision. If they succeeded in this, they were shown a short video in which the swimmer they had chosen to save was rescued. If they did not make a decision and exceeded the time limit, a time-out screen appeared informing them that they had failed to make a decision. Finally, participants advanced to a short demographic questionnaire that included information about gender, age, student status and some health related measures (to detect potential problems that could distort heart rate measures), marking the end of the experiment.

5 Experimental results

5.1 Analysis separated by methods

We used two methods for the elicitation of risk attitudes which can be induced from the results of both methods. We estimated individual-specific risk aversion coefficients r_i assuming $U_i(x) = x^{1-r_i}$ in an expected-utility

¹⁰This screen only served the purpose of using up participant’s time. Many participants clicked one or even both “more information” buttons, and some of these still managed to save one of the two swimmers.

(EUT) framework for each method.¹¹ For AH it is even possible to determine a coefficient of risk aversion for every choice made (r_{it}). This allows us to get an idea about the distribution of individual risk attitudes for both methods and make some general comparisons between them. Figures 1 (a) and (b), separated by gender, illustrate the estimated values for those participants with $s.d.(r_{it}) \leq 3$ for AH and participants with less than 4 switching points in HL.¹²

As can be seen in these overviews, there seem to be differences between the distributions of individual estimates by gender, as the distribution for females is flatter than for males. Women seem to be more risk loving than men in the AH method, but more risk averse in the HL method, the second of which is in line with previous findings. The estimated individual values for the methods, r_i^{AH} and r_i^{HL} , are significantly correlated at the levels of .53 for males ($p=.002$; Spearman's $\rho=.40$, $p=.025$), .41 for females ($p=.027$; $\rho=.50$, $p=.005$), and .42 for both males and females ($p=.001$; $\rho=.38$, $p=.002$).

In order to investigate a relationship between gender and age, and risk attitudes, we included these in our method-specific estimation procedure.¹³ As we also conjectured that we would see a relationship between risk attitudes and some of the personality traits and HRV measurements. In both methods we tested for potential relationships using maximum likelihood estimations.¹⁴ Table 1 reports the results of this procedure.

The results from the estimation support the first impression that the role of gender is different between the two methods: There is no apparent relationship between gender and risk-taking in AH and a significant negative relationship in HL. Similarly, there is no age effect in the AH method and a (statistically and economically) small effect in the HL method. Adding

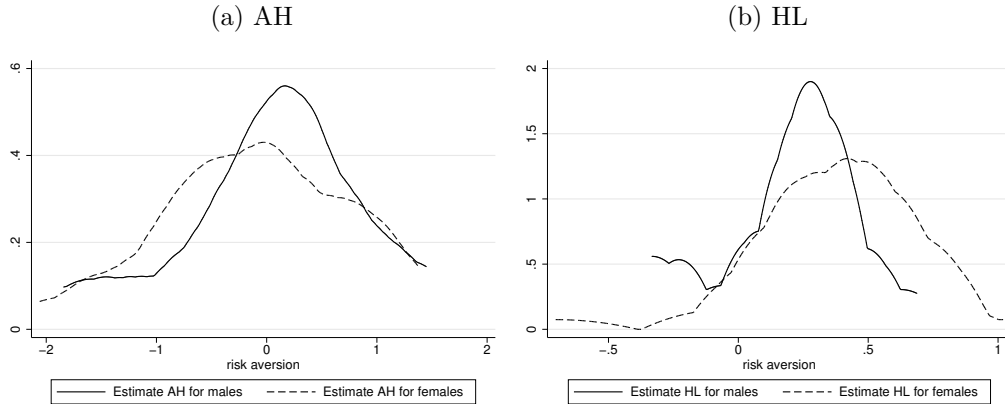
¹¹We also extended our analysis beyond EUT assuming a probability weighting function $w_i(p) = \frac{p^{\gamma_i}}{(p^{\gamma_i} + (1-p)^{\gamma_i})^{-\gamma_i}}$. We estimated an $\bar{r}_i=.04$ ($s.d. =.34$) and a $\bar{\gamma}_i=1.16$ ($s.d. =.14$) using HL. Hence, there is some evidence for probability weighting, however, we cannot determine a γ_i significantly different from 1 (representing no probability weighting) for most participants, probably due to our relatively small sample. See appendix A.1 for distributional overviews and more detail.

¹²In AH this leads to the exclusion of 5 individuals and in HL of 6 individuals. We use these restrictions as r_i -estimates for these individuals do not appear very meaningful in the context we are using; including these individuals does not qualitatively change the overall distribution, but makes the graphs less readable.

¹³Throughout this paper we use normalised values for variables included in our estimations.

¹⁴See Harrison and Rutström (2008) for a guideline on estimation procedures.

Figure 1: Distributions of r_i -parameters estimated using the two methods separated by gender



the personality characteristics and HRV measures does not change the significance level of any of the variables in the AH method and reports the personality characteristics as insignificant. However, there is a significant relationship between r^{AH} and the HRV ($\frac{LF}{HF}$), indicating that individuals who were physiologically less stressed during the AH task of the experiment took more risk, or vice versa, more stressed individuals displayed more risk aversion.

In the HL method, further adding information on personality traits shows that some of the personality characteristics have a significant influence on risk attitudes: There is a positive effect of extraversion and agreeableness. For extraversion, this is as expected. For agreeableness, the result is in the opposite of our expectation, which was based on previous findings in the literature. However, as the economic size of the effect is relatively small, we do not read too much into this result. Furthermore, there is no clear evidence that for the HL method HRV is significantly related to risk-taking.¹⁵

¹⁵An extension of our analysis allowing for probability weighting in HL (see Appendix A.2) shows a significant relationship between estimates of γ and the HRV and a positive relationship for r in HL. However, this result is not as easily interpretable, as r and γ are jointly needed to determine an individual's risk attitude. However, the result can be seen as indicating that the connection between HRV and risk attitudes is influenced by probability weighting whereas more stressed individuals are more likely to tend towards *inverse S shape*-type probability weighting.

Table 1: Determinants of r -estimates

	AH1	AH2	AH3	HL1	HL2	HL3
r	0.24** (0.10)	0.04 (0.55)	0.16 (0.61)	0.41*** (0.03)	0.35*** (0.11)	0.43*** (0.09)
Female		-0.10 (0.20)	0.14 (0.22)		0.16*** (0.05)	0.13** (0.06)
Age		0.01 (0.03)	0.00 (0.03)		-0.00 (0.00)	-0.01* (0.00)
Extraversion			0.00 (0.08)			-0.04* (0.03)
Agreeableness			-0.02 (0.12)			-0.04* (0.03)
Conscientiousness			-0.06 (0.10)			-0.01 (0.03)
Neuroticism			-0.08 (0.13)			-0.01 (0.02)
Openness			-0.14 (0.12)			-0.02 (0.03)
HRV ($\frac{LF}{HF}$)			0.23* (0.13)			0.02 (0.05)
N	1188	1188	1044	1152	1152	1026

The table illustrates the influence of potential determinants for each elicitation method of AH and HL. *** indicates significance at the 1% level, ** 5% significance and * 10 % significance. Standard errors (in brackets) are clustered by individuals. The availability of HRV data has reduced the sample between estimations (due to missing or unreadable data). The HRV measure for equation AH₃ represents the average HRV during the AH stage and for equation HL₆ the average HRV during the HL stage.

While this physiological measure of the HRV is insignificant for the HL method, the relationship is significant for the AH method (generally both have the same direction).¹⁶ This difference could be due to the fact that the level of risk taking in HL is relatively stable between the choices, while the risk taken between AH choices can vary noticeably: In HL for a slightly risk averse individual the first and last 3 rows of the choice list might be straightforward, while only the pivotal ones are critical in a physiologically relevant way. For AH in each period a full range of risky and riskless options can be chosen

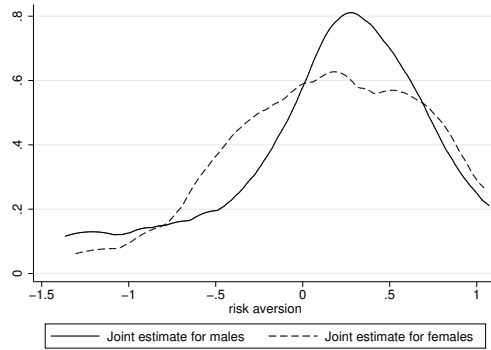
¹⁶The sign of this relationship was visible throughout basically all alternative specifications we looked at.

and most individuals make both risk-seeking and risk-averse choices during the course of this method. Hence, individuals vary more in their level of risk-taking and deviations from optimal stress-risk points can be detected in the data.¹⁷ Another possible explanation is that the two methods measure different types of risk taking which could also be reflected in the difference of their estimated values and their connection to demographics and personality traits, and one is simply more strongly related to the physiological state of the decision maker than the other.

5.2 Analysis with both methods with jointly estimated values for r

As the methods by HL and AH were designed with a utility function of $U_i(x) = x^{1-r_i}$ in mind r_i can be estimated with data from both methods in a joint procedure. Figure 2 illustrates the distribution of our r_i estimates using a joint procedure and as before separated by gender.¹⁸ As was visible before, estimates for women were more dispersed, but women are neither more or less risk loving than men from results of the joint procedure.

Figure 2: Distribution of estimated individual risk attitudes (r_i) jointly estimated:



Assuming this joint structure, we investigated whether any variables had a significant influence on the jointly estimated risk attitude. Table 2 illustrates

¹⁷Indeed, there is some evidence that in the AH method in periods where individuals have a lower $\frac{LF}{HF}$ they take more risky choices. However, this effect is not significant.

¹⁸We excluded the same individuals for the joint estimation as described on the method-specific procedures.

different specifications. Rather surprisingly, we find no variable which has a significant impact on r . While this could indicate that these variables simply have no significant connection to the risk attitudes, another reason could be that the two methods are measuring (slightly) different things, and the joint estimation washes out some of the effects visible in Table 1. We therefore allow for this possibility that the two methods measure different r -values in the next section.

Table 2: Determinants of the joint estimation assuming no structural difference between the methods

	JOI ₁₁	JOI ₁₂	JOI ₁₃	JOI ₁₄	JOI ₁₅
r	0.28*** (0.06)	0.00 (0.40)	0.14 (0.33)	0.27*** (0.08)	0.14 (0.31)
Female		0.00 (0.14)	0.15 (0.14)		0.14 (0.14)
Age		0.01 (0.02)	0.00 (0.01)		0.00 (0.02)
Extraversion			-0.04 (0.06)	-0.05 (0.06)	
Agreeableness			-0.02 (0.08)	-0.05 (0.07)	
Conscientiousness			-0.05 (0.07)	-0.06 (0.08)	
Neuroticism			-0.02 (0.06)	-0.02 (0.06)	
Openness			-0.07 (0.08)	-0.06 (0.08)	
HRV ($\frac{LF}{HF}$)			0.15 (0.09)	0.12 (0.10)	0.15 (0.10)
N	2160	2160	1944	1944	2016

*** indicates significance at the 1% level, ** 5% significance and * 10 % significance. Standard errors (in brackets) are clustered by individuals. The availability of HRV data has reduced the sample between estimations (due to missing or unreadable data).

5.3 Drivers of potential differences between HL and AH measures

As prior analysis indicated that the two methods do not provide with the same estimate for r_i , we investigated differences between the two methods and potential determinants of such differences. We did so assuming $U(x) = x^{1-r+\Delta HL}$ with ΔHL representing the difference between the methods (AH was used as the baseline and ΔHL hence reflects the additional effect of HL). We estimated individual-specific estimates of r_i as well as a uniform distribution of r for everyone, the first of which enables us to better identify potential individual-fixed effects that might drive individual risk attitudes. Sources of differences, as reflected in ΔHL are only related to general, non-individual-specific effects. The results from our estimations are included in Table 3 which shows that the judgment on the significance of differences between the methods is dependent on whether an individual-specific r_i or uniform r is assumed: Once we move away from assuming individual-specific risk attitudes and simply searching for general determinants of risk attitudes, we cannot find a difference between the methods and there are no clear factors that clearly drive towards differences (only extraversion seems to play a weakly significant role in having a higher risk attitude in HL compared to AH).

The picture is different when we take into account individual-specific risk attitudes. There is a general difference between the methods observable, with more risk aversion observable in the AH method. This difference becomes insignificant when controlling for gender and age of the participants (the effect is marginally significant when only gender is included). Similarly, including information about personality traits further decreases the significance of the variables, and none of the personality traits seem to have a significant impact on the difference. However, there is a statistically significant relationship of the difference between the two methods and the HRV measure under the assumption of individual-specific r_i -estimates.¹⁹ This means that individuals who were more stressed during the risk tasks displayed higher risk taking in the HL method than in the AH method.

¹⁹This difference is driven by the higher HRV during the HL task, as further regressions indicated that used the HRV during HL instead of the HRV during the full period of both AH and HL.

Table 3: Determinants of the joint estimation

	JOI ₁	JOI ₂	JOI ₃	JOI ₄	JOI ₅	JOI ₆
r	-0.89*** (0.33)	-0.86** (0.34)	-0.98*** (0.34)	0.28*** (0.04)	0.28*** (0.05)	0.29*** (0.05)
Individual effects	Yes	Yes	Yes	No	No	No
ΔHL	0.15** (0.07)	-0.84 (0.52)	-0.56 (0.59)	0.02 (0.07)	0.35 (0.39)	0.13 (0.27)
Female		-0.01 (0.15)	0.11 (0.17)		-0.17 (0.11)	-0.16 (0.13)
Age		0.05** (0.02)	0.03 (0.03)		-0.01 (0.02)	0.00 (0.01)
Extraversion			0.15* (0.09)			0.12* (0.06)
Agreeableness			0.02 (0.10)			0.05 (0.07)
Conscientiousness			-0.05 (0.07)			0.03 (0.06)
Neuroticism			0.09 (0.10)			0.05 (0.08)
Openness			-0.08 (0.09)			0.01 (0.06)
HRV ($\frac{LF}{HF}$)			0.18* (0.10)			-0.07 (0.07)
$\delta \frac{LF}{HF}$			-0.04 (0.08)			-0.05 (0.07)
N	2052	2052	1872	2052	2052	1944

The table shows the results of our ML estimation for determinants of risk attitudes, assuming individual-specific attitudes in JOI₁₋₃ and assuming uniform attitudes in JOI₄₋₆. *** indicates significance at the 1% level, ** 5% significance and * 10 % significance. Standard errors are in brackets. Including demographic, personality trait and physiological variables in JOI₄₋₆ to explain r did not lead to new insights about these variables, but makes the table less readable. For regressions JOI₃ and JOI₆ 4 participants older then 30 had to be excluded for the estimation model to converge. Leaving out the (insignificant) age variable and including these 4 participants provides the same qualitative results. The variable $\delta \frac{LF}{HF}$ measures $\frac{LF}{HF}(AH) - \frac{LF}{HF}(HL)$.

5.4 Determinants making a timely decision

We used the life saving dilemma to investigate in how far gender, age, risk attitudes, personality traits and physiological states during the decision pro-

cess were related to the ability of individuals to save a swimmer. Table 4 shows the results of probit regressions of making a decision to save one of the swimmers (or exceeding the time limit otherwise).

Table 4: Probit regressions of decision to save swimmer

	SLS ₂	SLS ₃	SLS ₄	SLS ₅
Female	-0.05 (0.30)	-0.15 (0.38)	0.23 (0.36)	0.13 (0.44)
Age	-0.00 (0.03)	0.01 (0.03)	0.00 (0.03)	0.01 (0.04)
$r_i(\text{JOI}_{11})$		0.18 (0.29)	0.16 (0.27)	0.10 (0.33)
Extraversion		-0.28 (0.19)		-0.61*** (0.24)
Agreeableness		-0.21 (0.21)		0.13 (0.26)
Conscientiousness		-0.34* (0.19)		-0.51** (0.24)
Neuroticism		-0.38* (0.22)		-0.49** (0.24)
Openness		0.04 (0.20)		0.25 (0.25)
HRV ($\frac{LF}{HF}$)			0.00 (0.18)	0.06 (0.19)
constant	-0.27 (0.59)	-0.70 (0.77)	-0.64 (0.65)	-0.90 (0.84)
N	71	61	59	56

The table shows the results of probit regressions on whether a participant made a decision to save a swimmer or not. *** indicates significance at the 1% level, ** 5% significance and * 10 % significance.

Gender and age had no significant effect on the ability to make a decision and a similar conclusion is true for risk attitudes, at least when using the joint estimate of an individual's risk attitude r_i . This is somewhat surprising, as we conjectured a more risk averse decision maker to be more hesitant as well which does not seem to be the case. Some of the personality traits did have an influence on the decision to save one of the swimmers although their sign is not always as expected. However, it seems that individuals with moderate

personality traits are more likely to make a decision. Finally, there was no clear relationship between the physiological activity of the 20 seconds during which the decision had to be made and the ability to make a decision. This is surprising as it indicates that more excitement is not related to the ability to make this tough decision in time.

6 Conclusion

In this paper, our main aim was to understand in how far risk attitudes, measured using two different elicitation methods were related to demographics and personality traits. In order to get a better picture about the decision making process, we also wanted to investigate, in how far these were connected to the physiological state at the time choices were made and the ability to make a decision in a dilemma in the context of a laboratory experiment. In the analysis of our data we find that the results from the two risk elicitation methods are correlated, but do not provide with the same results: Correlations as well as ranked correlations are far from one, there also seems to be a shifter effect between the methods and in AH the distribution of risk attitudes is also wider as it is in HL. Furthermore, the distribution of risk attitudes is more dispersed for females then for males and women are significantly more risk averse in HL but not in AH. However, there is no clearly statistically significant gender effect driving the difference between the two methods when analyzing results of a joint estimation.

With respect to personality traits based on the *Big Five* there is only some weak evidence that more extraversion and agreeableness are related to more risk seeking in HL, while there does not seem to be a strong effect in AH. Furthermore, there is no clear indication that personality traits drive the difference between the results. This could also be interpreted such that domain-specific risk taking, which prior literature showed to vary with personality traits, does not seem to be a major determinant of differences between the two methods.

Apart from searching for sources of the differences between the elicitation methods, a main aim was to investigate in how far risk attitudes and physiological states were connected. For this, we used HRV data as an indicator for mental stress during the time of the decision making. We tested whether such a relationship exists by including HRV in our estimation of the risk attitude. We find that the HRV and risk taking are related in a

way that individuals who are less stressed take higher risks in at least one of the methods. This could mean that risk taking is something not just *ad hoc* exciting but more basic and that less stressed individuals are less averse towards making more risky decisions reflecting their general attitude towards risk at the time of the decision making rather than their immediate reaction to the risk task at hand. This effect was significant for AH, but not for HL, although the direction of the effect is the same.²⁰ Hence, the HRV might represent more the general physiological state during the experiment, which influences which decisions are made, rather than the momentary excitement of the decision.

Finally, we linked risk attitudes, demographics, personality traits and physiological states to the ability to make a timely decision in a dilemma. We find that, except for some of the personality traits (extraversion, conscientiousness and neuroticism) these were not significant predictors of making the decision to save one of the swimmers. Hence personality traits can explain the ability to decide while risk attitudes do not extend to this context and the physiological state did not promote or inhibit timely decisions.

We conclude with the finding that less stressed individuals in the experiment were also less risk averse while the ability to make a tough decision is not necessarily linked to the physiological state at the time of the decision, but rather personality-based. Both findings are interesting for their implications in real life. For example in companies in which financial risk decisions are taken by individuals: If more stressed individuals are more risk averse, this could guide who should be asked to make risky decisions although further research might be needed as our study cannot answer if deviations in experimental risk attitudes between different days are reflected in different physiological states of a specific decision maker or if our results mainly reflect differences between individuals. Either result could have central implications, for example when managing personnel in companies and selecting certain individuals for specific positions, or for creating (more or less stressful) work environments.

With respect to the decision in the dilemma our results indicate that when having to make a tough decision it is more the underlying personality that leads to the ability to decide, while the stressfulness of this situation

²⁰Potentially the difference is influenced through the different role probability weighting plays in the two methods, as allowing for probability weighting in HL showed a significant effect suggesting that more stressed individuals might display more *inverse S-shaped* probability weighting in HL.

has a minor impact. This could be an interesting consideration, for example when we are choosing individuals for jobs where decisions under time pressure have to be made. As such, our results can, despite their explorative nature, be interesting for individual and institutional decision makers for whom understanding decision making processes is a major factor for personal and organizational success.

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A Extensions beyond EUT

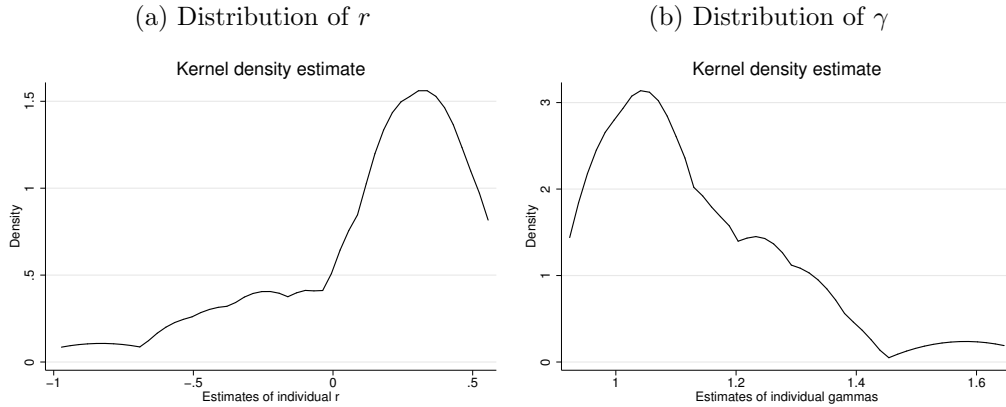
A.1 Individual estimates

During our estimation procedure we also considered implied results beyond an EUT framework, and the concept of probability weighting. We did so assuming a utility function of $U_i(x, p) = w_i(p) \cdot v_i(x)$ where $w_i(p)$ represents a probability weighting function, assigning objective probabilities a subjective individual weight, and $v_i(x)$ the utility (valuation) from receiving outcomes. We assumed functional forms of $w_i(p) = \frac{p^{\gamma_i}}{(p^{\gamma_i} + (1-p)^{\gamma_i})^{-\gamma_i}}$ and $v_i(x) = x^{1-r_i}$.

Figures 3 (a) and (b) illustrate these distributions of our estimates for the HL method.²¹ For this overview and in the following analysis we have restricted our sample to 45 individuals that had a single switching point

²¹Unfortunately, for the AH method no reasonable estimates of γ_i and r_i can be found, as the set of possible choices in each decision is too large a participant chooses one - optimal - out of a range of more than 30 choice options that all have a unique probability and outcome attached to them. From decisions in the HL method, however, values for r_i and γ_i can be estimated although with the size of our sample on each individual we cannot derive individual estimates that are significantly different from $r_i = 0$ and $\gamma_i = 1$.

Figure 3: Distributions of r_i - and γ_i -parameters estimated using HL



(SSP) in both periods of HL to make the graphs readable and to ensure convergence of our maximum likelihood models.

A.2 Potential determinants of r and γ

We also investigated in how far demographics, personality traits and physiological states were related to r and γ . Table 5 shows the results from our main specifications. The additional result emerging from this analysis is observable for the coefficient on the HRV measure as there is no clearly significant effect of any of the other variables. HRV is potentially positively related to utility curvature, which would be contrary to the result found for AH and the tendency in HL assuming EUT. However, there is a negative relationship between HRV and probability weighting indicating that more stressed individuals are more likely to display *inverse S shape*-type probability weighting. Taken these two effects together, this could indicate that the relationship observable before in the EUT-based analysis could be driven by probability weighting which we were unable to estimate in AH, but which might nevertheless play a significant role.

Table 5: Determinants of r and γ

	REDU1	REDU2	REDU3	REDU4
r	0.27*** (0.06)	0.31*** (0.07)	0.29*** (0.02)	0.35*** (0.08)
Age	0.00 (0.00)	-0.00 (0.00)		-0.00 (0.00)
Female	0.05 (0.04)	0.02 (0.05)		-0.02 (0.05)
Extraversion		-0.06 (0.05)		-0.07** (0.03)
Agreeableness		-0.02 (0.03)		-0.02 (0.03)
Conscientiousness		0.02 (0.04)		0.01 (0.03)
Neuroticism		-0.00 (0.02)		-0.01 (0.01)
Openness		0.01 (0.02)		0.01 (0.02)
HRV ($\frac{LF}{HF}$)			-0.04 (0.03)	-0.06* (0.03)
γ	1.06 (0.03)	0.94 (0.11)	1.05 (0.03)	1.04 (0.13)
Age	-0.00 (0.00)	0.01 (0.01)		0.01 (0.01)
Female	-0.02 (0.03)	-0.10 (0.16)		-0.28** (0.13)
Extraversion		-0.07 (0.18)		-0.10 (0.08)
Agreeableness		0.06 (0.06)		0.05 (0.05)
Conscientiousness		0.04 (0.14)		-0.01 (0.04)
Neuroticism		-0.03 (0.06)		-0.02 (0.03)
Openness		-0.04 (0.04)		0.00 (0.04)
HRV ($\frac{LF}{HF}$)			-0.11*** (0.02)	-0.18*** (0.06)
N	810	774	756	720

*** indicates significance at the 1% level, ** 5% significance and * 10 % significance. Standard errors (in brackets) are clustered by individuals. The availability of HRV data has reduced the sample between estimations (due to missing or unreadable data). The sample is limited to individuals with single switching points.

B Instructions and details on the risk elicitation methods

B.1 Introduction

The following part, or game, of this session is an economic experiment. This means that the amount of your final payment will depend on the decisions you take in the following stages. I.e., your decisions taken on the next screens, together with the random outcome of an external probability distribution, will directly translate into how much you will be paid at the end of the experiment. Please follow the instructions carefully, and please raise your hand if you have a question: an experiment administrator will come to you. During the experiment, any talking or other communication between participants is forbidden.

You will make decisions during this experiment by responding to questions displayed on the computer screen in front of you. After you have completed your responses for the decisions on each screen, please press the Continue button at the bottom of the screen to proceed to the next screen. Your decisions in this experiment are anonymous, and you are identified solely by your participant number. The payment you will receive at the end of the experiment will be kept confidential from all other participants.

This experimental game will be continued over two rounds. You will receive instructions for each step of the experimental game on your screen. At the conclusion of the experiment, the computer will randomly select one decision from Type One and one decision from Type Two to be played to determine the amount that you will be paid. This means that you (or the administrator) do not know which decision will be selected. Therefore, it would be reasonable to treat each decision as if it were the decision that will be selected for determining your final payoff.

B.2 HL instructions

B.2.1 HL example instructions

Please make sure to read all instructions very carefully. This is an instruction screen. You do not have to make any decisions on this screen. On the NEXT screen you will have to make nine decisions between two lotteries. For each of the nine decisions you MUST select either option A or option B. Each lottery

is characterised by the probability of receiving one of two payoffs. Below is an EXAMPLE of only two of the nine decisions that you will be required to make

Option A 1				Option B 1			
p	X_A	$1-p$	Y_A	p	X_B	$1-p$	Y_B
0.3	3	0.7	1	0.5	5	0.5	0

In decision 1 you have to choose between lottery A1 and lottery B1. In lottery A1 you either receive \$1 with probability 0.3 and \$3 with probability 0.7. In Lottery B1 you get \$0 with probability 0.5 and \$5 with probability 0.5.

Remember, at the end of the experiment one decision will be selected at random. This decision will then be played out and will then contribute to your final payment. Because the decision that is played is selected randomly you do not know which decision will be selected and hence it would be reasonable to answer all decisions as if they were the decision that determined your final payment. When you select an option, an X will indicate your choice. You can revise your choice as many times as you like. After you have made all nine choices, click the Continue button to move to the next screen.

B.2.2 HL choice list

Table 6 shows the choice list table presented to experimental subjects.

Table 6: Multiple price list design as in HL

Option A				Option B			
p	X_A	$1-p$	Y_A	p	X_B	$1-p$	Y_B
0.1	8	0.9	6.4	0.1	15.4	0.9	0.4
0.2	8	0.8	6.4	0.2	15.4	0.8	0.4
0.3	8	0.7	6.4	0.3	15.4	0.7	0.4
0.4	8	0.6	6.4	0.4	15.4	0.6	0.4
0.5	8	0.5	6.4	0.5	15.4	0.5	0.4
0.6	8	0.4	6.4	0.6	15.4	0.4	0.4
0.7	8	0.3	6.4	0.7	15.4	0.3	0.4
0.8	8	0.2	6.4	0.8	15.4	0.2	0.4
0.9	8	0.1	6.4	0.9	15.4	0.1	0.4

The table represents the lottery choice for $X_A = 8$, $Y_A = 6.4$, $X_B = 15.4$ and $Y_B = .4$ used in the first round. In the second round we used lotteries with $X_A = 10$, $Y_A = 8$, $X_B = 19.25$, $Y_B = .5$.

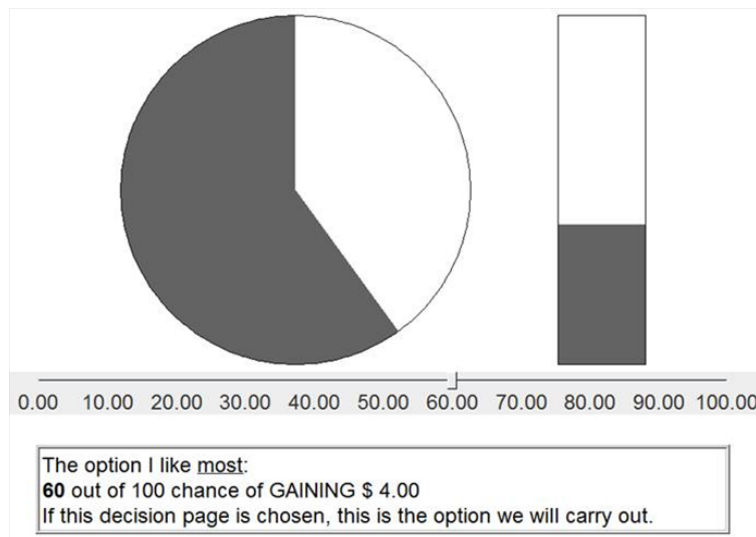
B.3 AH instructions

B.3.1 AH example instructions

In this part of the experiment you will consider many options of gambles. The gambles will differ according to the amount of money at stake and the chances of winning that money. An option of gambles might look like this. Notice, you see all available gambles in the option by moving the slider bar back and forth, GIVE IT A TRY! The pie chart represents the probability of winning while the bar chart represents the possible gain. See how there is a trade off between these two variables as you move the slider.

Maximum gain is \$10.00. Each 1 percent increase in the pie decreases possible earnings by \$0.10. Each 1 percent decrease in the pie increases possible earnings by \$0.10

Figure 4: AH picture



Notice that in this example, every time you try to increase the chance of winning by 1 percentage point, you reduce the amount you would gain by \$0.10. Likewise, each time you increase the amount you can gain by \$1, you reduce the chance of you winning it by 10 percentage points (that is 1 divided by 10). You are simply required to position the slider in the position that you like the most for each of the nine decision screens. Just as before, only one of your nine decisions will be selected at random. Because you do

not know which decision will be selected it would be reasonable to make each decision as if it were the decision that contributed to you final payment.

B.3.2 AH choice pairs

Table 7 includes the 9 pairs of budgets μ and *price* in the two rounds of our experiment.

Table 7: Pairs of maximum gain and cost of probability

<i>Round</i>	1	2	3	4	5	6	7	8	9
μ	27.3	56	172	88	49.4	39.2	54.5	207	116
<i>price</i>	0.28	1.17	10.75	2.75	0.77	0.41	0.68	8.62	2.42

The *price* reflects the cost of getting 1% extra of a winning probability, and μ the amount that can be won with a corresponding probability of zero, or the budget. To win with any positive probability, participants have to buy additional winning probability. For example, in round 1, a participant could chose to win $27.3 - 10 \cdot 0.28 = 24.5$ with a probability of 10%, $27.3 - 20 \cdot 0.28 = 21.7$ with a probability of 20%, and so on.

C Examples of experimental screens

Figure 5: Screenshot from the film



Figure 6: Pictures shown for option to save one of the two swimmers

(a) Save left swimmer

(b) Save right swimmer

