RUHR

ECONOMIC PAPERS

Ralf Bergheim
Michael W.M. Roos

Intuition and Reasoning in Choosing Ambiguous and Risky Lotteries

RUHR UNIVERSITÄT BOCHUM RUB

#440

Imprint

Ruhr Economic Papers

Published by

Ruhr-Universität Bochum (RUB), Department of Economics
Universitätsstr. 150, 44801 Bochum, Germany

Technische Universität Dortmund, Department of Economic and Social Sciences
Vogelpothsweg 87, 44227 Dortmund, Germany

Universität Duisburg-Essen, Department of Economics
Universitätsstr. 12, 45117 Essen, Germany

Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI)
Hohenzollernstr. 1-3, 45128 Essen, Germany

Editors

Editorial Office

Sabine Weiler
RWI, Phone: +49 (0) 201/81 49-213, e-mail: sabine.weiler@rwi-essen.de

Ruhr Economic Papers #440

Responsible Editor: Thomas K. Bauer

ISSN 1864-4872 (online) – ISBN 978-3-86788-497-6

Ruhr Economic Papers #440

Ralf Bergheim and Michael W.M. Roos

Intuition and Reasoning in Choosing Ambiguous and Risky Lotteries

Bibliografische Informationen der Deutschen Nationalbibliothek

Die Deutsche Bibliothek verzeichnet diese Publikation in der deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über: *http://dnb.d-nb.de* abrufbar.

http://dx.doi.org/10.4419/86788497
ISSN 1864-4872 (online)
ISBN 978-3-86788-497-6

Ralf Bergheim and Michael W.M. Roos[1]

Intuition and Reasoning in Choosing Ambiguous and Risky Lotteries

Abstract

This paper focuses on information acquisition and individual decision making in ambiguous situations and presents a novel experimental design which may help to tackle open questions from a fresh perspective. Instead of giving subjects the choice between risky and ambiguous Ellsberg urns, we let them choose between a safe option and a risky lottery, whose risk is a priori unknown to subjects. By acquiring information about the probability distribution of the lottery's payoffs, subjects can reduce or even eliminate the ambiguity and turn the decision situation into one of risk. Under the assumption that an ambiguity averse subject should reduce ambiguity within a decision process we predicted that these subjects would request more information. Moreover, we investigate whether the relation between attitudes towards risk and ambiguity is linked to intuitive and deliberate thinking. Based on a detailed analysis of subjects' information acquisition and decision processes we do not find that those subjects showing ambiguity aversion in an urn experiment based on Halevy (2007) significantly reduce the ambiguity more than others. More intuitive subjects acquire less information and are more likely to avoid the risky lottery. Intuition seems to be negatively correlated with risk aversion, but not with ambiguity aversion. Moreover, we find a positive correlation between risk and ambiguity aversion.

JEL Classification: C91, D03, D81

Keywords: Ambiguity aversion; risk aversion; uncertainty; experiment; decision making; binary system of thinking

September 2013

1 Both Ruhr University Bochum. – All correspondence to: Ralf Bergheim, Ruhr University Bochum, Institute for Macroeconomics, Institute for Accounting and Auditing, 44780 Bochum, Germany. E-Mail: ralf.bergheim@rub.de.

1. INTRODUCTION

Ambiguity as a situation of uncertainty in which no full probability distribution of possible events is known proved its relevance in the course of the global financial crisis. Although there is a considerable history of research on ambiguity there are still many open questions and the stylized facts about decision making under ambiguity are few (see Etner 2012).

One question on which there is disagreement in the literature is the prevalence of ambiguity aversion. While there is a number of studies showing that subjects are typically ambiguity averse (see Trautmann and van de Kuilen 2013 for a survey), some recent papers (Binmore et al. 2011; Stahl 2012; Charness et al. 2013) report very small fractions of ambiguity averse subjects. A possible conclusion from these studies is that the measured degree of ambiguity aversion may depend on the elicitation method.

A second open question refers to the relation between ambiguity aversion and risk aversion. Some papers report a positive correlation between subjects' aversion against risk and their ambiguity aversion (Abdellaoui et al 2011, Dimmock et al. 2012, 2013, Butler et al. forthcoming, Qui and Weitzel 2011), but others do not find a significant correlation or even a negative one (Cohen et al. 2011, Akay et al. 2012, Cubitt et al 2012, Sutter et al. 2013). Again, a possible explanation for the different findings is the way in which the attitudes towards risk and ambiguity are measured.

In this paper, we propose a new experimental design to observe subjects' behavior in situations of uncertainty which may help to tackle the open questions from a fresh perspective. The standard method to explore decision making under ambiguity is to conduct experiments with Ellsberg urns which Etner et al. (2012, p. 262) call "simple experimental choices that often consist in artificial draws from bizarre urns". Similarly, Trautmann and van de Kuilen (2013) write in the conclusion of their survey of the experimental ambiguity attitudes literature "real life is not about balls and urns, in contrast to most of the experimental ambiguity literature" (Trautmann and van de Kuilen 2013, p. 24). While Ellsberg urns are appealing because of their theoretical and practical simplicity, they are also quite abstract and distant from the choices people encounter outside the laboratory. An important shortcoming of these urns is that subjects face an exogenous and fixed ambiguity which cannot be influenced by subjects' actions. In many real-world applications, people may have a rough guess of the probability of a certain event and may be able to make this estimate more precise by acquiring information. This implies that subjects can influence the degree of ambiguity they face by their own decisions which is normally not possible in standard urn experiments. Being confronted with a binary choice between full ambiguity and risk, subjects might exhibit ambiguity-averse behavior although they are in principle willing to accept some ambiguity. The design we propose makes the degree of ambiguity endogenous and enables subjects to eliminate the ambiguity completely so that the situation is converted into a decision under risk.

Our experimental design also allows us to test the hypothesis that risk aversion and ambiguity aversion are linked by the decision mode of subjects. Butler et al. (forthcoming) argue that people who rely more on their intuition than on deliberate reasoning are better able to cope with uncertainty and hence less averse to both risk and ambiguity. Using data from both a survey and an experiment quite different from ours, Butler et al. (forthcoming) present evidence supporting their hypothesis. Exploring the relation between attitudes towards uncertainty and decision mode further is important, because the origins of non-neutral attitudes towards ambiguity are still not really understood.

The main idea of our experimental design is that subjects can choose between lotteries and a safe payoff. Each lottery has a discrete probability distribution over the 18 possible outcomes, which is initially unknown to subjects so that they start in a situation of complete ambiguity. Before deciding whether they choose the lottery or the safe option, subjects can freely acquire information about the probabilities of the different outcomes. The probabilities are aggregated over several outcomes, but can be disentangled by repeated information acquisition. Using the procedures in Holt and Laury (2002) and Halevy (2007) we elicit standard measures of risk and ambiguity attitudes. Furthermore, we determine the decision type of each subject by a self-assessment question. In a controlled setting we can hence analyze how uncertainty attitudes, decision mode, information acquisition, and lottery choice are related.

2. THEORY AND RESEARCH QUESTIONS

Although risk and ambiguity refer both to situations involving uncertainty it is important to differentiate between them. They are special cases of uncertainty and can be distinguished by the information that is available to the decision maker (see e.g. Ellsberg 1961). In situations that are called risky the decision maker knows the objective probabilities and possible outcomes of a decision problem. In contrast, ambiguous situations are characterized by less available information. In such situations probabilities are uncertain or unknown. Thus, risk can be thought of as a special case of ambiguity.

The research literature and also everyday experience suggest that most people do not like uncertainty. In the case of risk, decision makers typically prefer certain outcomes over risky ones, even if the latter have a higher expected value. This attitude towards uncertainty is called risk aversion. Similarly, many people seem to prefer less uncertainty over more uncertainty in the sense that they often choose risky lotteries instead of ambiguous ones, what is called ambiguity aversion. Risky lotteries are less uncertain than ambiguous ones, because they have fewer unknown elements. Assuming that humans have a general attitude towards uncertainty and normally prefer lower degrees of uncertainty over higher ones, it does not appear surprising that risk aversion and ambiguity aversion might be positively correlated. But then we might ask what determines the general attitude towards uncertainty.

Butler et al. (forthcoming) suggest that the predominant way of how people think, intuitively or deliberately, determines their attitude towards uncertainty in general. Thus, risk as well as ambiguity aversion would be driven by a binary system of thinking.

Research in psychology suggests that humans rely on a binary system of thinking involving an intuitive thinking mode and one mode relying on reasoning (e.g., Stanovich & West, 2000; Kahneman, 2003). The terms proposed by Stanovich and West (2000) for the two thinking modes are “System 1” and “System 2”. System 1 operates quickly and involves less effort than System 2. It is characterized by generating quick and intuitive decisions in less complex situations and operates mainly automatically. In contrast, System 2 involves much more mental effort and individuals rely on it if a situation demands more careful thinking, e.g. if a new and unfamiliar situation arises or if rather difficult computations are required.

It is evident that all people normally make use of both thinking modes, depending on the situation. While routine decisions are often based on intuitive thinking, new and demanding situations are likely to activate deliberate reasoning. However, the twin study of Bouchard and Hur (1998) finds that personal traits measured by the Myer-Briggs indicator which are related to the way of thinking have a considerable genetic component. This results suggests that people have a predominant mode of thinking (intuitive or deliberative), which is causal for their attitudes towards uncertainty. Butler et al. (2013) find that manipulating an individual’s reliance on intuitive thinking can reduce risk and ambiguity aversion pointing in the same direction of causation.

We assign a decision type to each subject based on his or her predominant reliance on a thinking mode in a decision situation. An indicator for thinking mode used in recent studies is response time. Assuming that deliberative thinkers, those who use more frequently System 2, need more time to derive a decision since they think more carefully and ponder more often, it is reasonable to consider response time as an indicator for decision time. Response time as a measure of thinking mode has also been used in Rubinstein (2007, 2012) and Butler et al. (forthcoming). In our experiment, we treat response time as an endogenous variable which is determined by the behavior of subjects. We hence need an additional variable describing the predominant decision mode and we create it by letting subjects characterize themselves as intuitive or deliberate decision makers in a post-experimental questionnaire.

We investigate the linkage between attitudes towards risk and ambiguity and decision type by introducing a new experimental framework. More precisely, the paper examines if individuals that are characterized by different attitudes towards risk and ambiguity show different decision and information acquisition processes. Much of the existing literature on uncertainty focuses on the decision itself and the potentially influential factors, but there is no evidence on individuals' behavior if they have the opportunity to reduce ambiguity. Our question is how information acquisition, decision time and uncertainty attitudes are related to intuitive and deliberate thinking and to one another. Furthermore, we investigate how all these factor affect the choice between the risky lottery and the safe outside option.

Based on the aforementioned prior findings, we predict that 1) intuitive subjects are less risk and ambiguity averse than deliberate thinkers, 2) more ambiguity averse subjects acquire more information in order to reduce the degree of ambiguity, 3) given the amount of information available, intuitive thinkers need less time to make a decision than deliberative thinkers, 4) more risk-averse subjects are more likely to choose the safe option.

3. EXPERIMENTAL DESIGN

Our experiment consists of three parts: repeated lottery decisions, measurement of subjects' risk attitude using the Holt and Laury (2002) procedure, and the elicitation of subjects' attitude towards ambiguity following Halevy (2007). At the end of the experiment subjects were asked to fill in a questionnaire that contains a self-assessment about their predominant mode of thinking and questions about their cognitive skills. Finally, we asked for some personal information about subjects' background.

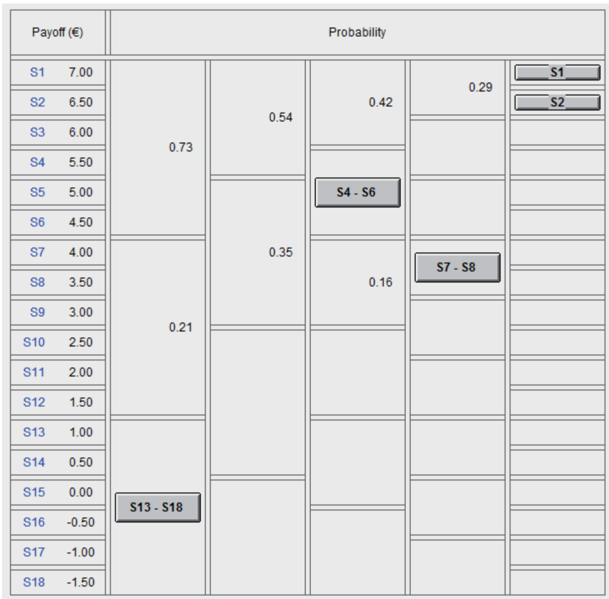
In the main part of the experiment, subjects were confronted with 15 independent decision situations[1] in which they had to choose between a safe payment and a lottery with an initially concealed probabilistic structure. The safe payment was held constant among all decision situations and was always fixed to EUR 2.00. The lotteries were characterized by 18 different payoffs occurring with different probabilities. The possible payoff ranged always from a loss of EUR 1.50 to a gain of EUR 7.00 in steps of EUR 0.50. While subjects always knew the possible payoffs of the lotteries, the corresponding probabilities were initially concealed by buttons, thus there was an unknown probabilistic structure and hence full ambiguity at the beginning of each decision situation. The probability properties of the lottery were presented in a table as shown in Figure 1.

Each table contained 40 fields arranged in five columns and each field contained the probability for the payoff(s) to the left of it. We labeled the covering buttons according to their information to avoid any confusion, for example the button “S1 – S6” covered the probability that one of the payoffs S1 to S6 would occur. The probability was revealed if the subject clicked on the button. The 18 fields on the far right contained the probabilities for each single payoff; the fields in the middle of the table contained aggregated probabilities for several payoffs. For example, the first column contained only three covered fields. Each of these fields contained the probability for the occurrence of one of the six payoffs to the left of it as described in the previous example “S1 - S6”. Subjects were allowed to retrieve as many probabilities in the table as they wanted. There was no time limit for the decision. They just had to click with the computer mouse on the buttons and the information about the probability appeared. Uncovering a field was possible if all directly adjacent fields on the left of the particular field had already been uncovered. Thus, it was not possible to see the probability for a single payoff without having uncovered all the fields to the left

[1] Subjects were only told that they would face several similar decision situations within the first part but the exact number was not mentioned to avoid biases.

of it. Opening up all fields means reducing ambiguity to risk since in this case the payoffs as well as the probabilistic structure are known.

Figure 1: Information table for the lotteries



Our research question requires a comparison of subjects with different decision modes and attitudes towards uncertainty, so that we use a between-subjects design. At the same time we want to analyze how each subject responds to the properties of the lotteries so that we also use a within-subjects design by letting subjects decide on whether to take a lottery 15 times in a row.

The 15 lotteries differ only in their probabilistic structure. We included seven lotteries with an expected payoff of EUR 5.00, seven with an expected payoff of EUR 3.50 and one lottery with an expected payoff of EUR 1.40. The latter served as a check to see whether subjects understood the task as only risk-loving subjects should choose a lottery with an expected value lower than the safe option. The lotteries did not only differ in terms of their expected value but also with respect to their standard deviation and their skewness. Table 1 contains a summary of the lotteries' moments.

Table 1: Moments of the lotteries

Lottery	Mean	SD	Skew	Risk
10	5	1.88	-0.06	1
12	5	1.9	-0.07	1
6	3.5	1.61	-0.03	2
8	5	0.65	0.00	2
2	3.5	0.65	0.00	3
3	5	2.2	-0.08	3
7	5	1.12	0.00	3
11	5	2.61	-0.19	3
1	3.5	1.12	0.00	4
9	3.5	2.07	-0.13	4
4	3.5	2.49	-0.07	5
5	3.5	3.26	-0.09	6
15	1.4	2.25	0.58	6

We classify the 15 lotteries according to their risk with the following procedure. First, we sort all lotteries in descending order by their means (expected payoffs) and assign the lowest rank of 1 to the lotteries with the highest means. Then, we rank the lotteries by standard deviation and skewness and assign low ranks for low values of the moments. Finally, we sum the three rank numbers for each lottery and assign the final categorical risk levels shown in the last column of Table 1 according to the sum of ranks.

The lotteries characterized by these moments are quite different as visible in Figures 2a -2c which show the probability distributions of the lottery with the lowest risk (lottery 12), the highest risk (lottery 15), and one with an intermediate risk level (lottery 11).

Figure 2a: Probability distribution of lottery 12

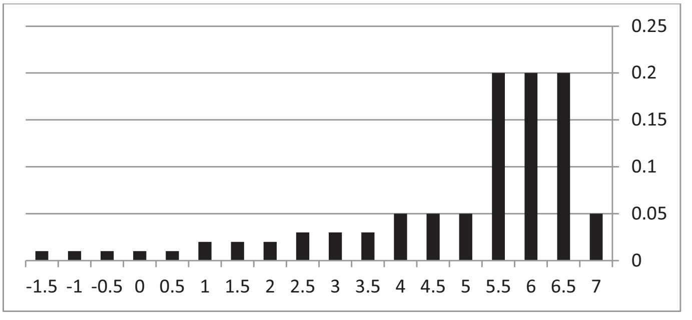


Figure 2b: Probability distribution of lottery 15

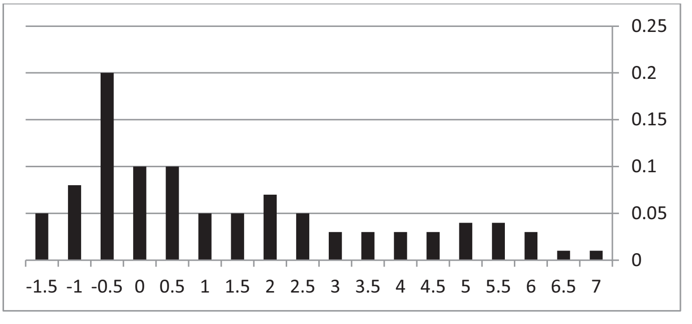
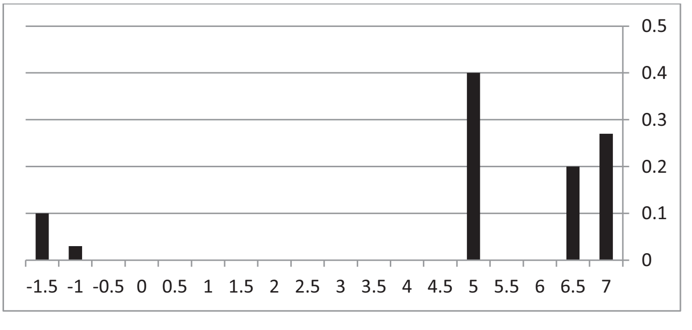


Figure 2c: Probability distribution of lottery 11



In lottery 12, most of the probability mass is concentrated in the right tail so that it is fairly likely that this lottery will generate a payoff that is much larger than the outside option. In contrast, lottery 15 is likely not only to generate an outcome lower than the safe one, but even a negative payoff. The particular feature of lottery 11 is that a lot of the probability mass is concentrated in both tails, while many of the intermediate payoffs have zero probabilities.

We hypothesize that the expected payoff of a lottery is an important criterion whether subjects choose the lottery or the safe option. In a standard framework of expected utility theory, risk-averse subjects should only prefer lotteries over the outside option, if the lotteries' expected payoffs are higher than the riskless payoff. According to standard portfolio theory, risk-averse subjects should furthermore take the variance of the expected payoff into account and prefer the lottery with the lower variance for identical expected payoffs. In order to test whether subjects apply this kind of reasoning, we vary the described design slightly in a treatment. In this treatment, subjects were shown the expected payoff of each lottery in addition to the table with the hidden probability. They also had the option to learn the variance of the expected payoff by clicking a button on the computer screen.

We also had a control group which received the same information as the benchmark group (without the displayed expected payoff) but the probabilistic structure of the lottery was already revealed. Thus, they did not have to acquire any information and there was no ambiguity involved. The control group allows us to observe how subjects decide for or against the lotteries if there is no ambiguity involved. We can hence compare the choices and the response times under risk and under ambiguity.

Subjects did not know the number of lottery choices they had to make in advance. We only informed them that there would be a sequence of choice situations in the first part and that the second part of the experiment would begin after all participants had completed all choices. By this design feature we avoid both time pressure and any incentive to rush through the lottery choices in order to maximize expected earnings per time unit.

In part two of the experiment we test for subjects' risk attitude by employing a standard lottery choice experiment based on Holt and Laury (2002). Subjects chose ten times between two lotteries, X and Y. While lottery X has a high payoff of EUR 2.00 and a low payoff of EUR 1.60, lottery Y has high payoff of EUR 3.85 Euro and a low payoff of EUR 0.10. Starting with the same probabilities of 10%, the probabilities for the high payoffs increase steadily in steps of 10% in both lotteries.

In the third part, we measure subjects' ambiguity attitude as in Halevy (2007) using the Becker-DeGroot-Marschak (1964) mechanism to elicit subjects' reservation prices for a risky urn and an ambiguous urn. Both urns contained 10 balls that could be either blue or red. Subjects were told that the computer would draw a random ball from each urn and that they had to bet on the color of the drawn balls. If the right color was predicted, subjects won the bet and received a payoff of EUR 8.00. Otherwise they would lose and get nothing. Subjects knew that the risky urn contained 5 blue balls and 5 red balls, while they did not receive any information about the distribution of balls in the ambiguous urn. For both urns, subjects had to report their reservation prices. The computer generated a random offer between EUR 0.00 and EUR 8.00. If subjects' reservation price was higher than the random offer, lottery was played. However, if the random offer was higher than the reported reservation price, the bet was sold and the subject received the amount that was offered by the computer instead of the reservation price. The dominant strategy for this mechanism is to truthfully report one's reservation price. The difference in subjects' reported reservation prices between these two urns is used as a measure of ambiguity attitude. If the reservation price for the risky urn is strictly higher than for the ambiguous urn, we classify this subject as ambiguity averse.

We paid all three parts of the experiment. From the 15 lottery choices, one was randomly picked and either the safe outside option or the payoff of the lottery was paid. All subjects received a show-up fee of EUR 4.00, which was high enough to cover the potential loss from the lottery.

After the three parts of the experiments, subjects were asked to fill in an unincentivized questionnaire which contained the following self-assessment question about subjects' decision type: "On a scale from 1 – 5, would you say that generally you decide spontaneously and intuitively or rather that you consider a decision thoroughly and ponder extensively?"

The experiment started with a brief welcome and an introduction by the experimenters. Thereafter, the instructions[2] for the first part were handed out and read aloud via an audio file. Subjects were informed that all of them would begin the second part together. Instructions for the second part were handed out and read after all subjects had finished part one. A similar procedure applies for the following parts of the experiment. The lotteries were presented to subjects in four different predetermined random sequences. Subjects were allowed to use the Microsoft Windows calculator in each decision situation. The program documented if a subject made use of this opportunity. Since the subjects seemed to have problems understanding the Halevy procedure in a pilot session, there was a practice session to ensure that subjects understood the underlying mechanism and the task (similar as in Borghans et al. 2009). Before subjects were able to start the stage containing the actual experiment, they had to answer a question. In particular, we asked for the reservation price of a 1-Euro coin. If a subject was not able to give the right answer, the mechanism was explained again.

The experiment was conducted at the RUBEX Laboratory of the Ruhr-University Bochum, Germany. The subjects were 77 university students from different fields of study. The average age of subjects was 23 years, 56.4 percent were males and 55.8 percent students of management and economics. 56 subjects took part in the main treatment with covered information and 14 subjects

[2] The instructions are available in the appendix.

in the control treatment in which information about the probabilistic structure was available without any action. Additional 10 subjects participated in the treatment with shown mean of the lottery and available variance. The experiment lasted about 70 minutes. The mean payoff across all sessions was EUR 14.18, the minimum was EUR 4.60 and the maximum EUR 21.90.

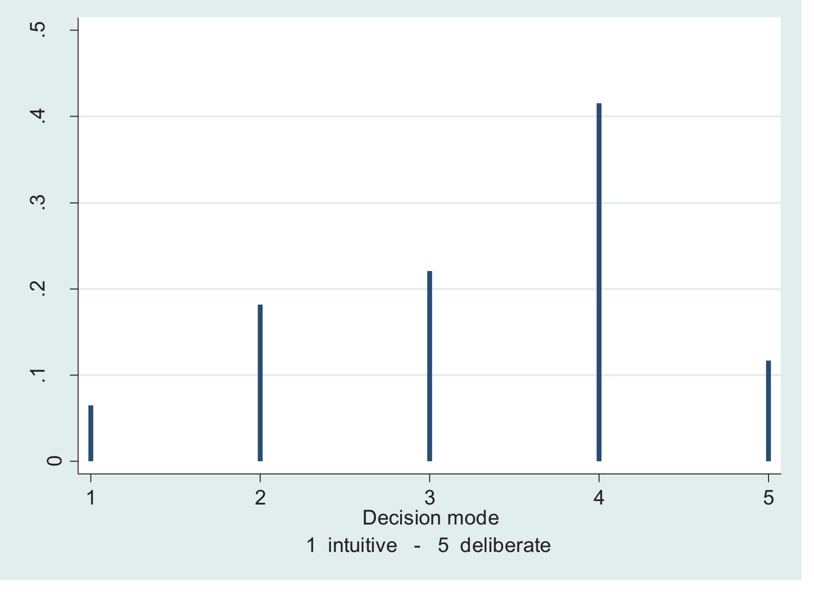
4. RESULTS

We organize the discussion of our results in the following way. First, we show how decision mode and uncertainty attitude are related to one another. After that we analyze the information acquisition of subjects depending on their decision mode and uncertainty attitude. In the next step we compare the decision times of intuitive and deliberate thinkers controlling for the amount of information acquired. Finally, we present how the choice behavior depends on decision mode and uncertainty attitude.

4.1 Decision mode and uncertainty aversion

The self-assessment of subjects of how they make decisions reveals considerable differences as Figure 3 shows. Slightly less than 10% of all subjects consider themselves very intuitive decision makers and slightly more than 10% say that they make decisions very deliberately. The most frequently chosen category (about 40%) on our scale from 1 to 5 is category 4. That a large majority of university students claim to be rather deliberate is not surprising and may in part be interpreted as the socially adequate response. However, a non-negligible fraction of about 25% chose categories 1 and 2 despite the potential academic bias. We are hence confident that the self-assessment measure provides enough variation for our purpose, even if it could be biased towards the deliberate end and might not give a perfectly accurate description of each individual's true type.

Figure 3: Decision modes of subjects according to self-assessment



The Holt-Laury test produces the common result that subjects on average are risk averse[3]. Over all subjects the mean number of safe choices is 6.87 with a standard deviation of 1.71. We also find that the majority of subjects is ambiguity averse. On average, the valuation of the risky urn is EUR 1.29 higher than the valuation of the ambiguous urn (std 1.80). However, for a quarter of the subjects the valuation of the ambiguous urn is equal or even larger than the one of the risky urn indicating ambiguity neutral or seeking behavior. The correlation between risk attitude and ambiguity attitude is positive (0.27) and significant (p=0.016). With regard to the prevalence of

[3] We do not find a gender effect. Neither a test on the equality of the mean number of safe choices nor the Mann-Whitney test indicate a significant difference.

risk and ambiguity aversion and the relation between the two, we hence confirm the results of studies that use similar methods as we do.

In order to analyze the relation between the attitudes towards uncertainty and the decision mode, we regress the measures of risk and ambiguity aversion on five dummy variables for the five categories of the self-assessment question[4] for each subject. Table 2 shows the results.

Table 2: Attitudes towards uncertainty and decision mode

	Decision mode 1 (intuitive)	**Decision mode 2**	**Decision mode 3**	**Decision mode 4**	**Decision mode 5 (deliberate)**	**Adj R^2**	**DM1 = DM5 p**
Risk	5.4*** (0.76)	6.78*** (0.45)	7.06*** (0.41)	6.81*** (0.30)	7.67*** (0.56)	0.94	0.02
Ambiguity	0.8 (0.81)	1.18** (0.48)	0.96** (0.44)	1.36*** (0.32)	2.11*** (0.60)	0.32	0.20

Notes: 77 observations, *, **, *** indicates significantly different from zero at 10%, 5%, 1%. The column on the right contains the p-values of a t-test in the equality of the coefficients on decision modes 1 and 5.

The regressions show that for both uncertainty aversions there is a tendency to increase with more deliberate decision making. The most intuitive subjects are almost risk neutral as the coefficient of 5.4 is close to 4 (significantly different at p= 0.07) and also ambiguity neutral since the valuation of the risky urn is not significantly larger than the one of the ambiguous urn. While the size of the coefficients increases, especially for decision modes 4 and 5, only in the case of risk aversion the difference between most intuitive and most deliberate persons is statistically significant (p=0.02) as the last column of Table 2 shows. All other coefficients do not differ statistically at conventional significance levels.

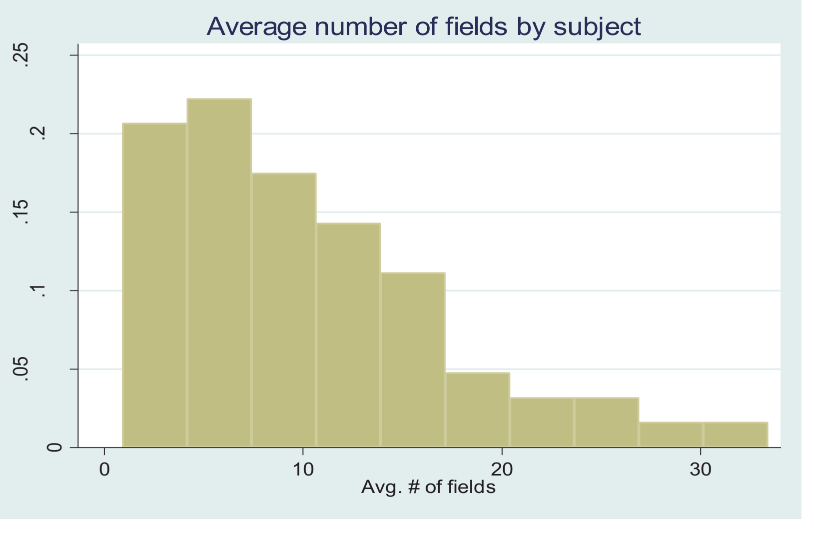
4.2 Information acquisition

By uncovering fields with probabilities, subjects could reduce the ambiguity of the choice situation and even eliminate the ambiguity totally. The total number of fields was 40, but it was

[4] We do not include a constant in the regression so that there is no collinearity problem.

not necessary to uncover all of them in order to learn the full probability distribution because the sum of two probabilities in the last column is always equal to the probability in the neighboring field in the column next to the last one. This means that the efficient number of fields to uncover was at most 31 and in some lotteries even less. Typically the number of uncovered fields was much lower than the efficient number to obtain the complete probability distribution, but in 6.3% of all the cases, subjects opened more than 31 fields. The mean is 10.1, the median is 6 and the standard deviation is 10.4. Figure 4 shows that most subjects acquired quite little information.

Figure 4: Histogram of the average number of fields uncovered per subject



We analyze the information acquisition of subjects depending on their decision mode and uncertainty attitude by regressing the number of retrieved probabilities on the decision mode variable, the measures of risk and ambiguity attitude and a set of control variables. We control for the risk of the lotteries measured as shown in Table 1. Furthermore, we include a dummy variable for female subjects to test for a potential gender effect. Since intellectual capabilities and statistical training might matter for this task, we also control for subjects' high-school leaving grade (abitur grade[5]) and whether subjects had taken a statistics course at the university. Finally, we check for first-round effects, time effects over the rounds of the experiment and order effects using dummy variables[6]. Table 3 contains the results of the regressions.

In column (1), we do not control for order effects and in column (2) we include the order dummies. The order dummies indicate that there are differences between the orders, but the coefficients of the variables of interest (decision mode, risk aversion, ambiguity aversion) are not affected strongly by the inclusion of the dummies. We nevertheless conclude that the order in which the lotteries are presented matters and prefer the specification with the controls for the order. The decision mode has a positive influence of the quantity of collected information which means that more deliberate decision makers request more information than more intuitive ones. More risk averse subjects also request more information, but subjects who are more ambiguity averse uncover *fewer* probabilities. The latter finding is very surprising, first because of the positive correlation between risk aversion and ambiguity aversion and second because we had expected that subjects who dislike ambiguity more would also try to reduce it more.

If the lotteries are more risky, subjects acquire more information, which is quite reasonable. Students with poor high school grade also collect more data, maybe because they find it difficult to draw conclusions from limited information sets. This interpretation is also consistent with the negative coefficient on the statistics dummy which implies that subjects without training in statistics request more information. Finally, we observe that there is a strong positive effect of the first round and that acquisition of information falls over the rounds of the experiment.

[5] Note that in the German grading system, good performance is indicated by low numbers. The best grade is 1.0 the worst passing grade is 4.0.

[6] We varied the order of the lotteries since we expected some first round or learning effects. In fact, first round effects and a time trend are observable. The order dummies are sometimes significant. Introducing order and round variables should control for any order effects sufficiently.

Table 3: Number of fields uncovered

	(1)	(2)	(3)	(4)
Dependent Variable	**Fields**	**Fields**	**Fields**	**Fields**
Decision mode	1.15***	0.89***	0.81**	0.95***
	(0.30)	(0.30)	(0.29)	(0.30)
Risk aversion	1.52***	1.34***	1.21***	1.63***
	(0.20)	(0.20)	(0.19)	(0.26)
Ambiguity aversion	-0.37**	-0.35*		1.49
	(0.19)	(0.18)		(1.00)
Risk aversion x Ambiguity avers.				-0.27*
				(0.14)
Risk of lottery	0.36*	0.36**	0.36*	0.36**
	(0.19)	(0.18)	(0.18)	(0.18)
Mean known	1.52*	3.50***	3.17***	4.36***
	(0.92)	(0.92)	(0.91)	(1.03)
Female	-3.17***	-0.88	-1.04	-0.71
	(0.68)	(0.74)	(0.74)	(0.75)
Abitur	0.84	1.35**	1.26**	1.44**
	(0.58)	(0.57)	(0.57)	(0.57)
Statistics	-1.44	-3.46***	-3.44***	-3.74***
	(0.99)	(1.03)	(1.01)	(1.02)
First round	5.58***	5.58***	5.24***	5.58***
	(1.37)	(1.33)	(1.36)	(1.33)
Round	-0.47***	-0.47***	-0.47***	-0.47***
	(0.08)	(0.08)	(0.08)	(0.08)
Constant	-1.27	5.05**	6.03**	2.77
	(2.30)	(2.46)	(2.41)	(2.75)
Order 1		-6.42***	-6.52***	-6.31***
		(1.00)	(1.00)	(1.00)
Order 2		-6.82***	-6.77***	6.73***
		(0.98)	(0.98)	(0.98)
Order 3		-4.10***	-3.89***	-3.80***
		(1.09)	(1.09)	(1.11)
Adj. R^2	0.18	0.23	0.22	0.23
#	945	945	945	945
	OLS	OLS	OLS	OLS

Another surprising result is that subjects uncovered more fields in the treatment in which the expected value of the lottery was displayed. Our expectation was that those subjects would use the expected value as a decision heuristic and on average would collect less additional information.

Since the negative coefficient of the ambiguity variable is puzzling, we exclude the ambiguity variable in model (3) and find that it does not affect the other results by much. In particular, the adjusted R^2 increases only by 0.0021 if the ambiguity variable is included. Given that the estimated coefficient in model (2) is quite small and it is only significantly different from zero at the 10%, we do not over-interpret the negative sign. A possible explanation might be that very ambiguity averse subjects are also strongly risk averse, given the positive correlation between the two measures, and hence know rather quickly that they will not choose the lottery. These subjects hence would acquire very little information and then choose the safe option. Only ambiguity averse subjects that are not particularly risk averse would then acquire more information. If this hypothesis is correct, we should observe a positive coefficient of the ambiguity variable and a negative sign of the interaction term (risk aversion x ambiguity aversion). We test this hypothesis by including the interaction term in column (4) and in fact find a (weakly) significant negative coefficient of the interaction term and a positive (though not significant) coefficient of ambiguity aversion.

Summing up, we find that most subjects do not eliminate all the ambiguity of the choice situation although they could do so and although the majority of them is ambiguity averse according to the Halevy test. We even find a negative effect of ambiguity aversion on information acquisition, but this effect is small and only weakly significant. More risk averse subjects, in contrast, seek more information which is also true for deliberate decision makers. The interaction between highly risk averse and ambiguity averse subjects seems to drive the negative relation between ambiguity aversion and information acquisition, because those subjects who are strongly averse against both types of uncertainty avoid the risky lottery.

4.3 Decision time

The computer program measured the time between the moment when a subject entered each decision screen and the time when the "OK" button confirming the decision was clicked. We hence know how much time each subject needed to acquire information and to make a decision in each decision round. Averaged across all sessions, subjects and lotteries the mean decision time was 19 seconds, the median was 11 seconds, and the standard deviation was 25 seconds indicating a considerable heterogeneity. It is also remarkable that in 5% of all the cases the decision time was 2 seconds or less and in 5% it was longer than a minute with a maximum of 288 seconds.

Figure 5: Distributions of average decision times per subject

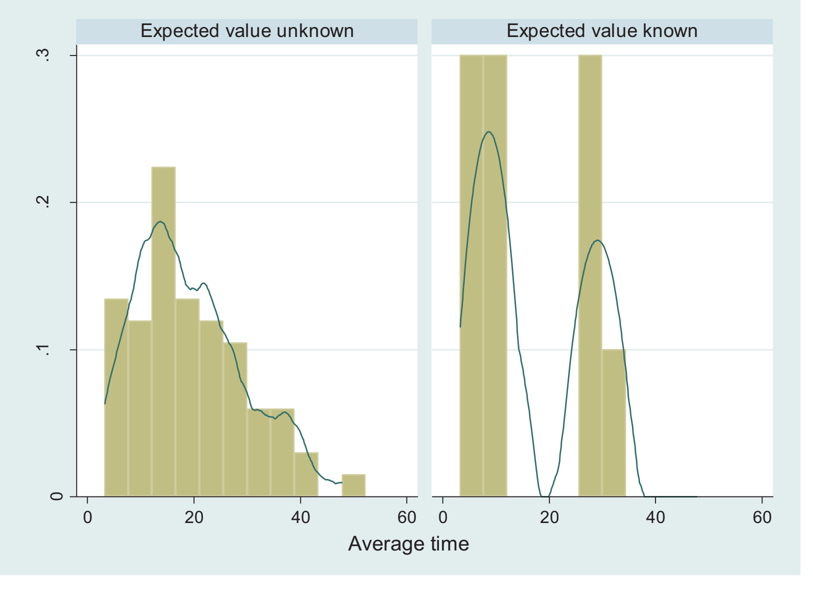


Figure 5 shows that the distribution of average decision times per subject is clearly right-skewed if subjects did not know the expected value (left panel), but bimodal if the expected value was displayed on the screen (right panel). In that treatment, 60% of the subjects decided in 11 seconds or less and the remaining 40% needed 27 seconds or more. If subjects had the information about the expected value available, there was a clear separation in very fast decision makers, who presumably relied mostly on the expected value, and rather slow subjects. The histograms also suggest that subjects had relatively stable individual speed as the diagrams show distributions of *average* decision times per subject.

We analyze the determinants of decision times in a similar way as before by regressing the time of each individual decision on the decision mode variable, the measures of risk aversion and ambiguity aversion and the same set of controls we used for the analysis of the acquired information. Table 4 presents the results.

We start with the analysis of the control group which saw the probability distribution right from the start without having to click in the fields (column (1)). Being a deliberate thinker is a significantly positive determinant of decision time which makes perfect sense. Ceteris paribus the most deliberate decision makers in category 5 needed about 17 seconds more than the most intuitive ones in category 1. The attitudes towards risk and ambiguity do not play a role. As there is no ambiguity in this treatment, this is plausible. If a lottery was more risky, subjects needed more time to make a decision implying that they recognized some of the properties of the lotteries. The high school grade has a negative influence meaning that weaker students decided faster[7] and statistics training does not matter. Again, we find a very large effect of the first round and the time needed decreases in the later rounds. Pooling the data from all treatments confirms most of these results (see column (2)). The coefficient of the decision mode variable is halved, but still highly significant. Ambiguity aversion remains insignificant, but now risk aversion has a significantly positive impact on decision time. The effect of the risk of the lottery is also reduced, because it is more difficult to assess the risk when the information is incomplete.

[7] Although they requested more information.

Table 4: Time needed for decision

	(1)	(2)	(3)
Dependent Variable	**Time**	**Time**	**Time**
Fields			0.59**
			(0.27)
Decision mode	4.28***	2.21***	0.85
	(1.65)	(0.60)	(0.68)
Risk aversion	-1.16	1.75***	1.67***
	(0.94)	(0.41)	(0.55)
Ambiguity aversion	1.36	0.28	0.10
	(0.91)	(0.37)	(0.38)
Risk of lottery	2.63***	1.03***	0.56
	(0.80)	(0.37)	(0.39)
Mean known		0.33	
		(2.05)	
Female	-5.19	-4.34***	-2.95*
	(3.82)	(1.49)	(1.63)
Abitur	-7.83***	-3.56***	-2.52**
	(2.37)	(1.13)	(1.19)
Statistics (yes/no)	1.42	-5.48***	-6.62***
	(4.32)	(2.00)	(2.05)
First round	31.68***	48.13***	47.93***
	(5.93)	(2.74)	(3.19)
Round	-0.65*	-0.43***	-0.11
	(0.33)	(0.16)	(0.21)
Open		-3.27*	
		(1.76)	
Constant	20.66	15.02***	8.34*
	(14.32)	(5.10)	(4.56)
Order 1	2.59	-3.08	
	(2.82)	(2.14)	
Order 2		-3.97*	
		(2.13)	
Order 3		-4.49*	
		(2.42)	
Adj. R^2	0.32	0.32	0.43
#	210	1155	945
	control	all sessions	Without control
	OLS	OLS	2SLS

2SLS: amb known_mean order as instruments

In contrast to the control group, we find that women decide faster than men as do subjects with training in statistics. Whether subjects knew the expected value or not does not make a difference and those in the control group (open) are faster. The order dummies are only weakly significant.

The time until a decision is made obviously depends on the amount of information subjects acquired. We therefore include the number of fields uncovered in the regression in column (3). As shown before, the number of fields is an endogenous variable that is explained by most of the regressors used here, too, so that we have to instrument this variable. We use the interaction between ambiguity aversion and risk aversion, the dummy variable for the known expected value and the order dummies as instruments, because they are significant factors of the number of fields but not of the decision time. Controlling for the number of fields changes the results in one important way: The coefficient of the decision mode variable is not significant now. Risk aversion is still negative, but the risk of the lottery is not significant anymore. The results imply that risk aversion has both a direct effect and an indirect on decision time, but decision mode has only indirect effect through the number of uncovered fields. The lacking correlation between decision time and deliberate thinking is in contrast to our prediction that intuitive thinker decide faster than deliberative thinker given the amount of available information. Thus, deliberate thinking individuals acquire more information in order to derive their decision but they do not spend more time on the actual decision. However, if subjects do not have to acquire the information about the probability distribution (control group), deliberate thinkers actually do need more time reaching a decision.

4.4 Lottery choices

To complete the picture we analyze how attitudes towards uncertainty and the way in which subjects think influence their choices of the uncertain lotteries or the safe alternative payoff. We ran probit estimations with an indicator variable of whether the lottery was chosen (0 = no, 1 = yes) and the same independent variables we used before. Due to the endogeneity of the number of fields and the decision time, we first omit these variables in columns (1) and (2). Our first estimation in column (1) again only uses the data from the benchmark session with the full known probability distributions. Fully consistent with our expectations, we find that more risk averse subjects are less likely to choose the lottery and that more risky lotteries are chosen less. Ambiguity aversion, once more, does not have a significant impact. In contrast to the hypothesis that intuitive people have an advantage in dealing with uncertainty over more deliberate thinkers, we find that the latter are more likely to make the risky choice. Another remarkable finding is that women are more prudent and choose the safe option more often than men although they are not more risk averse than men. All these results also hold for the complete sample (see column (2)). The dummy variable for the benchmark session indicates that subjects chose the safe option more frequently if they had all information available right from the start.

The results are also robust against the inclusion of the number of fields and the decision time. If we do not instrument these regressors (columns (3) and (4)), the number of fields is insignificant and the decision time has a small positive effect on the likelihood that the lottery is chosen. Instrumenting the variables[8] results in significantly negative effects of both factors. The negative effect of the number of fields on the choice of the lotteries remains if we include both variables jointly in the model, but decision time turns insignificant. Furthermore, the degree of risk aversion is not significant if we use the instrumented number of uncovered fields. It hence seems that risk aversion has an indirect effect on the choice of lotteries that is mediated through the higher amount of information that risk averse subjects collect.

[8] The instruments for the number of fields are ambiguity, mean known, statistics and the order dummies. We instrument decision time with the dummies for the first round and statistics. In column (7) we used both sets of instruments.

Table 5: Probit estimations of decision for lottery (against safe option)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent Variable	**Lottery**	**Lottery**	**Lottery**	**Lottery**	**Lottery**	**Lottery**	**Lottery**
Fields			-0.00 (0.01)		-0.07*** (0.01)		-0.08*** (0.01)
Time				0.005** (0.02)		-0.007* (0.003)	0.005 (0.003)
Decision mode	0.29** (0.13)	0.22*** (0.05)	0.17*** (0.05)	0.20*** (0.05)	0.19*** (0.04)	0.20*** (0.04)	0.18*** (0.04)
Risk aversion	-0.24*** (0.07)	-0.08*** (0.03)	-0.06* (0.03)	-0.09*** (0.03)	-0.03 (0.04)	-0.10*** (0.03)	0.03 (0.03)
Ambiguity aversion	-0.09 (0.08)	-0.02 (0.03)	-0.00 (0.03)	-0.02 (0.03)			
Risk of lottery	-0.32*** (0.07)	-0.33*** (0.03)	-0.34*** (0.03)	-0.33*** (0.03)	-0.22*** (0.05)	-0.30*** (0.03)	-0.21*** (0.04)
Mean known		-0.17 (0.16)	-0.13 (0.17)	-0.17 (0.16)			
Female	-1.00*** (0.33)	-0.76*** (0.11)	-0.74*** (0.13)	-0.74*** (0.12)	-0.76*** (0.10)	-0.74*** (0.10)	-0.74*** (0.10)
Abitur	0.08 (0.19)	-.0.17** (0.09)	-0.26*** (0.10)	-0.16* (0.09)	-0.11 (0.09)	-0.19** (0.08)	-0.09 (0.09)
Statistics (yes/no)	0.04 (0.33)	0.11 (0.15)	-0.11 (0.17)	0.14 (0.15)			
First round	-0.63 (0.48)	-0.41** (0.21)	-0.41* (0.22)	-0.63*** (0.22)	0.12 (0.22)		
Rounds	-0.04 (0.03)	-0.04*** (0.01)	-0.04*** (0.01)	-0.03*** (0.01)	-0.06*** (0.01)	-0.04** (0.01)	-0.06*** (0.01)
Open		-0.49** (0.13)		-0.47*** (0.13)		-0.26** (0.11)	
Constant	2.99*** (1.13)	2.78*** (0.39)	3.02*** (0.44)	2.71*** (0.39)	2.36*** (0.50)	3.14*** (0.31)	2.25*** (0.45)
Order 1	0.52** (0.23)	0.24 (0.17)	0.10 (0.19)	0.25 (0.17)			
Order 2		0.41** (0.17)	0.51*** (0.19)	0.43** (0.17)			
Order 3		-0.40** (0.18)	-0.42** (0.18)	-0.38** (0.18)			
Pseudo R^2	0.28	0.21	0.22	0.22			
#	210	1155	945	1155	945	1155	945
	control	All sessions	without control	All sessions	without control	All sessions	Without control
	Probit	Probit	Probit	Probit	IVProbit	IVProbit	IVProbit

4. DISCUSSION

In line with the majority opinion in the literature, we find that subjects in our experiment are in general risk averse and ambiguity averse and that there is a significantly positive correlation between risk aversion and ambiguity aversion. In contrast to many other papers, we do not observe a significant gender difference in the degree of risk aversion. Since we use standard tests to elicit uncertainty attitudes, it is not really surprising that our results are similar to those of other researchers that used the same methods.

Our more innovative research questions concern the relationship between uncertainty aversion, decision mode, information acquisition and risky choice. In our experiment, subjects who see themselves as very deliberate thinkers are more risk averse than subjects who reported to decide intuitively. While the most intuitive subjects are almost risk neutral in the Holt-Laury test, the average Holt-Laury score of the least intuitive persons is 7.7 which is significantly higher at the 5% level. We do not find a similar relation between ambiguity aversion and intuition. While there is a tendency that the degree of ambiguity aversion decreases with more intuitive decision making, there is no statistically significant difference between the most and the least intuitive subjects. This result confirms the findings of Butler et al. (forthcoming) for risk aversion, but not for ambiguity aversion. One difference between their study and ours is how the decision mode is measured. Instead of a self-assessment question, which we use, Butler et al. (forthcoming) measure the decision mode by the decision time in their experiment with the lowest quartile being classified as intuitive thinkers and the highest as the deliberative subjects.

We analyze the relation between decision time and ambiguity aversion, too, and do not find any significant effect of ambiguity aversion on the time needed for making decisions. In contrast to Butler et al. (forthcoming) we use decision time as the dependent variable and the decision mode and uncertainty aversion as regressors. We consider this approach more appropriate because, both thinking mode and attitude towards uncertainty seem to be personal traits which should determine decision behavior measured by decision time. But no matter whether we regress decision time on ambiguity aversion or vice versa, there is not significant correlation[9] between the two.

It is even more puzzling that ambiguity aversion is also unrelated to the amount of information that subjects acquire. Contrary to our expectation, more ambiguity averse subjects do not reduce the ambiguity of the choice situation more than less ambiguity averse subjects. This result is disturbing, because it raises questions about what the Halevy test really measures. If the ambiguity attitude measured by this test has little predictive power for ambiguous choice situations other than Ellsberg urn experiments, its practical use is fairly limited.

The risk attitude elicited with the Holt-Laury procedure seems to be more robust since it has significant and plausible effects on information acquisition, decision time, and risky choice. In particular, more risk averse subjects acquire more information, need more time, and are less likely to choose the lottery.

Our variable that describes the self-assessed decision mode of subjects also has explanatory power for the dependent variables. Intuitive thinkers acquire less information than deliberative ones which is in line with our expectations. There is also a plausible effect on decision time – intuitive decision makers are faster -, but this effect vanishes once we control for the number of fields uncovered so that decision mode affects decision time only indirectly. Finally, there is a robust effect on decision mode on the probability of choosing the lotteries. In all estimated models, more deliberative thinking increases the chances that the lotteries are chosen. Intuitive thinkers are more likely to go for the safe payment. This result contradicts the hypothesis of Butler et al. (forthcoming) who argue that more intuitive decision makers are better at bearing uncertainty.

[9] The raw correlation between the two variables is 0.066.

5. CONCLUSION

This paper presents a novel experimental design to study decision making in ambiguous situations. Instead of giving subjects the choice between risky and ambiguous Ellsberg urns, we let them choose between a safe option and a risky lottery, whose risk is a priori unknown to subjects. By acquiring information about the probability distribution of the lottery's outcomes, subjects can reduce or even eliminate the ambiguity and turn the decision situation into one of risk.

One of the advantages of our experimental design is that it contains an additional feature allowing us to check whether the individual ambiguity attitude measured by the urn experiment is consistent with the choice behavior. Under the assumption that an ambiguity averse subject should reduce ambiguity within a decision process if she is allowed to do so without any costs, we predicted to observe that these subjects request more information and thus reveal more fields in the tables. However, we do not find that subjects showing ambiguity aversion in the urn experiment based on Halevy (2007) significantly reduce the ambiguity in the first part of the experiment. In our experiment, subjects do not behave in a way which is consistent with the elicited degree of ambiguity aversion. A possible explanation for this inconsistency is that the ambiguity attitude measured with urn experiments is not applicable to all situations of uncertainty.

We also find that subjects' self-assessed classification as intuitive or deliberative decision makers is a good predictor of information acquisition and choice. More intuitive subjects acquire less information and are more likely to avoid the risky lottery. Intuition seems to be negatively correlated with risk aversion, but not with ambiguity aversion.

References

Abdellaoui, M., Baillon, A., Placido, A., & Wakker, P. P. (2011). The rich domain of uncertainty. *American Economic Review, 101*, 695–723.

Akay, A., Martinsson, P., Medhin, H., & Trautmann, S. T. (2012). Attitudes toward uncertainty among the poor: an experiment in rural Ethiopia. *Theory and Decision, 73*, 453–464.

Arad, A., & Rubinstein, A. (2012). Multi-Dimensional iterative reasoning in action: the case of the colonel blotto game. *Journal of Economic Behavior & Organization, 84 (2),*571-585.

Becker, G., DeGroot, M., & Marschak, J. (1964). Measuring utility by a single-response sequential method. *Behavioural Science 9,* 226–32.

Binmore, K., Stewart, L., & Voorhoeve, A. (2011). How much ambiguity aversion? Finding indifferences between Ellsberg's risky and ambiguous bets. *Working paper*, London School of Economics.

Butler, J. V., Guiso, L., & Jappelli, T. (2013). Manipulating reliance on intuition reduces risk and ambiguity aversion *(No. 1301). Einaudi Institute for Economic and Finance (EIEF).*

Butler, J. V., Guiso, L., & Jappelli, T. (forthcoming). The role of intuition and reasoning in driving aversion to risk and ambiguity. *Theory and Decisions.*

Borghans, L., Golsteyn, B. H. H., Heckman, J. J., & Huub, M. (2009). Gender differences in risk aversion and ambiguity aversion. *NBER Working Paper 14713. Available at http://www.nber.org/papers/w14713.*

Bouchard Jr, T. J., & Hur, Y. M. (2008). Genetic and environmental influences on the continuous scales of the Myers-Briggs type indicator: an analysis based on twins reared apart. *Journal of Personality, 66 (2),* 135-149.

Charness, G., Karni, E., & Levin, D. (2013). Ambiguity attitudes and social interactions: An Experimental Investigation. *Journal of Risk and Uncertainty, 46*, 1–25.

Cohen, M., Tallon, J.-M., & Vergnaud, J.-C. (2011). An experimental investigation of imprecision attitude, and its relation with risk attitude and impatience. *Theory and Decision*, *71*, 81–109.

Cubitt, R., van de Kuilen, G., & Mukerji, S. (2012). Sensitivity towards ambiguity: A qualitative test and measurement. *Working paper*, Oxford University.

Dimmock, S. G., Kouwenberg, R., & Wakker, P. P. (2012) Ambiguity attitudes in a large representative sample. *Working paper,* Erasmus University Amsterdam

Dimmock, S. G., Kouwenberg, R. R. P., Mitchell, O. S., & Peijnenburg, K. (2013). Ambiguity attitudes and economic behavior. *NBER Working Paper*, *w18743.*

Ellsberg, D. (1961). Risk, ambiguity, and the Savage Axioms. *The Quarterly Journal of Economics, 75 (4),* 643-669.

Etner, J., Jeleva, M., and Tallon, J.-M. (2012). Decision theory under ambiguity. *Journal of Economic Surveys, 26 (2),* 234-270.

Fischbacher, U. (2007). z-Tree: Zurich Toolbox for Ready-made Economic Experiments. *Experimental Economics,10,* 171-178.

Halevy, Y. (2007). Ellsberg revisited: An experimental study. *Econometrica, 75 (2),* 503-536.

Holt, C., & Laury, S. K. (2002). Risk aversion and incentive effects. *American Economic Review, 92*, 1644-1655.

Kahneman, D. (2003). Maps of bounded rationality: Psychology for behavioral economics. *American Economic Review, 93*, 449-475.

Qui, J., & Weitzel, U. (2011). Reference dependent ambiguity aversion: Theory and experiment. *Working Paper,* Nijmegen University.

Rubinstein, A. (2012). Response time and decision making: a "free" experimental study. *Working Paper.* Tel Aviv University

Rubinstein, A. (2007). Instinctive and cognitive reasoning: A study of response times. *The Economic Journal, 117*, 1243-59.

Stahl, D. O. (2012). Heterogeneity of Ambiguity Preferences. *Working Paper*, University of Texas.

Stanovich, K. E., & West, R. F. (2000). Individual differences in reasoning: Implications for the rationality debate? *Behavioral and Brain Sciences, 23*, 645-726.

Sutter, M., Kocher, M., Glätzle-Rützler, D., & Trautmann, S. T. (2013). Impatience and uncertainty: Experimental decisions predict adolescents‘ field behavior. *American Economic Review, 103*, 510–531.

Trautmann, S., & van de Kuilen, G. (forthcominig). Ambiguity attitude. *Blackwell Handbook of Judgment and Decision Making.*