Revealed Incomplete Preferences under Uncertainty: Evidence for Bewley Preferences*

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Abstract

The completeness axiom of choice has been questioned for long and theoretical models of decision making allowing for incomplete preferences have been developed. So far the theoretical accomplishments have not been paired with empirical evidence on the actual existence of incomplete preferences under uncertainty. We provide empirical evidence in support of the existence of incomplete preferences due to multiple priors over an ambiguous event, i.e. Bewley preferences. We design experimental decision tasks where specific choice patterns are consistent with Bewley preferences but inconsistent with models assuming completeness. We find that approximately half of the subjects behave consistent with variational Bewley preferences and that the observed behavioral pattern cannot be attributed to probability weighting, choice mistakes, or intransitive indifference. In a robustness test we show that the observed behavior is robust to a prize variation in the ambiguous prospect and consistent with comparative statics predictions based on variational Bewley preferences.

Keywords: Incomplete preferences, uncertainty, multiple priors, experiment

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1 Introduction

It is a standard assumption in economics that individuals are able to pair-wise compare all available choice options. In other words, it is assumed that decision makers have complete preferences. Although core to most decision making models, the completeness assumption has been questioned since a long time, especially for decision situations involving uncertainty. Already Aumann (1962) considered completeness of preferences as intuitively too demanding and not even appealing normatively: *"Like others of the axioms, [completeness] is inaccurate as a description of real life; but unlike them, we find it hard to accept even from the normative viewpoint"* (p.446). More recently, Wakker (2010) thoroughly discusses problems of the completeness assumption in models for decision making under risk and uncertainty. In this paper we provide empirical evidence in support of the existence of incomplete preferences due to multiple priors over ambiguous events, Bewley preferences for short (Bewley, 2002).

Evidence for the existence of incomplete references is not only interesting from a decision theoretical viewpoint. Also in applications knowledge about (in)completeness of preferences under uncertainty is important, as many decisions involve risky and ambiguous prospects. For instance, experts in the medical sector often need to choose between well tested traditional treatments and novel treatments with unknown success rates and side effects.[1] Financial markets arguably exhibit high uncertainty, and portfolio choices often require balancing risky options, such as bonds, against more ambiguous financial products, such as assets (e.g., Mukerji and Tallon, 2001). In such cases, models of incomplete preferences are likely delivering different predictions than models assuming completeness (e.g., Bossaerts et al., 2010), and it is thus important to know if individuals indeed exhibit incomplete preferences when facing uncertain decision situations.

Starting with the cited work of Aumann, the expressed intuitive doubts and practical importance led to the development of a number of theoretical models that drop the completeness axiom and allow the decision maker to remain occasionally indecisive. In these models a decision maker (henceforth, DM) may be indecisive when pursuing different, and possibly orthogonal, objectives which lead to multiple representations of the same choice option (see, e.g., Ok, 2002; Dubra et al., 2004; Ok et al., 2012, on multi-objective decision making). Further, a DM may be indecisive when lacking the information necessary to determine which option is best, such as when choice objects are uncertain prospects (see, e.g., Bewley, 2002; Gilboa et al., 2010; Ok et al., 2012; Faro, 2015). Theoretical models of incomplete preferences have also been suc-

[1] For a prominent example see the discussion regarding the application of experimental vaccines during the 2014-2015 Ebola outbreak in West Africa (Alang, 2015). For more information see, e.g., `http://www.who.int/mediacentre/factsheets/fs103/en/`.

cessful in explaining choice anomalies, such as the status quo bias and preference reversals (see, among others, Mandler, 2004, 2005; Masatlioglu and Ok, 2005; Eliaz and Ok, 2006; Ortoleva, 2010).

So far the theoretical accomplishments have however not been paired with empirical evidence on the actual existence of incomplete preferences.[2] The laboratory experiment of Danan and Ziegelmeyer (2006), reported in a working paper, constitutes the only empirical work in economics known to us that explicitly tests for incompleteness of preferences. In the experiment, it is observed that subjects postpone choices between risky prospects and sure amounts to a future session, even when postponing comes at a small cost. The authors conclude that such decisions reveal "true indecisiveness", but also note that this interpretation only holds under the assumption that a taste for flexibility is linked to incomplete preferences.[3] The latter assumption points to a general problem in obtaining convincing empirical evidence on incomplete preferences. Preferences need to be revealed via choice and incomplete preferences may remain hidden, unless some specific assumptions are introduced.

In this paper we employ an empirical strategy that circumvents this problem by using decision tasks where specific choice patterns are inconsistent with models assuming complete preferences under uncertainty. Specifically, we present the results of three experiments that together can reveal the existence of incomplete preferences, in the sense of so-called variational Bewley preferences (Faro, 2015).

In the first experiment, denoted *Risk-Ambi*, subjects face a series of decision situations where they are presented a risky and an ambiguous prospect. All prospects, risky and ambiguous, are characterized by the same two possible outcomes, and level as well as source of ambiguity are kept constant in all decision situations. For the risky prospect the likelihood of winning a positive prize differs across decision situations, in the range of 0 to 100 percent. In each of these situations, a subject can either choose one of the two prospects, or select an indifference option (option I), which delegates the choice between the two prospects to a fair random device. Importantly, the choice task is designed in a way that any choice model assuming transitivity and completeness of preferences predicts that subjects choose option I at most once. We argue that the preferences of subjects who repeatedly choose option I are incomplete, and that the observed choice behavior is consistent with variational Bewley preferences as in Faro (2015).

We also test whether repeated choice of option I could be consistent with Prospect Theory, and more specifically the idea that people weight probabilities non-linearly

[2]For a informative general discussion of the interaction between experimental empirical research and progress in theory development see Bardsley et al. (2010).

[3]See Kraus and Sagi (2006) for a theoretical model.

(Tversky and Kahneman, 1992). To explore this potential explanation, we implement a choice task that allows us to estimate subjects' probability weighting function at the individual level.

To provide additional support for the incomplete preferences interpretation, we conduct another experiment, denoted *Risk-Sure*, where subjects make choices between varying risky prospects and a sure payment. With this experiment we can control for whether subjects exhibit intransitive indifference under risk and certainty (Luce, 1956). If non-appreciable utility differences between prospects are driving repeated choice of option I, we should observe such a choice pattern also in this experiment.

Finally, we conduct a third experiment, denoted *Risk-Ambi-high*, that is identical to *Risk-Ambi*, except that we increase the winning prize for the ambiguous prospect. We provide theoretical comparative statics predictions based on the assumption of variational Bewley preferences and check if these predictions are carried out by the data.

In brief our empirical results are as follows. In *Risk-Ambi* we find that as many as about half of the subjects choose option I multiple times. These choices cannot be explained by likelihood insensitivity which, although present in our sample, is not pronounced enough to support this interpretation. This suggests already that the repeated choice of I could be an expression of Bewley preferences over the ambiguous event. The results in *Risk-Sure* support this interpretation. There we observe, in stark contrast to *Risk-Ambi* that option I is hardly ever chosen more than once. Hence, it is very unlikely that repeated choice of option I is a result of intransitive indifference under risk and certainty. Finally, in *Risk-Ambi-high* we observe again a large number of subjects (about 60 percent) choosing option I repeatedly, proving that this behavioral pattern is robust to a change in monetary incentives. Moreover, the comparative statics predictions assuming Bewley preferences are largely confirmed.[4]

Starting with the paper of Cohen et al. (1987), a few experiments have presented subjects with choice possibilities similar to our option I (see Cubitt et al., 2015, and references therein). These studies focus on decision making under risk and allow subjects to state that they do not have a precise preference between two lotteries, or between a lottery and a safe payment (similar to our *Risk-Sure* experiment). For instance, subjects can state "I do not know" or "I'm not sure about my preference" when presented with a choice task. Differently than in our study, these statements are however not incentivized. In Cubitt et al. (2015), for example, regardless of a stated preference imprecision, subjects *always* have to indicate the point at which they switch from a sure amount of money to a lottery, and this type of decision is the only relevant one for

[4]Our study and results are related to a few recent papers investigating a possible preference for randomness (Dominiak and Schnedler, 2011; Agranov and Ortoleva, 2015; Dwenger et al., 2014). We discuss these papers and how our work relates to them in Section 6.

payment. Together these studies have provided important suggestive evidence on the existence of imprecise preferences. However, the identification of the causes of imprecision was beyond the scope of these contributions. We are advancing this literature by designing a set of experiments that allows us to draw inferences on the (in)completeness of preferences and thus can shed light on the nature of imprecision.

The reminder of the paper is organized as follows. The next section lays out our general empirical strategy. Section 3 describes in detail the design and results of experiment *Risk-Ambi*, and Sections 4 and 5 report on experiments *Risk-Sure* and *Risk-Ambi-high*, respectively. The paper closes with a discussion and conclusions in Sections 6 and 7, respectively.

2 Empirical Strategy

Our empirical strategy to reveal incomplete preferences under uncertainty consists of running three decision making experiments. Each experiment has the same general structure and comprises three parts. In the first part, participants face a series of decision situations where they have to choose between risky and, depending on the experiment, ambiguous or certain prospects. Importantly, in each decision situation there is also the possibility to state indifference, effectively delegating the choice to a fair randomization device (henceforth, for brevity, option I). Our set-up is such that any model assuming transitive and complete preferences under uncertainty predicts at most one choice in favor of option I. In contrast, Bewley preferences can be revealed via repeated choices of option I.[5]

In the second part, participants face a lottery choice task that we use to elicit likelihood insensitivity. We use the data to estimate individual probability weighting functions and study their relation to choices in the first part. In the third part, subjects have to respond to questionnaires measuring some psychological constructs potentially important in decision making under uncertainty and individual background information.

In reporting on the three experiments, we start with experiment *Risk-Ambi*. It sets the stage, providing our main result regarding repeated choices of option I and suggests the existence of incomplete preferences under uncertainty. Experiment *Risk-Sure* tests whether our main result could be due to intransitive indifference under risk and certainty. In Experiment *Risk-Ambi-high* we explore the robustness of our main result with respect to an increased prize and test comparative statics predictions derived from a model of variational Bewley preferences.

[5] We note that with our procedure we likely underestimate repeated choices of I that are an expression of incomplete preferences. As participants are forced to make some choice in each decision situation, individuals with incomplete preferences may as well select the risky or ambiguous prospect. In this sense there may be unobserved incomplete preferences.

3 Experiment *Risk-Ambi* – Risk and Ambiguity

In this section we first describe experiment *Risk-Ambi* and explain the different parts of the experiment as well as the experimental procedures in detail. Thereafter we discuss theoretical predictions of different models of decision making under uncertainty regarding choices in favor of option I. The section closes with the presentation of the empirical results.

The experiment consists of three parts. Subjects were not informed about the structure of the experiment and instructions for each part were administered on the computer screen only before the beginning of the respective part.[6]

3.1 Part 1 – Decisions under Uncertainty

In the first part of the experiment participants face a series of decision situations where they are asked to choose between a risky and an ambiguous prospect. Every decision situations is displayed in a row of a table on the computer screen, and all prospects are characterized by the same potential outcomes of €15 and €0. Risk is implemented by using a nontransparent urn filled with 100 balls, colored red or black. In the experiment we call it Urn A. The color composition of the urn varies in each decision situation by 5 balls. In the first decision situation the urn contains 100 red balls, in the second decision situation it contains 95 red balls and 5 black balls, and so on, until the 21st, and last, decision situation where the urn contains 100 black balls.[7] The ambiguous prospect is the same in all decision situations. Ambiguity is also implemented with an urn, but now the urn contains 100 balls in unknown proportion of red and black. This urn is called Urn B in the experiment. To credibly implement ambiguity we applied the following procedure. The actual composition of Urn B is chosen by a fellow researcher at Maastricht University, who is completely free to choose the color composition, except that the total number of balls has to be 100. Our colleague then seals the urn and nobody except him, who is in no other way involved in the experiment, knows its composition. The urns are visibly placed in the experimental lab. Subjects are informed about the procedure and that they are free to inspect the contents of the urns after the experiment is over.

Table 1 reproduces some of the decision situations participants see on the computer screen.[8] Before the decision situations are displayed, each subject has to choose her personal winning color, either red or black, which is the color associated with the high outcome of €15. Each of

[6]The instructions used in the experiment can be found in Appendix E.

[7]Urn A is publicly composed during the payment phase, after a random draw determines which one the 21 decision situations is relevant for payment.

[8]A screen shot of the actual decision table can be found in Appendix F. To indicate their choice, participants had to click on a check box displayed to the left of each option.

the 21 decision situations corresponds to a choice between the risky and the ambiguous prospect. Importantly, different to most experiments on decision making under uncertainty, in each decision situation, subjects can also avoid to actively select one of the prospects. Specifically, participants are informed that by choosing the middle option the choice between prospects is delegated to a fair chance device, which selects one of the two prospects with equal probability. For this option, option I, we used the neutral phrase "I am indifferent between the two urns." to avoid any experimenter demand effect and connotation with respect to incompleteness. Simply put, option I is a costless randomization device that subjects can choose as many, or as few, times as desired. Note that option I is neither a default option nor the status-quo and, hence, the well known biases relating to these concepts cannot be a reason for participants to choose this option (see, e.g., Kahneman, 2003; Camerer, 2003; Camerer et al., 2011).

Table 1: The decision situations

Decision situation	Composition Urn A		Composition Urn B
1.	100 red balls	I am indifferent between the two urns.	100 black and red balls in unknown color ratio.
2.	95 red balls + 5 black balls	I am indifferent between the two urns.	100 black and red balls in unknown color ratio
3.	90 red balls + 10 black balls	I am indifferent between the two urns.	100 black and red balls in unknown color ratio
⋮	⋮	⋮	⋮
10.	55 red balls + 45 black balls	I am indifferent between the two urns.	100 black and red balls in unknown color ratio
⋮	⋮	⋮	⋮
20.	5 red balls + 95 black balls	I am indifferent between the two urns.	100 black and red balls in unknown color ratio
21.	100 black balls	I am indifferent between the two urns.	100 black and red balls in unknown color ratio

Choices are incentivized with the random incentive system (RIS).[9] In the written instructions at the beginning of the experiment, participants are informed that each decision situation is equally likely to be selected for payment. A subject earns the prize of €15 if, for the relevant decision situation, a ball of his/her preferred color is drawn, otherwise he/she earns nothing. The payment procedure takes place publicly at the end of the experiment and subjects are informed about it at the beginning of the experiment.

[9]See *http://people.few.eur.nl/wakker/miscella/debates/randomlinc.htm* for a discussion on the appropriateness of the RIS. For a theoretical argument in favor of this method, see Azrieli et al. (2014).

3.2 Part 2 – Lottery Task

In this part of the experiment we elicit participants' certainty equivalents for 33 lotteries (see Table 2). For each lottery subjects see a computer screen that contains a description of the lottery and a list of 20 equally spaced sure amounts, ranging from the lottery's high to its low potential outcome. In each row of the list subjects have to make a choice between the lottery and the sure amount. In order to facilitate comprehension, the lottery odds are expressed both in percentage points and with the aid of a pie chart.[10] Certainty equivalents are calculated as the arithmetic mean of the smallest sure amount preferred to the lottery and the consecutive sure amount in the list.

Table 2: Lotteries used in Lottery Task

p_1	x_1	x_2	p_1	x_1	x_2	p_1	x_1	x_2
0.05	10	0	0.35	25	10	0.65	20	5
0.05	20	5	0.45	10	0	0.65	25	10
0.05	25	10	0.45	20	5	0.75	10	0
0.1	5	0	0.45	25	10	0.75	20	5
0.1	10	5	0.5	5	0	0.75	25	10
0.1	25	0	0.5	20	5	0.9	5	0
0.25	10	0	0.5	25	10	0.9	10	5
0.25	20	5	0.55	20	5	0.9	25	0
0.25	25	10	0.55	25	10	0.95	10	0
0.35	10	0	0.55	10	0	0.95	20	5
0.35	20	5	0.65	10	0	0.95	25	10

Note: p_1 indicates the probability of winning €x_1; the probability of winning €x_2 is $1 - p_1$.

In order to determine subjects' payment for this part, at the end of the experiment one decision screen and one row within the decision screen, are randomly selected. The relevant lottery is then publicly played out and earnings are added to those of the first part.

3.3 Part 3 – Questionnaires

In the last part of the experiment we ask participants some questions measuring the ability of cognitive reflection and psychological constructs like analytical-rational processing and confidence in intuitive abilities. Specifically, we administered the Cognitive Reflection test (Frederick, 2005) and the Rational-Experiential Inventory (Epstein et al., 1996). In addition we asked sub-

[10] A screen shot of the computer display can be found in Appendix E.

jects questions about personal characteristics (age, gender, etc.) and how they experienced the experiment. Details on the questionnaires can be found in Appendix E.

3.4 Procedures

The computerized experiment was conducted at the Behavioral and Experimental Lab (BEElab) at Maastricht University, using the z-Tree software (Fischbacher, 2007). Upon entering the BEElab, participants were randomly assigned to computer cubicles and not allowed to communicate in any way. Of the 55 participants 90% were enrolled in Maastricht University's School of Business and Economics and 60% of them were male. The average age was 23 years. The experiment lasted on average 90 minutes and the average earnings per subjects were €32.95. After all parts have been finished earnings were determined as described above and paid out confidentially.

3.5 Choice Predictions

In the following we discuss predictions of the most prominent models of decision making under uncertainty, regarding the choice of option I in Part 1.

Subjective Expected Utility Theory. Subjective Expected Utility theory (SEU, Savage 1954) models decision making under uncertainty with an expected utility representation, where unknown probabilities are replaced by subjective priors on the ambiguous event. It is straightforward, that according to SEU theory, a participant would choose option I if and only if the winning probability of the risky prospect equals her subjective prior on the ambiguous event. Thus, SEU predicts that option I is chosen at most once.

Prospect Theory. Kahneman and Tversky (1979) and Tversky and Kahneman (1992) introduced Prospect Theory (PT) for decision making under risk and uncertainty, which argues that individuals' choices under uncertainty are best described by allowing for decision weights. These weights apply to both objective and subjective probabilities. In our decision task, in a given decision situation, an individual may choose option I when the risky and the ambiguous event receive equal decision weight. That is, when being truly PT-indifferent between the risky and ambiguous prospects. Moreover, option I may be chosen in several decision situations if and only if the winning probabilities of *different* risky prospects receive equal decision weight.[11] Stated differently, a participant may choose option I more than once only if she is sufficiently insensitive to likelihood changes. To investigate this possibility we use the data from Part 2 that allows us to estimate PT parameters at the individual level.

[11] For a formal proof, see Appendix A.

Uncertainty Aversion. The models in this class are based on the idea that the decision maker has standard preferences, but may hold multiple priors on the ambiguous event and may be averse to ambiguity. The seminal work of David Schmeidler initiated this approach (see Schmeidler 1989 and Gilboa and Schmeidler 1989), and more recently Cerreia-Vioglio et al. (2011) provided a representation result that allows to unify these models. For illustration purposes, we discuss only α-Maxmin Expected Utility theory (Ghirardato et al., 2004), but the derived result holds for the whole class of models. According to this theory, the expected utility of a prospect is given by the α-weighted sum of the worst and best possible scenario, with α capturing the DM's aversion to ambiguity. That is, although priors can be multiple, decision making is based on a unique representation of the ambiguous prospect.[12] Specifically, in a given situation, option I is chosen if its expected utility is weakly larger than *each* of the available, risky and ambiguous, prospects. This also implies that option I is possibly chosen if and only if the risky and the ambiguous prospect are deemed equivalent. Given that in our experiment the ambiguous prospect is the same in all decision situations but risky prospects differ, this implies that option I is chosen only once.

Bewley preferences. Here we consider decision making models that allow preferences to be incomplete because of uncertainty.[13] Such models have proposed specific decision rules that guide choice behavior when preferences are incomplete. In Bewley (2002) the DM follows a unanimity rule whereby an act f is preferred over g if, and only if, its expected utility is larger than that of g for all priors. When acts cannot be compared according to this rule, the decision maker keeps the status quo act as the default choice. As on our experiment there is no (explicit) status quo this approach does not make a clear prediction. In Gilboa et al. (2010) the decision maker is characterized by two preference relations that correspond to an objective and subjective idea of rationality. The first relation leads to a choice rule equivalent to Bewleys unanimity, the second to the maxmin rule. Thus, in our experiment this model makes either no clear prediction or predicts that option I is chosen at most once.

In our experimental setting, the model of variational Bewley preferences proposed by Faro (2015) is the most apt to provide choice predictions when preferences are incomplete due to uncertainty. We therefore discuss it here in a little bit more detail. In his approach Faro relaxes the strictness of Bewley's unanimity rule by allowing the DM to give different weights to different priors.

[12] For a formal proof, see Appendix A.

[13] We do not discuss approaches where incompleteness is due to taste (see Ok, 2002; Dubra et al., 2004; Ok et al., 2012). We do not exclude the possibility of incompleteness of that kind and if it exists we should detect it in our experiment *Risk-Sure* where choices are under risk and certainty. As we will see below our results do not suggest taste incompleteness plays a role in our experiment.

Specifically, for an indifference relation $\sim$ between two acts f and g it holds that

$$f \sim g \Leftrightarrow \eta(p) \geq \left| \int u(f)dp - \int u(g)dp \right| \text{ for all prior } p, \tag{1}$$

where the function $\eta(p)$ reflects the weight given to a prior, or differently stated, its plausibility.[14] That is, indifference between two acts implies that every prior p creates a gap in the acts' expected utilities bounded by the prior's plausibility function. In order to simplify notation and apply the model to our experiment, we indicate with $r(w)$ the expected utility of a risky prospect characterized by a winning probability of w and with $a(p)$ the expected utility of the ambiguous prospect (given prior p) in the Part 1 decision task.

From statement (1) above it follows that a subject is indifferent between risky acts and the ambiguous act in all decision situations characterized by

$$\eta(p) \geq |r(w) - a(p)| \text{ for all prior } p. \tag{2}$$

When priors have full plausibility, i.e. $\eta(p) = 0$, indifference entails that both acts have the same expected utility, $r(w) = a(p)$. Hence, it is predicted that option I may be chosen only in the decision situation where $w = p$. However, for lower degrees of plausibility, i.e. $\eta(p) > 0$, a wider class of indifference applies and option I may be chosen in several decision situations.

Thus, an important implication of the model is that a decision maker with incomplete preferences due to uncertainty may be characterized by a wide class of indifference relations over uncertain acts. In our context, choosing option I in a given situation effectively reveals indifference between the risky and the ambiguous prospect. Hence, we may expect that option I may be chosen multiple times by a DM characterized by variational Bewley preferences.

3.6 Results

For convenience, in what follows participants' choices in Part 1 of the experiment are recoded and analyzed as if red had been the selected winning color of each participant.[15]

We first explore if the choice pattern of our participants, when choosing between risky and ambiguous prospects, is consistent with behavior reported in the literature. We find that the

[14] Note that $\eta(p) = 0$ for priors with full plausibility, while higher values of η indicates priors that are given less weight.

[15] To preclude that results are due to noise and/or incomprehension we exclude from the analysis all participants who made (weakly) dominated choices in the first and last decision situation, such as choosing the ambiguous prospect instead of the sure payment or choosing to earn nothing for sure instead of selecting the ambiguous prospect. This leaves us with 35 observations. In Appendix C we report an analysis using data of all participants and find that the results are qualitatively the same. Note also that excluding participants who have made such dominated choices makes the case for incompleteness more difficult as such behavior could in principle also be a reflection of incompleteness.

risky prospect is chosen by the large majority of participants as long as the winning probability is at least 0.5, whereas the ambiguous prospect is the most common choice in all decision situations where the winning probability of the risky prospect is at most 0.4. Ignoring choices in favor of option I, we use binomial tests to verify for each decision situation separately, whether the risky or ambiguous prospect is chosen by the majority of participants. We find that the likelihood of choices favoring the risky prospect is significantly larger than 50% at the 1% significance level in all decision situations characterized by a winning probability of at least 0.5. On the other hand, choices favoring the ambiguous prospect are significantly more likely than 50% at the 1% significance level in all choice situations characterized by a winning probability $w \leq 0.4$. In the decision situations where the winning probability of the risky prospect is equal to 0.45, the number of individuals choosing the risky prospect is not significantly different from the number choosing the ambiguous one (p-value = 0.19). Consistent with the large body of results reported in the literature (see Camerer and Weber, 1992 for a review), these results thus indicate that subjects are moderately averse to ambiguity. This gives us confidence in that our pool of participants is similar to most other subject pools used in the literature.

We now turn to our main research question and analyze choices in favor of option I. Our first result in that respect is that the choice of option I is very frequent. When the winning probability of the risky prospect, w, is equal to 0.35 almost one third of the participants (29%) choose option I. Further, when $0.5 \leq w \leq 0.4$, the relative majority of participants (40%) choose option I, and when $w = 0.55$, 20% of the participants choose I. These figures already suggest that some individuals choose option I more than once.

This impression is corroborated by the histogram in Figure 1, which reports the relative frequency of participants who choose option I n times. Specifically, only 23% of the subjects never select option I and 29% select it exactly once. The remaining 48% of participants choose option I in at least two decision situations and more than 35% choose option I at least three times. Further, of those participants who choose option I more than once, 83% do so in consecutive decision situations.

To summarize, contrary to decision making models predicting at most one choice of I, we find that almost half of the participants choose option I more than once. This is consistent with about half of the subjects exhibiting variational Bewley preferences when choosing between risky and ambiguous prospects. However, as discussed in the previous section, when individuals are sufficiently insensitive to likelihood changes, PT may also account for such behavior. We address this possibility in the following section.

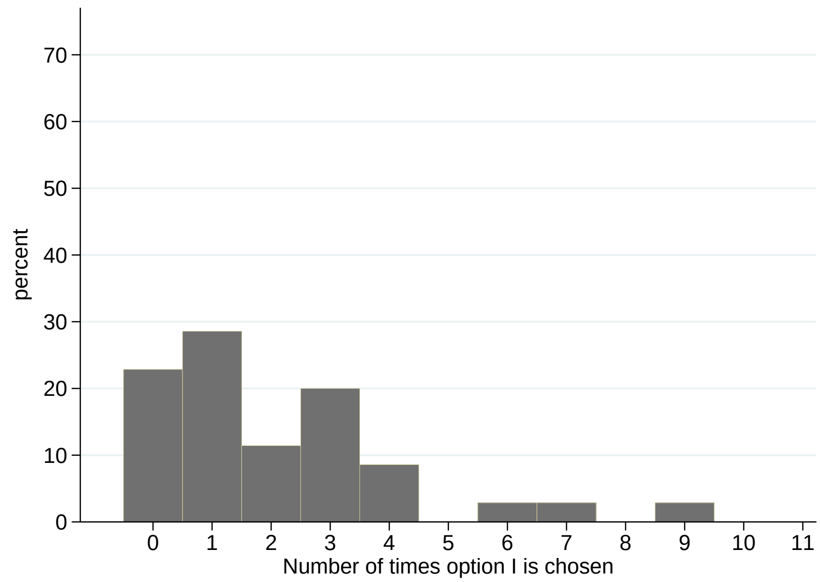

Figure 1: *Risk-Ambi* – Relative frequency of participants choosing option I n times.

Prospect Theory. To test if likelihood insensitivity can explain repeated choices of option I, we use the choice data of the second part of the experiment and estimate PT parameters at the individual level. For these estimations we need to choose specific functional forms, both for the value function $v(x)$ and probability weighting function $g(q)$, that combine parsimony with good data fit. For the value function it has been shown that a simple power function $v(x) = x^{\alpha}$, $\alpha > 0$ is a good compromise between these requirements (Wakker, 2008; Bruhin et al., 2010). For probability weighting we adopt the function originally proposed by Prelec (1998):

$$g(q) = \exp(-(-\ln q)^{\gamma}) \quad 0 < \gamma < 1 \tag{3}$$

As in the original formulation of prospect theory Kahneman and Tversky (1979), $g(q)$ has an inverted S-shape which implies that small probabilities are over-weighted and large probabilities are under-weighted. The degree of deviation from linearity is conveniently captured by the single parameter γ, where smaller values refer to larger deviations. The function has been used in several empirical applications (see, e.g., Gonzalez and Wu, 1999; Bruhin et al., 2010; Epper et al., 2011).

We jointly estimate the parameter values of α and γ at the individual level by minimizing the sums of squared distances between the predicted and observed certainty equivalents. To correct for heteroscedasticity, lottery outcomes are normalized.[16]

[16] The calculation of certainty equivalents in the lottery choice tasks (in Part 2 of the experiment) requires a unique switching point from the sure amount to the lottery. We did not impose this restriction on participants' behavior in the experiment and do observe sometimes multiple switching points. In these cases we use the most risk averse certainty equivalent.

From our discussion in Section 3.5 we know that PT can be used to explain repeated choices of option I if and only if the winning probabilities of different risky prospects receive the same decision weight. Empirically, we see that most choices of option I occur for winning probabilities between 0.35 and 0.50 of the risky options. Applying the probability weighting function (3) it can be shown that $\gamma \leq 0.2$ is needed to ensure that the difference in probability weights for consecutive decision situations is about 0.01 or lower, for probabilities in the interval 0.25 to 0.6. Put differently, probability weighting can explain repeated choices of option I only if γ is not larger than 0.2. We find that the average value of γ among subjects who choose option I more than once is 0.39, which is significantly above the threshold value of 0.2 (Wilcoxon test $p-$value < 0.01).[17] Moreover, out of the 17 participants who repeatedly choose option I only 3 have an estimated $\gamma \leq 0.2$. Hence, we conclude that likelihood insensitivity cannot explain the observed repeated choices of option I.

Our results so far show that about 50 percent of the participants repeatedly choose option I, which is (1) inconsistent with prominent models of decision making under risk and uncertainty (subjective expected utility, uncertainty aversion) and (2) cannot be explained by participants' insensitivity to likelihood changes. Although suggestive in favor of incomplete preferences due to multiple priors, one might argue that the repeated choice of option I could also be due to intransitive indifference under certainty and risk. In the next section we describe an experiment designed to test this hypothesis.

4 Experiment *Risk-Sure* – Testing for Intransitive Indifference

In order to test whether the repeated choice of option I could be due to intransitive indifference under risk and certainty, we run an additional experiment with 50 subjects. In this experiment, participants have to make choices between risky prospects as in *Risk-Ambi* (see Table 1) but the ambiguous prospect is replaced by a sure payment of €7.50. Option I is also available, and if chosen, it entails that either the risky prospect or the certain payment is assigned to the subject with equal probability.

The idea of intransitive indifference over constant acts and/or acts with known probabilities dates back to Luce' (1956) famous 'coffee and sugar' example and in essence says that decision makers may fail to appreciate the differences between choice options when these are not of sufficient magnitude.[18] In *Risk-Ambi* subjects may repeatedly choose option I, and thus display

[17] The average estimated value of α is 0.88.

[18] The example goes as follows. If one likes sugarless coffee one may be indifferent between a cup of coffee without sugar and one that contains just a grain of sugar. Similarly, one may be indifferent between a cup of coffee that contains x grains of sugar and one that contains $x + 1$ grains of sugar. However, one would surely prefer a

intransitive indifference over risky lotteries, if they do not sufficiently perceive the difference between consecutive risky lotteries. If so, we should also observe that option I is frequently and repeatedly chosen in *Risk-Sure*.

4.1 Results

Figure 2 depicts the relative frequency of choices in favor of option I.[19] It shows that 90 percent of the participants choose option I at most once. This is in stark contrast to the observation in *Risk-Ambi* where this was the case for only 51 percent. Hence, intransitive indifference cannot explain the repeated choice of option I observed in *Risk-Ambi*.

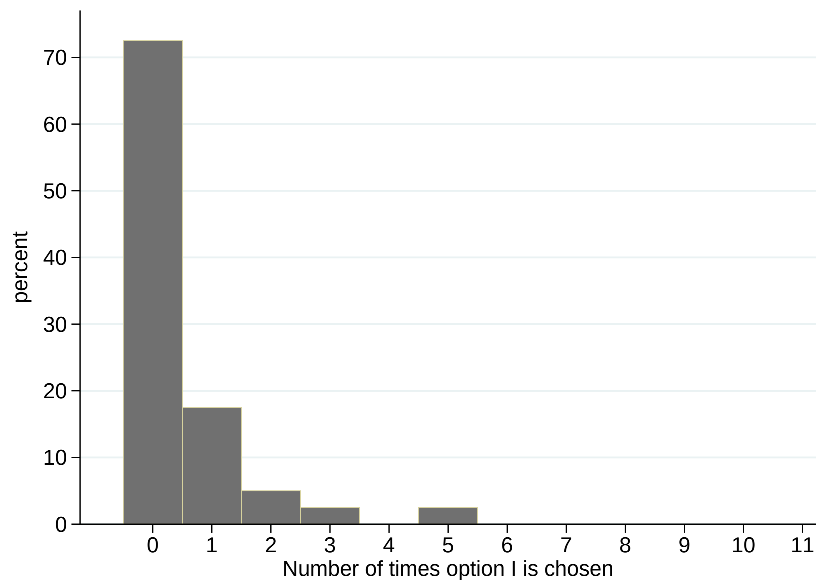

Figure 2: *Risk-Sure* – Relative frequency of participants choosing option I n times.

We note also that the infrequent choice of option I in *Risk-Sure* also corroborates our finding, reported further above, that probability weighting cannot account for the frequent choice of option I in *Risk-Ambi*.

sugarless coffee to one with a lot of sugar, and hence the preference relation over these cups of coffee is intransitive (Fishburn, 1970).

[19] Applying the same criteria as in *Risk-Ambi*, we excluded from the analysis 10 subjects that choose a weakly dominated option.

5 Experiment ***Risk-Ambi-high*** – Robustness and Comparative Statics Based on Variational Bewley Preferences

The purpose of our third experiment is to test, first, whether repeatedly choosing option I is robust against a change in incentives and, second, whether this behavioral regularity is consistent with comparative statics predictions based on variational Bewley preferences (Faro, 2015). To this end we conduct an experiment that is the same as *Risk-Ambi*, described in Section 3, except that the prize of the ambiguous prospect is now increased by 33 percent (i.e., €5) and is thus equal to €20.

We expect that in *Risk-Ambi-high* at least as large a percentage of participants as in *Risk-Ambi* will choose option I repeatedly. In addition, if repeated choice of option I is an expression of variational Bewley preferences, the decision situations where option I is most frequently chosen should differ between *Risk-Ambi* and *Risk-Ambi-high*. Specifically, we hypothesize that in *Risk-Ambi-high* these decision situations are characterized by higher winning probabilities of the risky prospects. To see this, recall from Section 3.5 that in *Risk-Ambi* a subject with variational Bewley preferences is predicted to choose option I in all the decision situations characterized by

$$\eta(p) \geq |r(w) - a(p)| \text{ for all prior } p, \tag{4}$$

where $r(w)$ denotes the expected utility of a risky prospect characterized by a winning probability of w, and $a(p)$ the expected utility of the ambiguous prospect in *Risk-Ambi*.

In the following, $a_h(p)$ denotes the expected utility of the ambiguous prospect in *Risk-Ambi-high*. Further, as the subject pool as well as all procedural details are the same in all experiments we can assume that participants in *Risk-Ambi* and *Risk-Ambi-high* hold on average the same priors and the same plausibility weighting function η.

The higher winning prize in *Risk-Ambi-high* compared to *Risk-Ambi* then implies that for any given prior p on the ambiguous urn it holds that, $a(p) \leq a_h(p)$. Hence, it follows that in *Risk-Ambi-high* we should observe that option I is chosen in decision situations characterized by higher values of w compared to *Risk-Ambi*.[20]

To illustrate this in terms of the experiments, consider the simple case where a subject's utility is linear in monetary prizes, holds a single prior $p = 0.5$ over the ambiguous urn, and is characterized by a plausibility function $\eta(0.5) = 0.05$. We can normalize the expected utility of the risky and ambiguous prospects such that $r(w) = w$, $a(p) = p$, and $a_h(p) = \frac{4}{3}p$, respectively.

[20] We note that for *Risk-Ambi-high* models of complete preferences under uncertainty imply a switching point from the risky to the ambiguous prospect at higher winning probabilities of the risky prospect. However, they do not predict a shift of repeated choices of I because these models predict at most one choice of I irrespective of the winning prize in the ambiguous prospect.

In *Risk-Ambi*, this subject is indifferent between the risky and the ambiguous urn in decision situations where $0.05 \geq |w - 0.5|$. This implies that the subject is predicted to choose option I in decision situations characterized by winning probability $w \in \{0.45, 0.50, 0.55\}$. In *Risk-Ambi-high*, a 'twin' of this subject is indifferent between the risky and the ambiguous urn in decision situations where $0.05 \geq \left|w - \frac{4}{3}0.5\right|$. Hence, s/he predicted to choose option I for risky decision situations characterized by winning probabilities $w \in \{0.65, 0.70\}$.[21]

For experiment *Risk-Ambi-high* we applied the same procedures as for the other two experiments and recruited 53 students from Maastricht University. Subjects who took part in *Risk-Ambi* or *Risk-Sure* were not allowed to participate. The experiment lasted on average 90 minutes and the average earnings per subjects were €28.70.

5.1 Results

Subjects' choices in *Risk-Ambi-high* reveal that the results obtained in *Risk-Ambi* are robust.[22] For the moment ignoring choices of option I, we find that the risky prospect is chosen by more than 50% of the subjects in all decision situations characterized by $w \geq 0.55$ ($p-$value ≤ 0.01, two sided binomial test). Conversely, the ambiguous prospect is chosen by more than 50% of the subjects in all decision situations where $w \leq 0.45$ ($p-$value < 0.01). In the decision situation where $w = 0.50$, the number of individuals choosing the risky prospect is not significantly different from the number choosing the ambiguous one ($p-$value $= 0.24$).

More interestingly, Figure 3 shows a histogram of the relative frequency of option I in *Risk-Ambi-high*. It shows that about only 40 percent of the participants choose option I at most once, whereas the remaining subjects choose it in at least two decision situations. This data thus confirm that the repeated choice of option I is robust against increases in the prize of the ambiguous prospect (cf. Figure 1 for *Risk-Ambi*).

When comparing participants' choices in the two experiments, we find additional support for variational Bewley preferences. Figure 4 shows how choices of option I are distributed over the decision situations in the two experiments involving and ambiguous urn. Compared to *Risk-Ambi*, in *Risk-Ambi-high*, option I is most common in decision situations characterized by a higher winning probability of the risky prospect, as predicted. To test whether this change in behavior is statistically significant, we conduct chi-square tests for every decision situation and

[21] Fewer choices of option I are predicted for *Risk-Ambi-high* than for *Risk-Ambi* because we assume that utility is linear, for the sake of the example. Small degrees of concavity are sufficient for intervals to be of equal size in the two experiments.

[22] As in the other experiments, we exclude from the analysis all subjects that made dominated choices in the first and last decision situation. This leaves us with 38 observations.

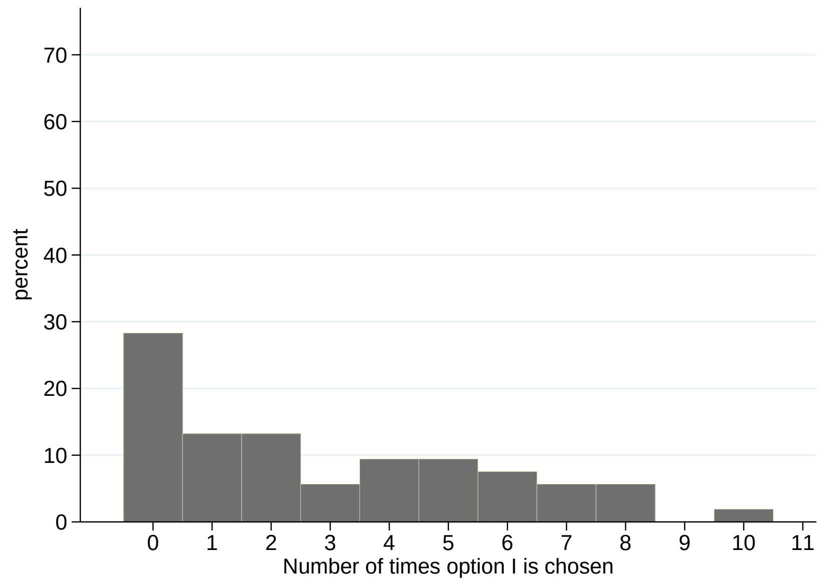

Figure 3: *Risk-Ambi-high* – Relative frequency of participants choosing option I n times.

test the hypothesis that option I is chosen more often in *Risk-Ambi-high* than in *Risk-Ambi*. These tests indeed show that in *Risk-Ambi-high* significantly more subjects choose option I in the decision situations characterized by $w = 0.60$ and $w = 0.55$ ($p-$value $= 0.05$ and 0.04, respectively), whereas differences are statistically insignificant in all other decision situations ($p-$values > 0.16).

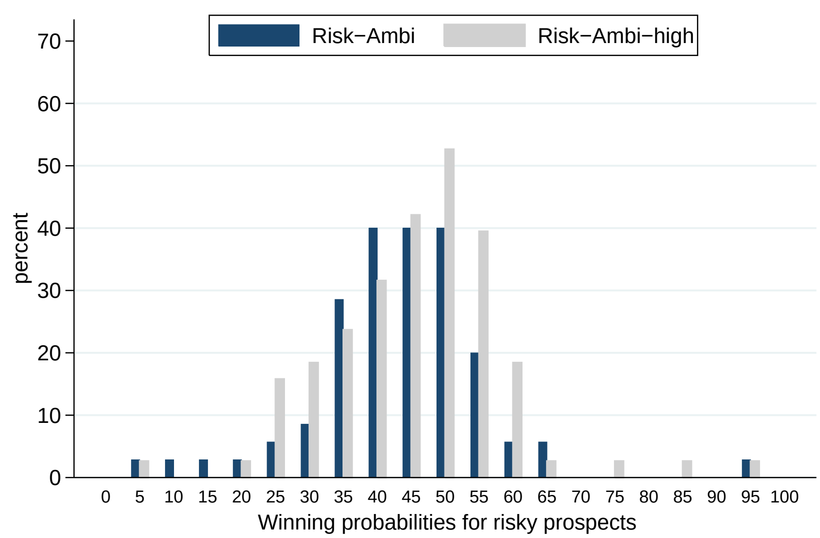

Figure 4: Frequencies of choices of option I in *Risk-Ambi* and *Risk-Ambi-high*.

6 Discussion

In our experiments subjects could delegate their choice to a fair random device, option I, which relates our study to a few recent empirical papers investigating a possible preference for randomization. Dominiak and Schnedler (2011) experimentally investigate the relationship between randomization-loving and uncertainty-aversion. They find that these are not negatively associated and that a non-negligible minority of subjects are even randomization-averse. More closely related to our study, Dwenger et al. (2014) conduct experiments where individuals have to choose between (sets of) vouchers twice, where each choice is implemented with a certain known probability. In one treatment subjects can also explicitly choose to randomize their choices. The authors find that a fraction of choices is implicitly consistent with a preference for randomization and that it increases when the randomization possibility is explicit.

To explain their observations the authors propose a theoretical framework in the spirit of regret theory (Loomes and Sugden, 1982). The key assumptions are that decision makers may be responsibility averse and that randomization allows them to minimize anticipated regret feelings associated with choice responsibility. This framework may also be used to explain our results when subjects have to choose between risky and ambiguous prospects (experiments *Risk-Ambi* and *Risk-Ambi-high*). For that it needs to be assumed, however, that choosing option I relieves the decision maker from anticipatory feelings of regret and rejoice. That is, the active choice of the randomization devise should not be affected by any feelings of regret and rejoice, whereas an active choice for the risky or ambiguous prospect will be affected. If one is willing to make this assumption, it would imply that subjects should have a preference for randomization also when they have to choose between risky prospects and certain payments.[23] However, this is not the case, as we have seen in our experiment *Risk-Sure* where subjects hardly ever choose option I (see Section 4). Thus, anticipated regret feelings do not appear to be a satisfactory explanation of the choice pattern observed in our experiments.

We note that our interpretation of the results should not be considered as a contradiction to the explanations put forward in Dwenger et al. (2014), because we consider choices and preferences under uncertainty, whereas these authors explore decisions under risk. We would rather suggest that incomplete preferences due to indecisiveness in taste (as in Ok et al., 2012) may be an alternative framework to understand their results.

[23]Specifically, it can be shown that, under the assumption that actively choosing option I does not lead to regret-rejoice whereas active choice of the risky or ambiguous prospect does, to rationalize (repeated) choice of option I in *Risk-Ambi* it is necessary that regret feelings are sufficiently stronger than rejoice feelings. If this is the case it can be further shown that repeated choice of I should also be observed in *Risk-Sure*. See Appendix B for a formal derivation of these statements.

One may wonder whether probabilistic choice and/or mistakes can account for the choice pattern observed in our experiments. Probabilistic choice models are based on the idea that individuals make choice mistakes and, thus, when confronted with two options do not necessarily choose the one that maximizes their utility. The likelihood of making a mistake is a function of the expected utility difference between the available options: the larger the expected utility difference, the lower the probability of choosing the dominated option. The first model of this kind was proposed by Luce (1959), and applications in its spirit appear, for instance, in Harless and Camerer (1994) and Hey and Orme (1994). According to this approach, the repeated choice of option I in our experiments *Risk-Ambi* and *Risk-Ambi-high* could be the result of mistakes, which are more likely when the expected utility difference between the risky and the ambiguous prospect is perceived as small.

However, when mistakes would be a good explanation for the behavior observed in *Risk-Ambi* and *Risk-Ambi-high*, we should observe that option I is also frequently and repeatedly chosen in *Risk-Sure*, which we do not see. We acknowledge that the results in *Risk-Sure* may not allow to completely rule out that subjects make mistakes in the experiments with ambiguous urns. The decision environments in *Risk-Ambi* and *Risk-Ambi-high* may be perceived as more complex, and thus may generate more mistakes, than in *Risk-Sure*. The idea that complexity increases decision errors is intuitively appealing, but it should also be noted that, to the best of our knowledge, there is no empirical evidence that systematically links complexity to mistakes. Moreover, the choice patterns in *Risk-Ambi* and *Risk-Ambi-high* are in itself not supportive of the mistakes hypothesis. Indeed, if choices in favor of option I would reflect decision errors one would expect them to be distributed more randomly instead of being clustered as repeated choices of I.

Incomplete preferences are also invoked as a plausible explanation for the results in Agranov and Ortoleva (2015). The authors use a series of experiments to demonstrate that stochastic choices can be deliberate instead of mistaken. They discuss the behavior observed in their experiments in light of the model by Cerreia-Vioglio et al. (2015), in which the decision maker can be characterized by a set of possible utility functions over outcomes. When the decision maker does not know which function she should maximize, a randomization device may be strictly preferred to a deterministic choice. Our results suggest that delegation to a chance device may also be 'optimal' when choices involve uncertain prospects. Moreover, by revealing the inadequacy of decision making models that assume completeness, our experiment supports the idea that randomization choices are due to incomplete preferences under uncertainty.

We also explored if individual characteristics can account for the repeated choice of option I. This is largely not the case (see Appendix D for statistical tests). Neither the psychological constructs measured by the Cognitive Reflection Test (Frederick, 2005) or the Rational-Experiential

Inventory (Epstein et al., 1996) nor risk-aversion or probability weighting are predictive for repeated choice of option I. The only exception is gender: female participants are significantly more likely to choose option I than male participants do.

Our paper is related to the literature on preference imprecision (see, for example, Cohen et al., 1987; Butler and Loomes, 2007; Cubitt et al., 2015). This growing area of research shows that, in decision making under risk, individuals may state having no clear preference for one of the available choice options. We document a similar phenomena when decisions involve ambiguous prospects but not when they involve only risky prospects and sure outcomes. Moreover, we dig into the determinants of imprecision and provide evidence that under uncertainty incomplete preferences may be at the core of subjects' stated imprecision.

Decision making models relaxing the completeness axiom have proposed specific decision rules that guide choice behavior. For example, a decision maker in Bewley (2002) follows a unanimity rule whereby an act f is preferred over g if, and only if, its expected utility is larger than that of g for all priors. When acts cannot be compared according to this rule, the decision maker keeps the status quo act as the default choice. As in our experiment there is no status quo this decision rule doe not make a prediction. In Gilboa et al. (2010), when preferences are incomplete in the Bewley sense, the maxmin rule guides choice behavior and thus does not allow for repeated choices of option I.

In our view, the choice behavior of the subjects in our experiment is closest to the characterization in Faro (2015). The author shows that indifference between uncertain acts can be the expression of an incomplete preference relation due to uncertainty, and more important, that wide intervals of indifference can emerge when the decision maker's maximum acceptable loss, $\eta(\alpha)$ in the model, is sufficiently high. Subjects' repeated choice of option I is consistent with this account. Nevertheless, we want to emphasize that our main goal is to provide first empirical evidence on the existence of Bewley preferences and not a horse race between different models. Future empirical research should aim at identifying more precisely which decision rule individuals employ when their preferences are incomplete.

7 Conclusion

The completeness axiom has been identified as a questionable assumption of economic decision making models, especially when uncertainty is involved, and in response a number of theoretical models relaxing it have been developed. However, empirical evidence on actual incompleteness of preferences is difficult to gather as such evidence has to come from observed choices. In this paper we propose a series of laboratory experiments with the aim to reveal whether preferences may be incomplete under uncertainty. Our empirical strategy is to create a choice environment that allows us to interpret behavior to be either consistent with decision making models, both normative and descriptive, that assume completeness or with incomplete preferences due to uncertainty.

We find that half of the studied subjects display a choice pattern that is inconsistent with models that allow for a single representation of the ambiguous prospect. We show that the observed choice pattern is consistent with the existence of incomplete preference à la Bewley (2002) and more specifically Faro (2015). Furthermore, we also provide evidence showing that intransitive indifference under certainty and risk is not at the basis of the observed choices.

We show that incomplete preferences under uncertainty – next to being a theoretically interesting and intuitively appealing concept – can also be empirically revealed. Our approach also shows that not all people seem to exhibit incomplete preferences under uncertainty as some appear to be less indecisive than others.

Guided by the work of Gilboa et al. (2010), we would like to conclude with a reflection on the rationality of the observed choice pattern. These authors propose that a decision maker can make two types of choices. Objective rational choices are such that the decision maker could convince others that she is right in making them, while choices are subjectively rational when the decision maker cannot be convinced that she is wrong when making them. These two notions of rationality are directly related to the completeness axiom: when preferences are incomplete because of uncertainty, an *objectively* justifiable choice may not exists, but *subjective* rationality eventually guides choice behavior. The repeated choice of option I seems consistent with this notion of subjective rationality.

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Appendix

A Models of Decision Making under Uncertainty

In the following we consider the discussed models of decision making under uncertainty and prove that they cannot account for the repeated avoidance of active choice.

A.1 α-maxmin Expected Utility Theory

Consider $\alpha-$ maxmin expected utility (MEU) theory as in Ghirardato et al. (2004). The decision maker holds a set of priors $C = [\underline{c}, \overline{c}] \subseteq [0, 1]$ on the ambiguous event and is characterized by an index α which captures attitude to ambiguity. The index lies in the interval $[0, 1]$ and can be viewed as the weight that the decision maker places on the most pessimistic scenario, given his set of prior C. The utility function $U(\cdot)$ is the same as assumed in expected utility theory. In our experiment, subjects would evaluate ambiguous prospects as follows:

$$\alpha - MEU_a(x_1, x_2; q, \alpha) = \alpha \min_{q \in [\underline{c}, \overline{c}]} [qU(x_1) + (1 - q)U(x_2)] + (1 - \alpha) \max_{q \in [\underline{c}, \overline{c}]} [qU(x_1) + (1 - q)U(x_2)].$$

Where q is the (unknown) winning probability of the ambiguous prospect, x_1 is the monetary prize equal to €15 and x_2 is the €0 outcome. Since the worst prior is $\underline{c}$ and the best prior is $\overline{c}$ and $U(x_1)$ $(U(x_2))$ can be normalized to 1 (0), the above function is equivalent to:

$$\alpha - MEU_a(x_1, x_2; q, \alpha) = \alpha\underline{c} + (1 - \alpha)\overline{c}.$$

Applying the same normalizations, expected utility from a risky prospect is given by $EU_r(x_1, x_2; p_r) = p_r$. A subject chooses option I if:

$$\frac{1}{2} [\alpha\underline{c} + (1 - \alpha)\overline{c}] + \frac{1}{2} p_r \geq \alpha\underline{c} + (1 - \alpha)\overline{c}$$

And, at the same time, if:

$$\frac{1}{2} [\alpha\underline{c} + (1 - \alpha)\overline{c}] + \frac{1}{2} p_r \geq p_r$$

This implies that option I is chosen when the DM is indifferent between the risky and the ambiguous lottery:

$$\alpha\underline{c} + (1 - \alpha)\overline{c} = p_r$$

■

A.2 Prospect Theory

Prospect theory (PT) as proposed in Tversky and Kahneman (1992) allows for non-linear decision weights. Let $W^+(p_r)$ and $W^+(A)$ be the decision weighting functions for risky and ambiguous prospects, respectively, and let $v(x)$ be a PT value function. A decision maker evaluates the ambiguous prospect as

$$PT_a(x_1, x_2; A) = W^+(A)v(x_1) + W^+(\neg A)v(x_2) \Leftrightarrow PT_a(x_1, x_2; A) = W^+(A)v(x_1),$$

where A the denotes the winning event and $\neg A$ its complement and the second equation follows (w.l.o.g.) from the normalization $v(x_2) := 0$. Similarly, a risky prospect with winning probability p_r is evaluated as

$$PT_r(x_1, x_2; p_r) = W^+(p_r)v(x_1) + W^+(1 - p_r)v(x_2) \Leftrightarrow PT_r(x_1, x_2; p_r) = W^+(p_r)v(x_1).$$

It follows that multiple choices of option I for different winning probabilities $p_i, p_{i+1}, \ldots, p_{i+k}$ of the risky prospect are PT rationalizable if and only if

$$W^+(A) = W^+(p_i) = W^+(p_{i+1}) = \cdots = W^+(p_{i+n}).$$

In other words, multiple choices of option I are possible under PT if and only if the decision weight function is very flat, at least locally. ■

B Anticipated Regret-Rejoice

Here we first show the conditions under which anticipated regret-rejoice may account for repeated choice of option I in experiment *Risk-Ambi*, where participants had to choose between different risky prospects, an ambiguous prospect, and option I. Thereafter, we derive the conditions for repeated choice of option I in *Risk-Sure*, where participants had to choose between risky prospects, a sure fixed payment, and option I. We will show that an asymmetry of the utility effect of regret and rejoice is a necessary condition for rationalizing the choice of option I in both, *Risk-Ambi* and *Risk-Sure*. Therefore, since we observe repeated choice of option I in *Risk-Ambi*, we should also observe it in *Risk-Sure*. This is not the case and it is thus – on theoretical grounds – not possible to rationalize repeated choice of option I in *Risk-Ambi* with anticipated regret-rejoice.

Note first that we need to assume that actively choosing option I does *not* lead to anticipated regret or rejoice and, hence, outcomes of the chance device are evaluated according to expected utility (EU). Without this assumption anticipated regret-rejoice could never explain repeated choice of option I as active choices and delegated choices would have the same regret-rejoice consequences.

In contrast to option I, active choices of a risky, ambiguous, or certain prospect may lead to regret or rejoice and are therefore evaluated using a regret-rejoice utility (RRU) as introduced by Loomes and Sugden (1982). Hence, outcomes are evaluated according to $V(x,y) = u(x) + R(u(x) - u(y))$ where x is the actual outcome, y the counter-factual outcome, $u(.)$ a "choiceless utility function" (Loomes and Sugden, 1982, p.807), and $R(x - y)$ the real-valued regret-rejoice function with $R(0) = 0$; $R(.)$ is non-decreasing. In the following, under slight abuse of notation we will simply write x (y) for the assigned real-valued utility index $u(x)$ ($u(y)$) for outcomes x (y).

Regret-rejoice in experiment *Risk-Ambi*. Consider the 21 decisions between the risky and the ambiguous prospects in *Risk-Ambi*. Below the possible states of the world are listed, where w_R (l_R) denotes that a winning (losing) ball is extracted from the risky urn and w_A (l_A) denotes that a winning (losing) ball is extracted from the ambiguous urn. L_R (L_A) denotes that the risky lottery matters for the payment when option I was chosen.

The possible states of the world are:

S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
w_R, L_R, w_A	w_R, L_A, w_A	l_R, L_R, w_A	l_R, L_A, w_A	l_R, L_R, l_A	l_R, L_A, l_A	w_R, L_R, l_A	w_R, L_A, l_A

Let $p(S_r)$ denote the probability that state r is the true state of the world, p_r the winning probability of the risky urn in decision situation r, q the subjective winning probability a participant assigns to the ambiguous urn, x_1 the choiceless utility index of winning the (high) prize (€15,- in the experiment), and x_2 the choiceless utility index of winning the (low) prize (€0,- in the experiment). Below we will assume $x_2 = 0$ w.l.o.g.

It follows that the RRU of the risky prospect is not smaller than the EU of choosing option I, i.e., $RRU(\text{risky}) \geq EU(\text{option } I)$, if and only if:

$$
\begin{aligned}
&p(S_1)[x_1 + f(x_1 - x_1)] + p(S_2)[x_1 + f(x_1 - x_1)] + p(S_3)[x_2 + f(x_2 - x_2)] + p(S_4)[x_2 + f(x_2 - x_1)] + \\
&p(S_5)[x_2 + f(x_2 - x_2)] + p(S_6)[x_2 + f(x_2 - x_2)] + p(S_7)[x_1 + f(x_1 - x_1)] + p(S_8)[x_1 + f(x_1 - x_2)] \geq \\
&p(S_1)x_1 + p(S_2)x_1 + p(S_3)x_2 + p(S_4)x_1 + p(S_5)x_2 + p(S_6)x_2 + p(S_7)x_1 + p(S_8)x_2 \\
&\Leftrightarrow \\
&p(S_4)[0 - x_1 + f(0 - x_1)] + p(S_8)[x_1 - 0 + f(x_1 - 0)] \geq 0 \\
&\Leftrightarrow \\
&(1 - p_r)\frac{1}{2}q[-x_1 + f(-x_1)] + p_r\frac{1}{2}(1 - q)[x_1 + f(x_1)] \geq 0 \\
&\Leftrightarrow \\
&p_r[x_1 + f(x_1) - qf(-x_1) - qf(x_1)] \geq q[x_1 - f(-x_1)] \\
&\Leftrightarrow \\
&p_r[x_1 + [1 - q]f(x_1) - qf(-x_1)] \geq q[x_1 - f(-x_1)] \\
&\Leftrightarrow
\end{aligned}
$$

$$
p_r \geq \frac{q[x_1 - f(-x_1)]}{x_1 + [1 - q]f(x_1) - qf(-x_1)} := \overline{p}_{\text{exp1}} \tag{5}
$$

Similarly, the RRU of the ambiguous prospect is not smaller than the EU of choosing option I, i.e., $RRU(ambiguous) \geq EU(\text{option } I)$, if and only if:

$$
\begin{aligned}
&p(S_1)[x_1 + f(x_1 - x_1)] + p(S_2)[x_1 + f(x_1 - x_1)] + p(S_3)[x_1 + f(x_1 - x_2)] + p(S_4)[x_1 + f(x_1 - x_1)] + \\
&p(S_5)[x_2 + f(x_2 - x_2)] + p(S_6)[x_2 + f(x_2 - x_2)] + p(S_7)[x_2 + f(x_2 - x_1)] + p(S_8)[x_2 + f(x_2 - x_2)] \geq \\
&p(S_1)x_1 + p(S_2)x_1 + p(S_3)x_2 + p(S_4)x_1 + p(S_5)x_2 + p(S_6)x_2 + p(S_7)x_1 + p(S_8)x_2 \\
&\Leftrightarrow \\
&p(S_3)[x_1 - 0 + f(x_1 - 0)] + p(S_7)[0 - x_1 + f(0 - x_1)] \geq 0 \\
&\Leftrightarrow \\
&(1 - p_r)\frac{1}{2}q[x_1 + f(x_1)] + p_r\frac{1}{2}(1 - q)[-x_1 + f(-x_1)] \geq 0 \\
&\Leftrightarrow \\
&q[x_1 + f(x_1)] \geq p_r[x_1 - [1 - q]f(-x_1) + qf(x_1)] \\
&\Leftrightarrow
\end{aligned}
$$

$$
p_r \leq \frac{q[x_1 + f(x_1)]}{x_1 - [1 - q]f(-x_1) + qf(x_1)} := \underline{p}_{\text{exp1}} \tag{6}
$$

To rationalize repeated choice of option I as an optimal decision under regret-rejoice it must hold that $RRU(\text{risky}) < EU(\text{option } I)$ and $RRU(\text{ambiguous}) < EU(\text{option } I)$ and, hence, that there are some winning probabilities p_r of the risky prospect such that $p_r < \overline{p}_{\text{exp1}}$ and $p_r > \underline{p}_{\text{exp1}}$ simultaneously hold. A first observation is that this can never hold when regret and rejoice have a symmetric effect as for $f(x_1) = -f(-x_1)$ equations (5) and (6) collapse to $\overline{p}_{\text{exp1}} = \underline{p}_{\text{exp1}}$. Further, a necessary condition for option I to be an optimal choice is that

$$\underline{p}_{\text{exp1}} < \overline{p}_{\text{exp1}} \Leftrightarrow \frac{q[x_1 + f(x_1)]}{x_1 - [1-q]f(-x_1) + qf(x_1)} < \frac{q[x_1 - f(-x_1)]}{x_1 + [1-q]f(x_1) - qf(-x_1)} \Leftrightarrow$$

$$[x_1 + f(x_1)][x_1 + [1-q]f(x_1) - qf(-x_1)] < [x_1 - f(-x_1)][x_1 - [1-q]f(-x_1) + qf(x_1)] \Leftrightarrow$$

(after some rearrangements)

$$q[2x_1[-f(-x_1) - f(x_1)] + [-f(-x_1)]^2 - [f(x_1)]^2] < 2x_1[-f(-x_1) - f(x_1)] + [-f(-x_1)]^2 - [f(x_1)]^2.$$

In the last inequality both sides are identical, except for the multiplication with q on the l.h.s. Hence, on the one hand, the inequality will be satisfied for all $q \in [0, 1[$ if the r.h.s. is strictly positive, that is, if $-f(-x_1) > f(x_1)$. On the other hand, it will never be satisfied for any $q \in [0, 1[$ if $-f(-x_1) \leq f(x_1)$. Thus, the necessary condition for anticipated regret-rejoice to be an explanation for repeated choice of option I in *Risk-Ambi* can be satisfied only if the disutility from anticipated regret is sufficiently stronger than the anticipated utility from rejoice. ■

Regret-rejoice in experiment *Risk-Sure*. Here we show that if regret-rejoice would be the motivational force behind the repeated choice of option I in *Risk-Ambi*, we should observe repeated choice of option I also in *Risk-Sure*.

Recall that in *Risk-Sure* subjects made 21 decisions between varying risky lotteries and a fixed sure payment. Below the possible states of the world are listed, where w_R (l_R) denotes that a winning (losing) ball is extracted from the risky urn. The letter R indicates that the risky prospect is relevant, whereas the letter S indicates that the sure payment is relevant, in case a subject has chosen option I (i.e., has delegated the choice to the fair chance device). As before x_1 (x_2) denotes the choiceless utility index for the high and low prize, respectively. In the experiment the high prize was €15, the low prize €0, and the sure payment €7,50. We assume below $x_2 = 0$ and indicate the utility index of the sure payment by $x_s := \alpha x_1$ $(0 < \alpha < 1)$ w.l.o.g.

The possible states of the world are:
$\overset{S_1}{w_R, R} \quad \overset{S_2}{w_R, S} \quad \overset{S_3}{l_R, R} \quad \overset{S_4}{l_R, S}.$

It follows that the RRU of choosing a given risky prospect with winning probability p_r is not smaller than the EU of choosing option I, i.e. $RRU(\text{risky}) \geq EU(\text{option } I)$, if and only if:

$$p(S_1)[x_1 + f(x_1 - x_1)] + p(S_2)[x_1 + f(x_1 - \alpha x_1)] + p(S_3)[x_2 + f(x_2 - x_2)] + p(S_4)[x_2 + f(x_2 - \alpha x_1)] \geq$$

$$p(S_1)x_1 + p(S_2)\alpha x_1 + p(S_3)x_2 + p(S_4)\alpha x_1$$

$$\Leftrightarrow$$

$$p_r \frac{1}{2}[x_1 - \alpha x_1 + f(x_1 - \alpha x_1)] + (1 - p_r)\frac{1}{2}[-\alpha x_1 + f(-\alpha x_1)] \geq 0$$

$$\Leftrightarrow$$

$$p_r[x_1 + f(x_1 - \alpha x_1) - f(-\alpha x_1)] \geq \alpha x_1 - f(-\alpha x_1)$$

$$\Leftrightarrow$$

$$p_r \geq \frac{\alpha x_1 - f(-\alpha x_1)}{x_1 + f(x_1 - \alpha x_1) - f(-\alpha x_1)} =: \overline{p}_{exp2}. \tag{7}$$

Similarly, the RRU of the safe payment is not smaller than the expected utility of option I, i.e., $RRU(\text{safe}) \geq EU(\text{option } I)$, if:

$$\begin{aligned}
p(S_1)[\alpha x_1 + f(\alpha x_1 - x_1)] + p(S_2)[\alpha x_1 + f(\alpha x_1 - \alpha x_1)] + \\
p(S_3)[\alpha x_1 + f(\alpha x_1 - x_2)] + p(S_4)[\alpha x_1 + f(\alpha x_1 - \alpha x_1)] \geq p(S_1)x_1 + p(S_2)\alpha x_1 + p(S_3)x_2 + p(S_4)\alpha x_1 \\
\Leftrightarrow \\
p_r \frac{1}{2}[\alpha x_1 - x_1 + f(\alpha x_1 - x_1)] + [1 - p_r]\frac{1}{2}[\alpha x_1 + f(\alpha x_1)] \geq 0 \\
\Leftrightarrow \\
p_r [-x_1 + f(\alpha x_1 - x_1) - f(\alpha x_1)] \geq -[\alpha x_1 + f(\alpha x_1)] \\
\Leftrightarrow \\
p_r [x_1 - f(\alpha x_1 - x_1) + f(\alpha x_1)] \leq \alpha x_1 + f(\alpha x_1) \\
\Leftrightarrow
\end{aligned}$$

$$p_r \leq \frac{\alpha x_1 + f(\alpha x_1)}{x_1 - f(\alpha x_1 - x_1) + f(\alpha x_1)} =: \underline{p}_{exp2}. \tag{8}$$

To rationalize repeated choice of option I as an optimal decision under regret-rejoice it must hold that $RRU(\text{risky}) < EU(\text{option } I)$ and $RRU(\text{safe}) < EU(\text{option } I)$ and, hence, that there are some winning probabilities p_r of the risky prospect such that $p_r < \overline{p}_{exp2}$ and $p_r > \underline{p}_{exp2}$ simultaneously hold. From conditions (7) and (8) it follows that $\underline{p}_{exp2} < \overline{p}_{exp2}$ is a necessary condition for this to hold; or equivalently

$$\frac{\alpha x_1 + f(\alpha x_1)}{x_1 - f(\alpha x_1 - x_1) + f(\alpha x_1)} < \frac{\alpha x_1 - f(-\alpha x_1)}{x_1 + f(x_1 - \alpha x_1) - f(-\alpha x_1)}.$$

After some rearrangements this inequality can be written as

$$\begin{aligned}
\alpha x_1[f(x_1[1-\alpha]) + f(-x_1[1-\alpha])] + [1-\alpha]x_1[f(\alpha x_1) + f(-\alpha x_1)] + \\
f(x_1[1-\alpha])f(\alpha x_1) - f(-x_1[1-\alpha])f(-\alpha x_1) < 0,
\end{aligned}$$

which can hold only if $f(z) < -f(-z)$, i.e., when regret generates a stronger disutility than rejoice generates additional utility.

To see this suppose to the contrary that $f(z) \geq -f(-z)$. It is easy to see that for $f(z) = -f(-z)$ all terms vanish and the inequality can thus not be satisfied. Therefore, suppose $f(z) > -f(-z)$. It follows that both terms in square brackets (first row of the inequality) are strictly positive. It is now sufficient to show that $f(x_1[1-\alpha])f(\alpha x_1) - f(-x_1[1-\alpha])f(-\alpha x_1) > 0$. Note, that $f(x_1[1-\alpha]) > -f(-x_1[1-\alpha]) > 0$ and $f(\alpha x_1) > -f(-\alpha x_1) > 0$ and, hence, $f(x_1[1-\alpha])f(\alpha x_1) > -f(-x_1[1-\alpha])f(\alpha x_1) > 0$ as well as $-f(-x_1[1-\alpha])f(\alpha x_1) > -f(-x_1[1-\alpha])[-f(-\alpha x_1)] > 0$, which implies $f(x_1[1-\alpha])f(\alpha x_1) > -f(-x_1[1-\alpha])[-f(-\alpha x_1)]$ and, thus, $f(x_1[1-\alpha])f(\alpha x_1) - f(-x_1[1-\alpha])f(-\alpha x_1) > 0$.

That regret is sufficiently stronger than rejoice is also a necessary condition for the regret-rejoice motive to rationalize repeated choice of option I in *Risk-Ambi*. Therefore, if regret-rejoice would explain repeated choice of option I there, we should observe repeated choice of option I also in *Risk-Sure*. However, as shown in Section 4 this is not the case. ■

C Robustness Checks

In the following we present results for the three experiments when the analysis is conducted with all participants, including those who have taken (weakly) dominated choices.

C.1 Experiment ***Risk-Ambi***

The number of choices in favor of the risky prospect is significantly larger than 50 percent in all decision situations characterized by $p \geq 0.5$ ($p-$value < 0.01). Choices favoring the ambiguous prospect are significantly larger than 50 percent in all choice situations characterized by $p \leq 0.4$ ($p-$value < 0.01). In the decision situation where $p = 0.45$, the number of individuals choosing the risky prospect is not significantly different than the number choosing the ambiguous one ($p-$value $= 0.11$).

Option I is chosen by 35 percent of the subjects when $p = 0.50$, by 38 percent when $p = 0.45$, and by 35 percent when $p = 0.40$ and $p = 0.35$. In all the other decision situations, option I is chosen by at most 22 percent of the subjects. The histogram in Figure C.1 reports the relative frequency of subjects that choose option I for n times. Only 22 percent of the subjects never select option I and 20 percent select it exactly once. The remaining 58 percent of the subjects choose option I in at least two decision situations.

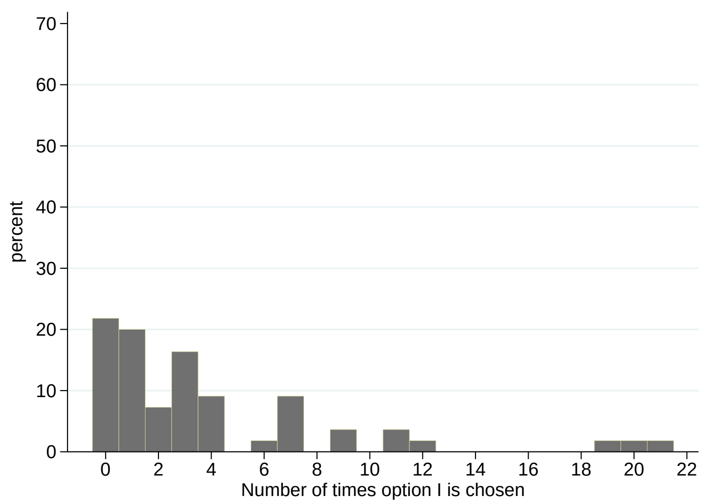


Figure C.1: *Risk-Ambi* – Relative frequency of participants choosing option I n times.

Likelihood insensitivity We find that on average subjects who choose option I more than once are characterized by $\alpha = 0.92$ and $\gamma = 0.39$. A Wilcoxon signed-rank test shows that γ is significantly higher than the threshold value of 0.2 ($p-$value < 0.01). When considering all participants to the experiment we find that $\alpha = 0.89$ and $\gamma = 0.43$ on average.

Hence, overall the results of *Risk-Ambi* reported in the main text also hold when using the whole sample.

C.2 Experiment ***Risk-Sure***

Figure C.2 reports the relative frequency of choices in favor of option I when participants make choices between risky prospects and a safe payment of €7,50. A comparison with Figure 2 shows that there are no substantial differences and the results reported in the main text also hold here.

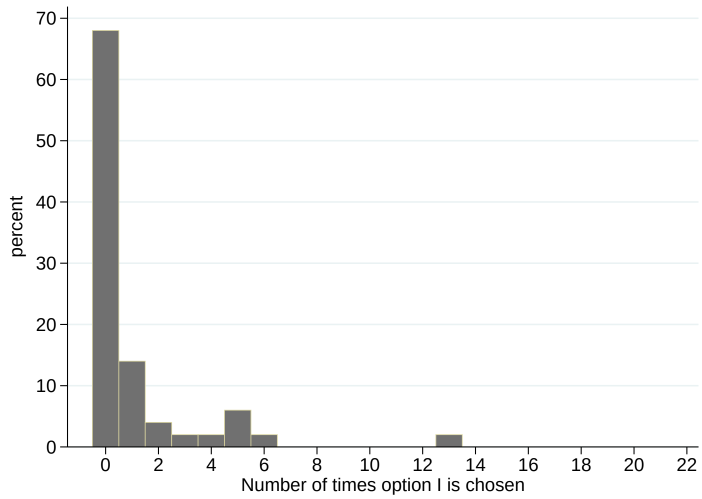


Figure C.2: *Risk-Sure* – Relative frequency of participants choosing option I.

C.3 Experiment ***Risk-Ambi-high***

A binomial test shows that the risky prospect is chosen by more than 50 percent of the subjects in all choice situations characterized by a winning probability of at least 0.55 ($p-$value ≤ 0.02). Choices in favor of the ambiguous prospect are significantly larger than 50 percent in all choice situations where the winning probability of the risky prospects is at most 0.45 ($\mathrm{p-value} \leq 0.03$). When the winning probability is 50 percent subjects do not clearly favor one type of prospect ($p-$value $= 0.19$). Figure C.3 shows a histogram of the relative frequency of indecisive choices. Similarly to the results reported in the main text, approximately one third of the subjects never choose option I, whereas almost 60 percent choose it in at least two decision situations.

Figure C.4 shows how choices in favor of option I are distributed over the decision situations in *Risk-Ambi* and *Risk-Ambi-high*. Behavior in *Risk-Ambi-high* is qualitatively consistent with the predictions based on the existence of incomplete preferences. That is, in comparison to *Risk-Ambi*, option I is more frequent in decision situations characterized by a higher winning probability. We conduct Chi-square tests in every decision situation and test the hypothesis that option I is chosen by the same number of subjects in the two experiments. Due to the behavior of inconsistent subjects, especially in *Risk-Ambi*, we observe that in a few decision situations option I is significantly more frequently chosen in that experiment than in *Risk-Ambi-high*. Thus, overall, the results are similar to those reported in the main text, except that the comparative statics predictions do not fully carry over.

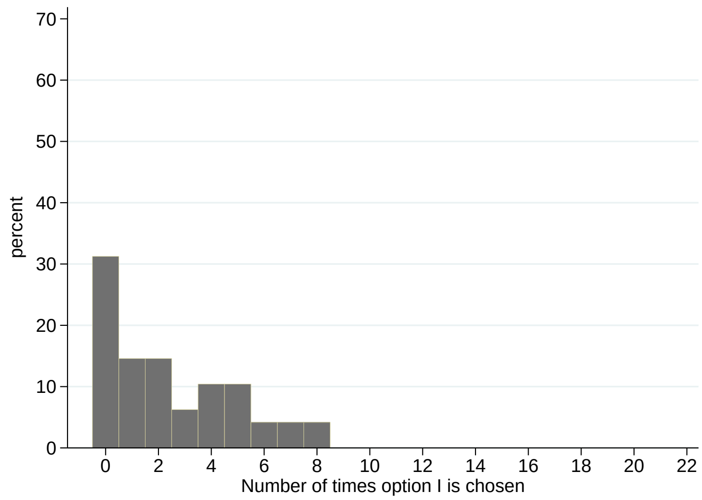


Figure C.3: *Risk-Ambi-high*– Relative frequency of participants choosing option I.

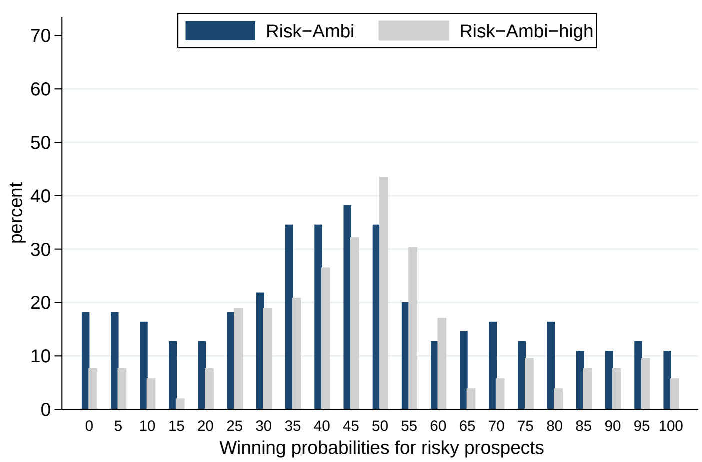


Figure C.4: Frequencies of choices of option I in *Risk-Ambi* and *Risk-Ambi-high*.

D Individual characteristics

In the following we present some descriptive statistics on the participants' individual characteristics, as measured in the last part of the experiment, and relate them to choices in favor of option I. Since we do not observe significant differences between subjects participating in *Risk-Ambi* and *Risk-Ambi-high*, we pool the data of these two experiments. In order to investigate how cognitive abilities and thinking styles affect decision making in part 1 of the experiments, subjects are administered the Cognitive Reflection Test (CRT) (Frederick, 2005) and the Rational-Experiential Inventory (Epstein et al., 1996). The CRT is a 3 items test that measures the ability to reflect on a problem. The score ranges from 0 to 1, where higher values indicate a higher performance. Subjects are rewarded with €0.50 for each correct answer and have a limited time. The REI includes a measure on a 5 point scale of analytical-rational processing (abbreviated as NFC, Need For Cognition) and another measure, also on a 5 points scale, of engagement and confidence in one's intuitive abilities (abbreviated as FI, Faith in Intuition). In the following we first report results for participants who did not make weakly dominated choices, followed by the results when taking all participants into account.

Table D.1 compares individual characteristics of participants who choose option I at most once with those choosing option I at least twice. The table also includes information on gender and means of the parameters estimates that capture the shape of subjects' probability weighting and value function. Individuals that choose Option I more than once appear to be quite similar in the measured characteristics to those who only choose it at most once, except that there are more female subjects in the former group. Regression results in Table D.2 confirm that gender is the only significant correlate of repeated choice of option I.

Table D.1: Individual characteristics by number of times option I is chosen.

	Option $I \leq 1$	Option $I > 1$
male	73%	33%
mean CRT	0.57 (0.35)	0.47 (0.29)
mean NFC	2.35 (0.39)	2.40 (0.34)
mean FI	3.39 (0.58)	3.60 (0.54)
mean γ	0.48 (0.23)	0.39 (0.22)
mean α	0.82 (0.26)	0.87 (0.23)
N	33	40

Note: Standard deviations in parentheses.

Tables D.3 and D.4 report the same analysis when taking all participants into account. Results are very similar, except that the gender difference vanishes.

Table D.2: Determinants of number of option I choices (OLS)
(no weakly dominated choices)

	Coefficient	(Std. Err.)
male	-1.945***	(0.635)
CRT	-0.558	(0.795)
NFC	0.787	(0.698)
FI	-0.120	(0.455)
γ	-0.056	(1.403)
α	0.761	(1.035)
Constant	1.537	(2.534)
N	73	
R^2	0.198	
$F_{(6,66)}$	2.716	

Table D.3: Individual characteristics by number of times option I is chosen.

	Option $I \leq 1$	Option $I > 1$
male	71%	44%
mean CRT	0.50 (0.36)	0.47 (0.30)
mean NFC	2.38 (0.39)	2.43 (0.35)
mean FI	3.39 (0.56)	3.57 (0.51)
mean γ	0.44 (0.23)	0.37 (0.24)
mean α	0.81 (0.24)	0.90 (0.32)
N	45	63

Note: Standard deviations in parentheses.

Table D.4: Determinants of number of option I choices (OLS)
(no weakly dominated choices)

	Coefficient	(Std. Err.)
male	-0.737	(0.945)
CRT	0.173	(1.286)
NFC	0.886	(1.122)
FI	-0.358	(0.776)
γ	-0.870	(1.964)
α	1.404	(1.426)
Constant	2.039	(4.173)
N	108	
R^2	0.026	
$F_{(6,101)}$	.455	

E Instructions of the Experiment

We report here the original instructions used in experiment *Risk-Ambi* and in brackets the parts changing in experiment *Risk-Sure*. The instructions used in *Risk-Ambi-high* are identical except for the increased winning prize of the ambiguous prospect and available upon request. The instructions were computerized.

E.1 Part 1

Shortly you are going to face 21 choice situations (situations 1-21). These choice situations will involve two urns (i.e. boxes). These urns really exist and they will play an important role in determining your earnings. You might have seen them on the table when you entered the lab. At the end of the experiment you will have the possibility to personally check their content.

In one urn there are 100 balls colored black and red. The exact number of black and red balls contained in this urn is always displayed in the decision table that you will see shortly. For convenience we call this urn **Urn A**. The other urn, that we call **Urn B**, contains 100 balls as well. However, the **exact number of black and red balls in this urn is unknown** to you. In fact, the composition of Urn B is also unknown to us because it was composed by a colleague of us and sealed thereafter, while we were absent. Our colleague was free to put any number of red and/or black balls into this urn provided the total number of balls is 100.

In each choice situation you will be asked to bet on a draw of a ball of a certain color by selecting one of the two different types of urns. You are first given the possibility to select the color (black or red) that you like to bet on. The color you select will neither be to your advantage nor to your disadvantage. Also note that you will choose the color once for all choice situations.

[Shortly you are going to face 21 choice situations (situations 1-21). These choice situations will involve one urn (i.e. a box). This urn really exists and it will play an important role in determining your earnings. In the urn there are 100 balls colored black and red. The exact number of black and red balls contained in the urn changes in each choice situation and is always displayed in the decision table that you will see shortly. In each choice situation you will be asked whether you want to bet on a draw of a ball of a certain color from the urn or whether you prefer to receive a certain amount of money. You are first given the possibility to select the color (black or red) that you like to bet on. The color you select will neither be to your advantage nor to your disadvantage. Also note that you will choose the color once for all choice situations.]

This is a **screen shot** of a part of the table you are going to see. Each row of the table represents one choice situation:

In each row you have to decide between **Urn A** and **Urn B** to bet on the color you have selected. You can also state that you are indifferent between the two urns.

Recall that Urn B contains an unknown proportion of 100 black and red balls. Urn A contains 100 balls as well: the proportion of black and red balls is always displayed in the table.

[In each row you have to decide whether you want to bet on the color you have selected or whether you want to receive 7.50 Euro for sure. You can also state that you are indifferent between these two options.]

Remember that the color you have chosen to bet on is Red

CHOICE SITUATION	COMPOSITION OF URN A		COMPOSITION OF URN B
1. I bet on:	☐ 100 red balls	☐ I am indifferent between the two urns	☐ 100 black and red balls in unknown color ratio
2. I bet on:	☐ 95 red balls + 5 black balls	☐ I am indifferent between the two urns	☐ 100 black and red balls in unknown color ratio
3. I bet on:	☐ 90 red balls + 10 black balls	☐ I am indifferent between the two urns	☐ 100 black and red balls in unknown color ratio
4. I bet on:	☐ 85 red balls + 15 black balls	☐ I am indifferent between the two urns	☐ 100 black and red balls in unknown color ratio
5. I bet on:	☐ 80 red balls + 20 black balls	☐ I am indifferent between the two urns	☐ 100 black and red balls in unknown color ratio
6. I bet on:	☐ 75 red balls + 25 black balls	☐ I am indifferent between the two urns	☐ 100 black and red balls in unknown color ratio
7. I bet on:	☐ 70 red balls + 30 black balls	☐ I am indifferent between the two urns	☐ 100 black and red balls in unknown color ratio
8. I bet on:	☐ 65 red balls + 35 black balls	☐ I am indifferent between the two urns	☐ 100 black and red balls in unknown color ratio
9. I bet on:	☐ 60 red balls + 40 black balls	☐ I am indifferent between the two urns	☐ 100 black and red balls in unknown color ratio
10. I bet on:	☐ 55 red balls + 45 black balls	☐ I am indifferent between the two urns	☐ 100 black and red balls in unknown color ratio
11. I bet on:	☐ 50 red balls + 50 black balls	☐ I am indifferent between the two urns	☐ 100 black and red balls in unknown color ratio
12. I bet on:	☐ 45 red balls + 55 black balls	☐ I am indifferent between the two urns	☐ 100 black and red balls in unknown color ratio
[illegible]	[illegible]	[illegible]	[illegible]

Determination of earnings

At the end of the experiment one of the choice situations in the table is randomly selected with equal probability to determine your earnings. Thereafter, a ball is drawn from the urn you decided to bet on in the choice situation that was randomly selected.

Suppose, for example, that red is your color and that choice situation 7 is randomly selected. Suppose further that you decided to bet on Urn A in that choice situation. At the end of the experiment, a ball is drawn from Urn A, which contains 70 red balls and 30 black balls in choice situation 7. You receive 15 Euro if the ball is red and nothing otherwise.

Similarly, if in choice situation 7 you have decided to bet on Urn B, which contains 100 balls in unknown color composition, a ball is drawn from it. You receive 15 Euro if the ball is red and nothing otherwise. In case you were indifferent between the two urns, one is randomly selected with equal probability to determine your earnings.

[At the end of the experiment one of the choice situations in the table is randomly selected with equal probability to determine your earnings. Depending on which choice situation is selected, the experimenter will put the appropriate number of red and black balls in the urn. For instance, if choice situation 12 is selected for payment, the experimenter will put 55 red balls and 45 black balls in the urn. At the end of the experiment you will have the possibility to personally check the content of the urn.

Suppose, for example, that you selected red and that choice situation 7 is randomly selected at the end of the experiment. Suppose further that you chose to bet on the urn in that choice situation. A ball is then drawn from the urn which contains 70 red balls and 30 black balls in situation 7. You receive 15 Euro if the ball is red and nothing otherwise.

Differently, the ball drawn from the urn does not influence your earnings if in choice situation 7 you decided that you prefer to get 7.50 Euro for sure. In case you were indifferent between betting on the urn and earning 7.50 Euro for sure, one of these two options is randomly selected with equal probability to determine your earnings.]

Estimation of the composition of Urn B

Now that you have made your choices, we would like to ask you for your **best estimate of the color composition of Urn B.**

The categories below are intervals indicating the number of red balls that might be contained in Urn B. Please click on the check box that represents your best estimate. You can also click on more than one box.
Consider the following random examples.
For instance, if you believe that there are between 12 and 34 red balls in Urn B, you should click on the 3rd, 4th, 5th 6th and 7th check box from the left.
For instance, if you believe that there are between 72 and 74 red balls in Urn B than you should click on the 15th check box form the left.
For instance, if you believe that there are exactly 6 red balls in Urn B than you should click on the 2nd check box from the left.
If you believe that there between 17 and 24 red balls or between 63 and 69 red balls in Urn B then you should click on the 4th, 5th, 13th and 14th check box. *Notice that this part was not included in experiment* Risk-Sure.

E.2 Part 2

You are now going to make another series of choices. These choices will not influence your earnings from the choices you just made, nor will your earlier choices influence the earnings from the choices you are going to make. After you have made the these choices you will be asked to answer some questions. Thereafter the experiment will be over.
In the following, you will be confronted with a **series of 33 decision situations** that will appear in random order on the screen. All these decision situations are completely independent of each other. A choice you made in one decision situation does not affect any of the other following decision situations.
Each decision situation is displayed on a screen. The screen consists of 20 rows. You have to decide for **every** row whether you prefer **option A** or **option B**. Option A is a lottery and is the same for every row in a given decision situation, while the secure option B takes 20 different values, one for each row. By clicking on NEXT you will see an example screen of a decision situation.
This is a **screen shot** of one decision situation you are going to face. You are not asked to make choices now! Please have a careful look. **Determination of earnings**
At the end of the experiment one of the 33 decision situations will be randomly selected with equal probability. Once the decision situation is selected, one of the 20 rows in this decision situation will be randomly selected with equal probability.
The choice you have made in this specific row will determine your earnings. Consider, for instance, the screen shot that you have just seen.
Option A gives you a 55% chance to earn 10.- Euro and a 45% chance to earn nothing. Option B is always a sure amount that ranges from 10.- Euro in the first row, to 0.50 Euro in the 20th row. Suppose that the 12th row is randomly selected. If you would have selected option B, you would receive 4.50 Euro. If, instead, you would have selected option A, the outcome of the lottery determines your earnings. The lottery will be paid out by publicly drawing a card from a stack of numbered cards.
Please note that each decision situation has the same likelihood to be the one that is relevant for your

DECISION SITUATION 13.	OPTION A LOTTERY	YOUR CHOICE	OPTION B SURE AMOUNT
choice 1		A ◦ ◦ B	10.-
choice 2		A ◦ ◦ B	9.50
choice 3		A ◦ ◦ B	9.-
choice 4		A ◦ ◦ B	8.50
choice 5		A ◦ ◦ B	8.-
choice 6		A ◦ ◦ B	7.50
choice 7	With 55% chance you receive 10.- Euro, with 45% chance you receive nothing.	A ◦ ◦ B	7.-
choice 8		A ◦ ◦ B	6.50
choice 9		A ◦ ◦ B	6.-
choice 10		A ◦ ◦ B	5.50
choice 11		A ◦ ◦ B	5.-
choice 12		A ◦ ◦ B	4.50
choice 13		A ◦ ◦ B	4.-
choice 14		A ◦ ◦ B	3.50
choice 15		A ◦ ◦ B	3.-
choice 16		A ◦ ◦ B	2.50
choice 17		A ◦ ◦ B	2.-
choice 18		A ◦ ◦ B	1.50
choice 19		A ◦ ◦ B	1.-
choice 20		A ◦ ◦ B	0.50

earnings. Therefore, you should **view each decision independently** and consider all your choices carefully.

E.3 Part 3

Cognitive Reflection Test

You have now finished with the 33 decision situations. In the following screens we ask you to answer some questions. Please read the following questions carefully and type your answer in the boxes. You will earn 0.50 Euro for each correct answer provided.

(1) A bat and a ball cost 1.10 Euro in total. The bat costs 1.00 Euro more than the ball. How many cents does the ball cost?

(2) If it takes 5 machines 5 minutes to make 5 widgets, how long (in minutes) would it take 100 machines to make 100 widgets?

(3) In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how many days would it take for the patch to cover half of the lake?

(4) Two cars are on a collision course, traveling towards each other in the same lane. Car A is traveling 70 km an hour. Car B is traveling 80 km an hour. How far apart are the cars one minute before they collide? Please answer in km.[24]

[24] This question is not part of the original CRT by Shane (2005). We added it to increase the complexity of the task. However, in the data analysis we do not consider answers to this question.

Rational Experiential Inventory

What is your opinion on the following statements?(subjects had to answer on a 5 point scale, where 1="completely false"; 5="completely true")

1. I would rather do something that requires little thought than something that is sure to challenge my thinking abilities

2. I don't like to have the responsibility of handling a situation that requires a lot of thinking.

3. I would prefer complex to simple problems.

4. I find little satisfaction in deliberating hard and for long hours.

5. Thinking is not my idea of fun.

6. The notion of thinking abstractly is not appealing to me.

7. I prefer my life to be filled with puzzles that I must solve.

8. Simply knowing the answer rather than understanding the reasons for the answer to a problem is fine with me.

9. I don't reason well under pressure.

10. The idea of relying on thought to make my way to the top does not appeal to me.

11. I prefer to talk about international problems rather than gossip about celebrities.

12. Learning new ways to think doesn't excite me very much.

13. I would prefer a task that is intellectual, difficult, and important to one that is somewhat important but does not require much thought.

14. I generally prefer to accept things as they are rather than to question them.

15. It is enough for me that something gets the job done, I don't care how or why it works.

16. I tend to set goals that can be accomplished only by expending considerable mental effort.

17. I have difficulty thinking in new and unfamiliar situations.

18. I feel relief rather than satisfaction after completing a task that required a lot of mental effort.

19. I try to anticipate and avoid situations where there is a likely chance I will have to think in depth about something.

20. My initial impressions of people are almost always right.

21. I trust my initial feelings about people.

22. When it comes to trusting people, I can usually rely on my "gut feelings."

23. I believe in trusting my hunches.

24. I can usually feel when a person is right or wrong even if I can't explain how I know.

25. I am a very intuitive person.

26. I can typically sense right away when a person is lying.

27. I am quick to form impressions about people.

28. I believe I can judge character pretty well from a person's appearance.

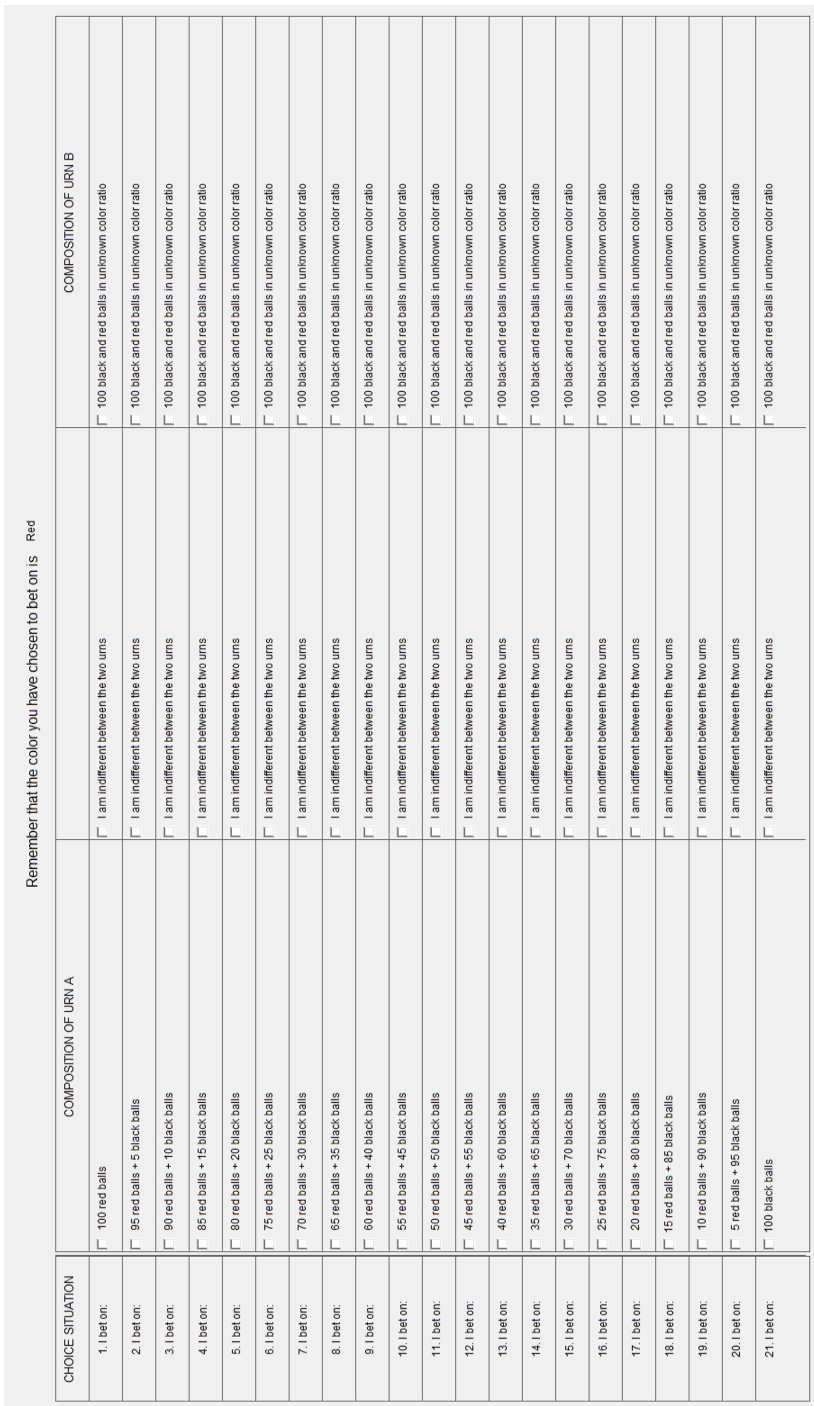
29. I often have clear visual images of things.

30. I have a very good sense of rhythm.

31. I am good at visualizing things.

F Screen Shot of Decision Situations

Figure F.1 displays a screen shot of the whole decision table in *Risk-Ambi*.



Remember that the color you have chosen to bet on is Red

CHOICE SITUATION	COMPOSITION OF URN A		COMPOSITION OF URN B
1. I bet on:	100 red balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
2. I bet on:	95 red balls + 5 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
3. I bet on:	90 red balls + 10 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
4. I bet on:	85 red balls + 15 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
5. I bet on:	80 red balls + 20 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
6. I bet on:	75 red balls + 25 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
7. I bet on:	70 red balls + 30 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
8. I bet on:	65 red balls + 35 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
9. I bet on:	60 red balls + 40 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
10. I bet on:	55 red balls + 45 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
11. I bet on:	50 red balls + 50 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
12. I bet on:	45 red balls + 55 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
13. I bet on:	40 red balls + 60 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
14. I bet on:	35 red balls + 65 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
15. I bet on:	30 red balls + 70 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
16. I bet on:	25 red balls + 75 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
17. I bet on:	20 red balls + 80 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
18. I bet on:	15 red balls + 85 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
19. I bet on:	10 red balls + 90 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
20. I bet on:	5 red balls + 95 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio
21. I bet on:	100 black balls	I am indifferent between the two urns	100 black and red balls in unknown color ratio

Figure F.1: Decision table in Part 1.