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# Uncertainty Aversion and Preference for Randomization

Wendelin Schnedler*
and Adam Dominiak**

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*Department of Economics, University of Heidelberg, email: wendelin.schnedler@awi.uni-heidelberg.de

**Alfred-Weber-Institut, email: adam.dominiak@awi.uni-heidelberg.de

Universität Mannheim
L 13,15
68131 Mannheim

# Uncertainty Aversion and Preferences for Randomization: An Experimental Study

Adam Dominiak
Department of Economics
University of Heidelberg

Wendelin Schnedler*
Department of Economics
University of Heidelberg

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**Abstract**

Individuals exhibit preferences for randomization if they prefer random mixtures of two bets to each of the involved bets. Such preferences provide the foundation of various models of uncertainty aversion. However, it has to our knowledge not been empirically investigated whether uncertainty-averse decision makers indeed exhibit such preferences. Here, we examine the relationship experimentally. We find that uncertainty aversion is not positively associated with preferences for randomization. Moreover, we observe choices that are not consistent with the prevailing theories of uncertainty aversion: a non-negligible number of uncertain-averse subjects seem to dislike randomization.

Keywords: uncertainty aversion, ambiguity, subjective expected utility, preference for randomization, Choquet expected utility, minmax utility

JEL-Codes: D8, C9

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*wendelin.schnedler@awi.uni-heidelberg.de, University of Heidelberg, Department of Economics, Grabengasse 14, D-69117 Heidelberg, Germany
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# 1 Introduction

The canonical framework for economists to model choice behavior is that of subjective expected utility theory (Savage, 1954; Anscombe and Aumann, 1963). Ellsberg (1961) challenged this framework by suggesting a series of experiments. Consider, for example, two urns that are filled with yellow and white balls. In one urn, half of the balls are yellow, the other white. In the other urn, the proportion of yellow and white balls is unknown. A ball is drawn and subjects receive 100$ if they guess the color correctly. Many subjects are indifferent between yellow and white but prefer betting on the urn with known proportions ("risky urn") to betting on the urn with unknown proportions ("uncertain urn"). They are *uncertainty-averse* and their choices violate subjective expected utility theory; moreover, their behavior is not consistent with probabilistic sophistication in the sense of Machina and Schmeidler (1992).

In a direct comment on Ellsberg's thought experiment Raiffa (1961) suggested the following. After drawing a ball from the uncertain urn, subjects flip a fair coin to decide on which color to bet. By tossing a fair coin and betting on yellow when heads appear and on white otherwise, the objective chances of winning the bet with the uncertain urn are 50% and thus identical to those with the risky urn. This seems to contradict the idea that betting on the risky urn is preferable to betting on the uncertain urn. Indeed, Raiffa proposes the randomization to "undermine the confidence" of uncertainty-averse subjects in their choices. However, subjects who value bets on the risky urn and randomized bets on the uncertain urn equally may still exhibit uncertainty aversion, if they prefer tossing a coin rather than betting on either white or yellow when they face uncertainty. In short, subjects may agree with Raiffa's argument and still be uncertainty-averse if they display *preferences for randomization.*

In view of the overwhelming empirical evidence indicating uncertainty aversion (see the survey article by Camerer and Weber, 1992), various alternatives to subjective expected utility theory have been proposed. The most prominent are Choquet expected utility, which has been axiomatized by Schmeidler (1989), Gilboa (1987) and Sarin and Wakker (1992), and maxmin expected utility, which was justified by Gilboa and Schmeidler (1989), Casadesus-Masanell, Klibanoff, and Ozdenoren (2000). While both approaches can explain the Ellsberg paradox, they have very different predictions with respect to preferences for randomization. Eichberger and Kelsey (1996), Ghirardato (1997) and Klibanoff (2001) analyze the relationship between uncertainty aversion and preferences for randomization from a theoretical point of view. However, it has to our knowledge never been empirically investigated. Here, we examine the relationship between uncertainty aversion and preferences for randomization in an experimental study.

Subjects in our experiment were faced with three sources of uncertainty: a coin, a risky urn and an uncertain urn. We offered subjects lotteries based on these sources and elicited their reservation prices. We classify subjects as uncertainty-averse if the reservation prices for lotteries involving the risky urn are higher than those involving the uncertain urn. In addition, we offered a lottery in the spirit of Raiffa that involved deliberate randomization. By comparing the reservation price of this lottery to an appropriate lottery without such randomization, we determine whether subjects are willing to pay for randomization and thus exhibit preferences for randomization.

Our main finding is that uncertainty aversion is not positively associated with preferences for randomization. The hypothesis that uncertainty aversion and preferences for randomization are positively related is rejected at any conventional level in favor of a negative relationship. This finding contrasts with a wide-spread notion of uncertainty aversion. In his seminal article, Schmeidler (1989) relates uncertainty aversion to the idea that an individual who is indifferent between two bets under uncertainty prefers a mixture of these bets.[1] This idea is directly imposed as an axiom on preferences in maxmin models (e.g Gilboa and Schmeidler, 1989, Casadesus-Masanell, Klibanoff, and Ozdenoren, 2000) and several generalizations of it (Maccheroni, Marinacci, and Rustichini, 2006, Gajdos, Hayashi, Tallon, and Vergnaud, 2008). The rationale behind this notion of uncertainty aversion is that the individual likes smoothing expected utility across outcomes. It may also be interpreted as saying that individuals will in general prefer the mixture, because it allows to hedge against uncertainty. Our finding indicates that this rationale only explains the behavior of very few subjects.

One popular way to model uncertainty aversion is to employ Choquet expected utility models with convex capacities. Whether uncertainty aversion implies preferences for randomization in this case depends on how the randomization device is modeled. There are two approaches. The first approach represents the randomization device in the tradition of Anscombe and Aumann (1963) as part of the consequence space. The second approach

[1] See Epstein (1999) and Ghirardato and Marinacci (2002) for alternative definitions of uncertainty aversion.

models the randomization device as an extension of the state space à la Savage (1954). We refer to the first approach as *C (consequence space) approach* and the second as *S (state space) approach*. The distinction does not matter for decision makers who satisfy the axioms of subjective expected utility theory. However, for uncertainty-averse decision makers, it has important repercussions. Eichberger and Kelsey (1996) investigate these repercussions in Choquet expected utility models. They show that uncertainty-averse decision makers who are indifferent between two acts prefer randomization in the C-approach but must be indifferent with respect to randomization (or: randomization neutral) in the S-approach.

The question of whether uncertainty-averse subjects exhibit preferences for randomization is of importance to an emerging literature that examines the consequences of uncertainty aversion in different economic applications. Those applications include financial markets (see for example Dow and Werlang 1992, Epstein and Wang 1994, Chen and Epstein 2002, Nishimura and Ozaki 2007, Epstein and Schneider 2007), contract theory (see Mukerji 1998 and Ghirardato 1994), auction theory (see Lo 1998, Chen, Katuscak, and Ozdenoren 2007, and Bose, Ozdenoren, and Pape 2007), and search economics (Nishimura and Ozaki, 2004). Preferences for randomization affect, in particular, whether mixed equilibria can be strict in the presence of uncertainty-averse subjects. For instance, Klibanoff (1996) and Lo (1996) adopt the view that uncertainty-averse subjects have a strict incentive to randomize, while Dow and Werlang (1994), Eichberger and Kelsey (2000) and Marinacci (2000) argue against preferences for randomization. While the preferences for randomization of uncertainty-averse decision makers matter for the choice of the theoretical approach (C or S) and affect applications, little is known about them.

Our second finding directly relates to the differing predictions by S- and C-approach and concerns the attitude toward randomization among uncertainty-averse subjects who are indifferent between betting on yellow and white. We find that a considerable fraction of them does not value randomization. The hypothesis that uncertainty-averse subjects have an equal chance of preferring or being neutral with respect to randomization is rejected at any conventional level in favor of them being neutral.

This finding indicates that the S-approach is more suited to describe the behavior of the subjects in our experiment. However, Klibanoff (2001) points out an interesting feature of this approach: subjects, who are uncertainty-averse and regard the randomization device as risky,[2] must violate a property called stochastic independence. This means that such subjects view the outcomes of the coin and the uncertain urn as correlated. If we thus represent preferences of uncertainty-averse subjects using the S-approach and if we believe that they view the coin as risky, they should perceive coin and uncertain urn as dependent. As a first step to see whether uncertainty-averse subjects violate independence more often, we compare their behavior to uncertainty-neutral subjects. While uncertainty-averse subjects exhibit a somewhat higher tendency to violate independence, the finding is not significant.

Our experiment also raises a puzzle: there are a considerable number of

[2]Risky means here that they can assign probabilities to the outcomes of the randomization device.

subjects who are uncertainty-averse and dislike randomization. This behavior cannot be explained by either of the two approaches to uncertainty aversion. We suggest some explanations and provide tentative evidence on what may cause this behavior.

The rest of the paper is organized as follows. The next section describes the experimental design and important definitions. In Section 3, we derive our hypotheses. Section 4 presents the results. The article ends with some concluding remarks.

# 2 Experimental design

In this section, we describe the sources of uncertainty used and the lottery tickets offered to the subjects. We also discuss how we elicited reservation prices for the lottery tickets and define key concepts in terms of observable behavior.

## Sources of uncertainty

Lotteries are based on three devices:

- a coin provided by one of the subjects,
- a risky urn R with 20 table tennis balls of which ten were white and ten were yellow, and
- an uncertain urn U with 20 table tennis balls with an unknown proportion of yellow and white balls.

Subjects were informed that only white and yellow balls are used in the experiment. The contents of urn R were shown to the subjects before the experiment, while the contents of urn U were only revealed after the experiment. During the experiment, both urns were placed on a table in view of the subjects to convince them that the content were not manipulated.

## Lottery tickets

During the experiment subjects were offered different lottery tickets. We informed subjects that the lottery tickets involve one or more of the three sources of uncertainty. They did not know, however, how many and which tickets they would face. In the following we explain the lottery tickets in the same sequence in which they were presented and evaluated by the subjects. In the description of the tickets, as in the experiment, prizes are expressed in Taler, our experimental currency unit. The first two tickets are defined on the outcome of the coin toss.

1. **Head ticket, $H$:** 100 Taler are paid if the coin lands heads up and nothing otherwise.

2. **Tails ticket, $T$:** 100 Taler are paid if the coin lands tails up and nothing otherwise.

The heads and tails tickets are later used to check whether subjects regard the coin as fair. The next two tickets involve the risky urn.

3. **White ticket for urn R**, $W^R$: 100 Taler are paid if the drawn ball from urn R is white and nothing otherwise.

4. **Yellow ticket for urn R**, $Y^R$, 100 Taler are paid if the drawn ball from urn R is yellow and nothing otherwise.

These two tickets help us to detect whether subjects are indifferent between yellow and white when the ball is drawn from the urn with known proportions. The fifth and sixth ticket are defined on the outcome of a draw from the uncertain urn.

5. **Yellow ticket for urn U**, $Y^U$: 100 Taler are paid if the drawn ball from urn U is yellow and nothing otherwise.

6. **White ticket for urn U**, $W^U$: 100 Taler are paid if the drawn ball from urn U is white and nothing otherwise.

Since the draw from urn U involves more uncertainty than the draw from urn R, the difference in reservation prices of the lottery tickets for R and U is informative about the subject's attitude toward uncertainty.

The next ticket was designed in the spirit of Raiffa's idea. It involves two sources of uncertainty: the coin and the uncertain urn. The subject always receives a ticket for urn U. Whether this ticket will be yellow or white is determined by flipping the coin. Since the color of the ticket changes with the outcome of the coin toss, we use the name chameleon ticket.

7. **Chameleon ticket for urn U, $C^U$:** If the coin lands heads up, the subject receives a yellow ticket for urn U. If the coin lands tails up the subject receives a white ticket for urn U.[3]

[3]Put differently, the subject receives 100 Taler in two cases: if the coin lands heads up and the drawn ball from urn U is yellow and if the coin lands tails up and the ball drawn from urn U is white. In the other two cases, the subject receives nothing.

By comparing the reservation price for the chameleon ticket with that of a yellow or white ticket for urn U, we can draw some inference about a subject's preferences for randomization.

The last ticket combines a draw from urn U with a coin toss and the reservation price for the heads ticket.[4]

8. **Combination ticket for U**: If the drawn ball is yellow, then the subject receives a heads ticket. If the drawn ball is white, then the subject receives its reservation price for a heads ticket.[5]

The comparison of this combination ticket with a heads ticket later gives us some indication whether the subject regards urn U and the coin flip as independent.

## Eliciting reservation prices

A critical experimental design question is how to elicit the reservation price. We used the following procedure. For each lottery, the subject had to make twenty choices. The first choice was between a ticket for the lottery and a payment of 2.5 Taler. The second was between a ticket and a payment of 7.5 Taler etc. The payments offered to the subject increased in steps of 5 Taler until the last choice, in which the subject had to choose between a ticket and 97.5 Taler. The point at which the subject switches from the ticket to the payment then reveals the reservation price (up to 2.5 Taler). All of

[4]How the reservation price is elicited is described in the next section.

[5]Put differently, the subject receives 100 Taler if the coin lands heads up and the drawn ball from urn U is yellow; the subject gets its reservation price for a heads ticket if the drawn ball from urn U is white; and nothing otherwise.

the subject's choices were implemented and affected the subject's payoff. To ensure independence, a separate draw was carried out for each ticket.

Many experiments employ less time-consuming and laborious elicitation mechanisms that combine the choices over lotteries with additional randomization. An example is the method by Holt and Laury (2002) who randomly select one of the choices to be payoff relevant. Another popular mechanism, which has recently been used in experiments on uncertainty aversion (Halevy, 2007; Hey, Lotito, and Maffioletti, 2008), is that of Becker, DeGroot, and Marschak (1964). In the Becker-DeGroot-Marschak mechanism, the subject receives a lottery ticket and states the reservation price. Then, a random price offer is generated and the subject has to sell the ticket if the offer exceeds the stated price.

Despite the considerable effort involved,[6] we decided to pay all decisions rather than employing a mechanism that relies on additional randomization. We do so for two reasons. First, as Karni and Safra (1987) point out a method based on additional randomization, such as the Becker-DeGroot-Marschak mechanism, is no longer guaranteed to elicit the true (subjective) value of a lottery once the independence axiom is violated.[7] Uncertainty-averse subjects, however, violate the independence axiom. As we are interested in the reservation prices of uncertainty-averse subjects, we employ a mechanism that truly reveals these prices even if the independence axiom is violated.

[6]Up to 120 draws and 80 coin flips are needed in order to determine the outcome of the twenty choices for the eight lottery tickets.

[7]A similar observation has been made by Holt (1986). The Becker-DeGroot-Marschak mechanism also fails to elicit true valuations if the compound lottery axiom is violated (Segal, 1988).

Second, had we introduced another source of randomness, all lotteries faced by the subject would have been compound lotteries; none would have been purely based on the three sources that we are interested in (coin, uncertain urn, risky urn). By implementing all choices, we avoided that preferences for randomization interact with other sources of randomness.

## Definitions

Denote the reservation price for lottery ticket $t$ by $v(t)$, where $t$ is the abbreviation for tickets used earlier: $t \in \{H, T, Y^R, W^R, Y^U, W^U, C^U\}$. In line with standard practice, we say a subject is uncertainty-averse if she assigns a lower value to tickets from the uncertain rather than the risky urn.

**Definition 1** (Uncertainty aversion)**.** *A subject is*
*uncertainty-averse if* $\min\left(v(Y^R), v(W^R)\right) > \max\left(v(Y^U), v(W^U)\right)$,
*uncertainty-loving if* $\max\left(v(Y^R), v(W^R)\right) < \min\left\{v(Y^U), v(W^U)\right\}$,
*and uncertainty-neutral if* $v(Y^R) = v(W^R) = v(Y^U) = v(W^U)$.

The definition simply reflects the idea that a subject who values both tickets for urn R more than those for urn U prefers to know more about the urn. Analogously, a subject is uncertainty-loving if she generally prefers tickets for urn U to tickets for urn R. Notice that the order induced by this definition is not complete.

Taking up the definition from the introduction, we say a subject prefers randomization if she values the chameleon ticket more than the white and the yellow ticket for urn U.

**Definition 2** (Randomization preferences)**.** *A subject*

*prefers randomization if* $v(C^U) > \max\left(v(Y^U), v(W^U)\right)$,
*dislikes randomization if* $v(C^U) < \min\left(v(Y^U), v(W^U)\right)$
*and is randomization-neutral if* $v(C^U) = v(Y^U) = v(W^U)$.

For a subject who values yellow and white tickets for urn U equally, this definition collapses to a simple comparison between the chameleon ticket and a plain ticket for urn U, e.g. a white ticket. If a subject who values yellow and white tickets for urn U equally also regards the coin as fair, we say that it has symmetric preferences.

**Definition 3.** *A subject has symmetric preferences if* $v(H) = v(T)$ *and* $v(W^U) = v(Y^U)$.

Symmetric preferences play an important role because the two leading approaches generate specific and different predictions for subjects with symmetric preferences. These differences are explained in the next section.

# 3 Predictions

In order to motivate the first hypothesis, consider the following definition by Schmeidler (1989), which serves as the backbone for various models of uncertainty aversion. Let $f$ and $g$ be acts, i.e. mappings that assign to every event a probability distribution over outcomes.[8] Next, we define for any $\alpha \in (0, 1)$ an $\alpha$-mixture over $f$ and $g$ such that the decision maker receives bet $f$ with probability $\alpha$ and $g$ with probability $(1 - \alpha)$. Let $\succeq$ represent

[8]For instance, a white ticket for urn U is an act that assigns probability one to 100 Taler and zero to 0 Taler on the event "ball drawn from urn U is white" and probability zero to 100 Taler and one to 0 Taler otherwise.

the preferences over bets. Then, a subject is uncertainty-averse according to Schmeidler's definition if for all $\alpha \in (0, 1)$ and all $f \succeq g$ it holds that

$$\alpha f + (1 - \alpha) g \succeq g.$$

Notice that this definition is weak in the sense that it also encompasses subjective expected utility maximizers for whom $f \sim g$ implies $\alpha f + (1 - \alpha) g \sim g$. For subjects who violate the independence axiom, in our setup those who prefer to bet on the risky rather than the uncertain urn, the mixture of $f$ and $g$ is strictly preferred. Conversely, a preference for betting on the uncertain urn is reflected by a strict preference for the pure acts rather than the mixture.

This close relationship between uncertainty aversion and preferences for randomization suggests the following hypothesis:

**Hypothesis H1** Uncertainty aversion is positively associated with preferences for randomization.

As explained earlier, there are two different approaches for modeling uncertainty aversion (C-approach and S-approach). Depending on which approach is used, one gets specific but differing predictions about the preferences for randomization of uncertainty-averse decision makers. We can evaluate these predictions against the benchmark that preferences for randomization are randomly distributed. This benchmark leads to the following null hypothesis:

**Hypothesis H2$_{\mathbf{O}}$** Uncertainty-averse subjects with symmetric preferences are equally likely to prefer randomization or to be randomization-neutral.

In contrast to this hypothesis, uncertainty aversion in the C-approach requires subjects with symmetric preferences to prefer randomization. This suggests the following alternative:

**Hypothesis H2$_{\mathbf{C}}$** Uncertainty-averse subjects with symmetric preferences are more likely to prefer randomization.

In the S-approach, randomization plays a less prominent role and it is not obvious how uncertainty aversion relates to preferences for randomization. However, Eichberger and Kelsey (1996) have shown that –unlike in the C-approach– subjects with symmetric preferences are randomization neutral (see Proposition 3.2 in Eichberger and Kelsey, 1996). This leads to our second alternative hypothesis:

**Hypothesis H2$_{\mathbf{S}}$** Uncertainty-averse subjects with symmetric preferences are more likely to be randomization-neutral.

Klibanoff (2001) relates the different predictions of S- and C-approach to violations of stochastic independence. He starts with the observation that subjects should regard a randomization device as risky and independent from other sources of uncertainty. He shows that it is possible to model such a stochastic independent randomization device and uncertainty aversion simultaneously in the C-approach but not in the S-approach (see his Theorem

2). Suppose that we model the behavior of uncertainty-averse subjects with the S-approach. If we additionally believe that the subjects regard the coin as risky, Klibanoff's result implies that they violate stochastic independence.

By comparing the combination and heads ticket, we can observe violations of stochastic independence. Recall that the combination ticket involves both the coin and the uncertain urn, where the draw from the urn only affects whether the subject gets an actual heads ticket or the certainty equivalent of the heads ticket. A subject, who regards coin and uncertain urn as independent, should attach the same value to the combination and heads ticket. A subject, who cannot separate the randomness involved in the coin flip from that involved in the draw from the uncertain urn, will value the combination ticket differently than the heads ticket.

Uncertainty-averse subjects violate stochastic independence in the S-approach and uncertainty-neutral subjects do not. Accordingly, we take the behavior of uncertainty-neutral subjects as a benchmark and formulate the following hypothesis.

**Hypothesis H3**: Randomization-neutral subjects with symmetric preferences are more likely to value the combination ticket differently than the heads ticket if they are uncertainty-averse rather than uncertainty neutral.

# 4 Implementation

We ran a total of 5 sessions with 90 subjects. All sessions were conducted in the experimental laboratory at the University of Mannheim in late September 2008. Subjects were primarily undergraduate students who were randomly recruited from a pool of approximately 1000 subjects using an e-mail recruitment system. Each subject only participated in one of the sessions. Reservation prices were elicited electronically using the software z-tree (Fischbacher, 2007).

After the subjects arrived at the laboratory, they were randomly seated at the computer terminals. Instructions were read out loud and ticket types were practically explained. Then, the subjects were given time to study the instructions on their own. Finally, they were asked to answer a series of questions to test their understanding of the instructions. During all this time, subjects could ask the experimenters clarifying questions. This part lasted about 30 minutes. It was followed by the evaluation of the lottery tickets. In order to simplify the input for subjects, we programmed a slider that allowed them to specify the reservation price. The program then automatically selected choices that were consistent with the reservation price. Using the slider was not obligatory and a subject could arbitrary alter its choice until he or she decided to finish evaluation of a specific lottery ticket. After the evaluation of lottery tickets, we asked subjects questions about their demographics and attitudes toward uncertainty. We also gave them some problems to test their statistics knowledge and cognitive ability. Subjects took about 30 minutes for this second part. The last and final part required drawing balls and flipping coins in order to determine payoffs. With 8 types of lottery tickets and twenty choices between ticket and fixed payment for each type, subjects could obtain up to 160 tickets. This last part required roughly 30 minutes so that the whole experiment lasted about 90 minutes.

At the end of the experiment, we paid each subject privately in cash. All payoffs were initially explained in Taler that were later converted using the rate that 100 Taler=10 cents. Subjects earned on average 11.35€.

# 5 Results

Two subjects violate transitivity in their choices, which leaves us with 88 independent observations. Of those, we can classify 63 according our definition of uncertainty-aversion. In line with previous experimental studies (see Camerer and Weber, 1992), a large fraction of the subjects exhibit the Ellsberg paradox and prefer betting on the risky urn to betting on the uncertain urn (45 of 63 classifiable subjects). The behavior of eleven subjects is consistent with subjective expected utility maximization and seven prefer the uncertain urn.

Examining the relationship between uncertainty aversion and preferences for randomization, we obtain the following main finding.

**Result 1.** *Uncertainty aversion is not positively associated with preferences for randomization.*

Of the 88 subjects 58 can be classified according to their uncertainty aversion *and* preferences for randomization. The relationship between the two is depicted in Table 1. From Hypothesis H1, we expect a positive relationship between preferences for randomization and uncertainty aversion. Accordingly, observations should lie on the diagonal from the top-left to the bottom-right of the table. Entries on the diagonal from the bottom-left to the top right, however, are larger. The null hypothesis that uncertainty aversion and preferences for randomization are independent or positively associated can be

Table 1: Association between uncertainty aversion and preferences for randomization

| | | uncertainty | | | Total |
|---|---|---|---|---|---|
| | | loving | neutral | averse | |
| randomization | averse | 1 | 0 | 14 | 15 |
| | neutral | 2 | 11 | 20 | 35 |
| | loving | 2 | 0 | 9 | 8 |
| | Total | 5 | 11 | 43 | 59 |

rejected at any conventional level (Fishers exact test has a p-value below 0.01); Goodman and Kruskal's $\gamma$ as well as Kendall's $\tau$, which measure the association between the ordinally scaled uncertainty aversion and preferences for randomization, are both negative and significant.

Of the 58 subjects whose preferences with regard to randomization and uncertainty aversion can be classified, 42 have symmetric preferences. For the next step, we restrict the analysis to these subjects in order to examine the specific and differing predictions of the S and C-approach.

**Result 2.** *Uncertainty-averse subjects with symmetric preferences are more likely to be randomization-neutral rather than randomization-loving.*

Twenty uncertainty-averse subjects with symmetric preferences exhibit preferences for randomization that are predicted by prevailing theories. Sixteen of these are randomization-neutral and their behavior is hence in line with the S-approach. Only four out of the twenty show the behavior expected from C-approach and are randomization-loving. The hypothesis that symmetric and uncertainty-averse subjects are equally likely to be randomization-loving or neutral can be rejected at any conventional level:[9] a significantly larger fraction of subjects are randomization neutral.

Recall that based on a theorem by Klibanoff (2001), we hypothesized that randomization-neutral subjects with symmetric preferences are more likely to value the combination ticket differently than the heads ticket if they are uncertainty-averse rather than uncertainty-neutral.

**Result 3.** *Subjects with symmetric preferences are more likely to value the combination ticket differently than the heads ticket if they are uncertainty-averse rather than uncertainty neutral. The difference, however, is not significant.*

There is a total of 24 subjects with symmetric preferences who are randomization-neutral. Five of the 15 uncertainty-averse subjects violate stochastic independence, amongst the nine uncertainty-neutral subjects, there is only one. The difference, however, is not significant.[10] This result provides some indication that uncertainty-averse subjects are not particularly prone to violating stochastic independence. However, the test is not conclusive. In order to check whether a subject regards the coin flip and the draw from the uncertain urn as independent, one needs to observe the values of three additional combination tickets. What varies amongst the required combination tickets is the color of the ball that leads to a fixed payment and the side of the coin that wins. It is possible that uncertainty-averse subjects are more likely to violate stochastic independence for one of the other three variations, which we do not examine in our experiment. However, it seems unlikely that the

[9]The respective binomial test has a p-value of 0.01.

[10]The two-sample test of proportion has a p-value of 0.11

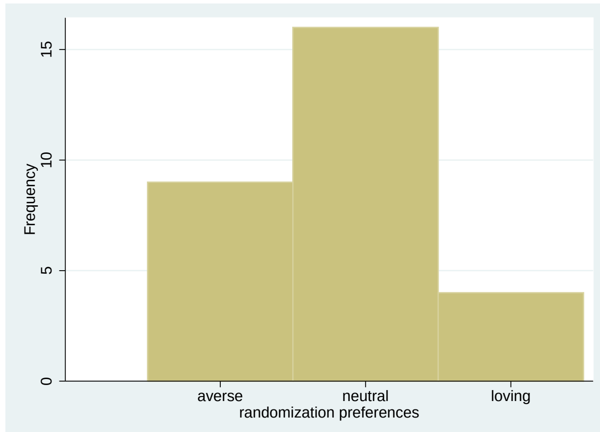


Figure 1: Attitude toward randomization amongst uncertainty-averse subjects with symmetric preferences

color of the ball and the side of the coin, which did not matter for any other decision of these subjects, matters with respect to the combination ticket.

In addition to these results, which directly relate to our hypotheses, we also want to report on an unexpected finding. A priori, we expected the share of randomization-averse subjects to be considerably smaller than one third because the respective behavior is not backed by any theory.

**Result 4.** *A non-negligible fraction of uncertainty-averse subjects dislikes randomization.*

Of the 41 uncertainty-averse subjects, 14 express a dislike for randomization. If we restrict attention to the smaller group of subjects with symmetric preferences to which the theoretical predictions apply, a similar picture emerges: 9 out of the 29 uncertainty-averse subjects prefer the pure lottery tickets over the mixture—see Figure 1. In both cases, the share is statistically not distinguishable from one third at any conventional level and hence surprisingly large. The respective subjects prefer to know whether the ticket, which they receive, is white or yellow—although they are indifferent between receiving a white and a yellow ticket. While this behavior is widely spread amongst uncertainty-averse subjects, it does not occur amongst uncertainty-neutral subjects. It is this feature which leads to the negative relationship between preferences for randomization and uncertainty aversion from Result 1.

There are a few tentative explanations for the observed behavior. We briefly introduce these explanations and discuss them. First, subjects may simply value more information. A ticket of known color may be preferred to a ticket of unknown color (randomization aversion) just as a ticket for an urn with known proportions is preferred to a ticket for an urn with unknown proportions (uncertainty aversion).

Second, the chameleon ticket pertains to the most complicated lottery in the experiment. Subjects may be less inclined to forgo money for a ticket that they find difficult to analyze. There are some indications that this could be the case. Amongst uncertainty-averse subjects, the dislike for randomization is associated with the failure to solve a problem from Frederick's cognitive-reflection test (2005)—see Table 2.[11]

The complexity is partly due to the conditional structure of the chameleon ticket. In our statistics questions, we asked the following related question: What is the conditional probability that a four appears when a ten-sided fair dice has been thrown and it is known that the number is even. Amongst uncertainty-averse subjects who answer this question wrongly, the dislike for

[11] We asked the following question: A bat and a ball cost \$1.10. The bat costs \$1.00 more than the ball. How much does the ball cost?

| solution to problem | Randomization averse no | yes | total |
| --- | --- | --- | --- |
| wrong | 1 | 4 | 5 |
| correct | 30 | 10 | 40 |
| total | 31 | 14 | 45 |

Fisher's exact test of association (one-sided): P-value = 0.027.

Table 2: Randomization Aversion and Cognitive Reflection

| probability calculation | Randomization averse no | yes | total |
| --- | --- | --- | --- |
| wrong | 5 | 8 | 13 |
| correct | 26 | 6 | 32 |
| total | 31 | 14 | 45 |

Fisher's exact test of association (one-sided): P-value $< 0.01$.

Table 3: Randomization Aversion and Statistics Knowledge

randomization is much more prevalent than for uncertainty-averse subjects who answered correctly—see Table 3.

A third reason could be that subjects are randomization-neutral but fail to remember the value for the benchmark, e.g. the white ticket for the uncertain urn. This reason is unlikely since we provided subjects with a history of their reservation prices. Moreover, one would expect deviations in both directions, whereas more subjects express a distaste for randomization rather than preferences for randomization.

Finally, the finding could be related to the loss of control associated with the randomization device. Social psychologists argue that decision makers sometimes prefer to keep control to using a randomization device (see Keren and Teigen 2008). Whether decision makers like to maintain control seems to depend on the circumstances: Dittmann, Kübler, Maug, and Mechtenberg (2008) find that experimental subjects are willing to pay a premium for exerting the right to vote even if the probability that this affects the outcome is very low, while Cettolin and Riedl (2008) observe that subjects prefer a random draw when having to decide between risky and uncertain prospects.

A conclusive answer to the question, which of these different ideas is best suited to explain why uncertainty-averse subjects may dislike randomization, is beyond the scope of our study and is left to future research.

# 6 Conclusions

We start our analysis with the classical observation from the two-color experiment by Ellsberg (1961): individuals prefer to bet in situations about which they are better informed. Existing explanations for such behavior often rely on the idea that access to an objective randomization device mitigates the problem of lack of information. Accordingly, uncertainty-averse individuals are supposed to exhibit preferences for randomization. The data from our experiment, however, does not support this view: there is no positive association between uncertainty-aversion and preferences for randomization. Uncertainty-averse subjects are more likely to be randomization-neutral rather than randomization-loving. This implies that modeling uncertainty-aversion in a Savage framework (S-approach) is better suited to describe their behavior than modeling uncertainty-aversion using a consequence space in the tradition of Anscombe-Aumann (C-approach). Neither of the two approaches, however, explains another phenomenon observed in our experiment: a considerable number of uncertainty-averse subjects exhibits a contempt for randomization. This could indicate that for many subjects, the randomization device does not reduce but enhances the problem of missing information.

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