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Framing Decisions in Experiments on Higher-Order Risk Preferences

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Alexander Haering[1]

Framing Decisions in Experiments on Higher-Order Risk Preferences

Abstract

In this study I analyze how lottery framing and lottery display type affect the degree of higher-order risk preferences. I explore differences by comparing reduced and compound lottery framing, and by comparing lotteries in an urn-style and in a spinner-style display format. Overall, my findings show that individual behavior is influenced by lottery framing but not by display format.

JEL-Code: C91, D81

Keywords: Risk aversion; prudence; temperance; higher-order risk preferences; lottery framing

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1. Introduction

Risk aversion is the established concept when analyzing decision-making under uncertainty. Most economic models assume that the majority of people are risk averse, meaning that they do not like risk involved in decisions. In general, this is captured by a negative second-order derivative of the utility function in an expected utility framework. However, it turned out that risk preferences of individuals are only captured partially by this concept. Higher-order risk preferences like prudence (positive third-order derivative of the utility function (Kimball, 1990)) and temperance (negative fourth-order derivative (Kimball, 1992)) also impact decisions made by individuals when facing uncertainty (see, e.g., Esö & White, 2004; Eeckhoudt & Gollier, 2005; and White, 2008). These theoretical studies typically assume an unobservable utility function of a decision-maker who maximizes her expected utility. Contrary to this, Eeckhoudt & Schlesinger (2006) derive a definition of higher-order risk preferences outside the expected utility framework. They define the concepts of prudence and temperance linked to individual preferences over certain lottery pairs. In general, they show that prudence, temperance and even risk preferences of any order can be associated with the preference to disaggregate harms. This work paved the way for measuring higher-order risk preferences in economic lab experiments.

In my experiment, I rely on the lotteries introduced by Deck & Schlesinger (2010). I answer the question how lottery framing and lottery display type influence[1] the degree of individual risk preferences from order 1 to order 6, using a binary choice approach. My results show that lottery framing influences individual behavior, whereas lottery display type does not. Hence, my study contributes to the understanding of higher-order risk preferences measured in the lab by being the first to analyze both − lottery framing and display type − in a between-subject design.

In general, previous work (see Noussair et al., 2014 and Trautmann & van de Kuilen, 2018 for overviews), using the theoretical framework of Eeckhoudt & Schlesinger (2006), differs in the way prudence, temperance and even higher-order risk preferences are measured: Some authors elicit individuals' risk premia, others use a binary choice approach.

In case of risk premia elicitation, the subjects are asked how much their valuations of, for instance, a prudent lottery differ compared to an imprudent lottery. This method provides information on the exact degree of prudence and temperance because subjects can be ordered with regards to their premia. Furthermore, the risk premia can be used to estimate an individual's utility function. Ebert & Wiesen (2014) first used the risk premia approach, classifying the overwhelming majority of subjects as prudent and

[1] In the proper meaning of words, reducing a compound lottery also leads to a different "display type" of a lottery. But I choose these descriptions to separate the effect caused by pure visualization from the effect that might arise because reduced lotteries are often valued differently by subjects (see, e.g., Budescu & Fischer, 2001 for an overview).

temperate. Using the Ebert & Wiesen (2014) method in a social interaction experiment, Heinrich & Mayrhofer (2018) confirmed their findings.

Contrary to the risk premia approach described above, the binary choice approach is the common way to measure higher-order risk preferences in the lab. It presents several pairs of lotteries to the subjects, e.g., one prudent and one imprudent. Subsequently, subjects are asked which lottery they prefer. By counting the amount of prudent, temperate and higher-order choices, subjects are classified accordingly. The binary choice method is used by the majority of studies. Deck & Schlesinger (2010) first used the binary choice approach classifying the majority of subjects as prudent, and only a minority as temperate. Following Deck & Schlesinger (2010), several studies confirm their findings in case of prudence (Deck & Schlesinger, 2014, 2018; Noussair et al., 2014; Baillon et al. 2018; and Haering et al., 2020). In contrast, the findings concerning temperance are less clear. On the one hand, Deck & Schlesinger (2014, 2018), Noussair et al. (2014), and Haering et al. (2020) observe an above average share of temperate choices in their subject pool. On the other hand, Baillon et al. (2018) observe only around 43% of temperate choices, confirming the first findings by Deck & Schlesinger (2010).

It is important to note that these experiments partially differ in the presentation of the lotteries to the subjects. They differ in the lottery framing (compound or reduced) and how the lotteries are displayed (spinner or urn). The majority of studies use compound lotteries (e.g., Deck & Schlesinger, 2010, 2014; Ebert & Wiesen, 2014; Noussair et al., 2014; and Heinrich & Mayrhofer, 2018), less use reduced lotteries (e.g., Baillon et al. 2018) and few studies use both framings (Deck & Schlesinger, 2018; Haering et al. 2020). Exploring differences with regard to the lottery display type reveals that a spinner design is the most common in the studies (e.g., Deck & Schlesinger, 2010, 2014, 2018 and Haering et al. 2020), and less studies use an urn design (e.g., Ebert & Wiesen, 2014 and Heinrich & Mayrhofer, 2018). In addition, some studies only measure higher-order risk preferences up to order 4 (temperance).

I, therefore, focus on risk preferences up to order 6 and rely on the most commonly used binary choice approach. I investigate how lottery framing and lottery display type influence the degree of individual risk preferences from order 1 to order 6. My two explicit research questions are: (1) Is individual behavior influenced by the lottery framing (compound or reduced)? And (2) how does the lottery display type (spinner or urn) affect behavior?

The remainder of this paper is structured as follows. In section two, I summarize the theoretical background. In section three, I present the experimental design. I summarize my findings in section four and discuss them in section five.

2. Theoretical background

This section briefly reviews the theoretical background based on Deck & Schlesinger (2014). To measure higher-order risk preferences, they use different sets of compound lotteries, which are based on the theoretical background established by Eeckhoudt & Schlesinger (2006), Eeckhoudt et al. (2009) and Crainich et al. (2013). These lottery sets consist of binary lotteries with equal probabilities, $[x, y]$. Here, the lottery contains two potential outcomes x and y, with a 50% chance of receiving x and a 50%t chance of receiving y. In case of lotteries with an order higher than 2, x and y might themselves be lotteries.

Based on the theoretical background of Deck & Schlesinger (2014), Figure 1 shows risk apportionment up to order 4 and for any order. Here, W is an individual's initial wealth ($W > 0$), and k_1 and k_2 are fixed values ($k_1 > 0$ and $k_2 > 0$). Due to the negative sign, they represent two sure losses. Two independent zero-mean background risks are represented by δ and ε.

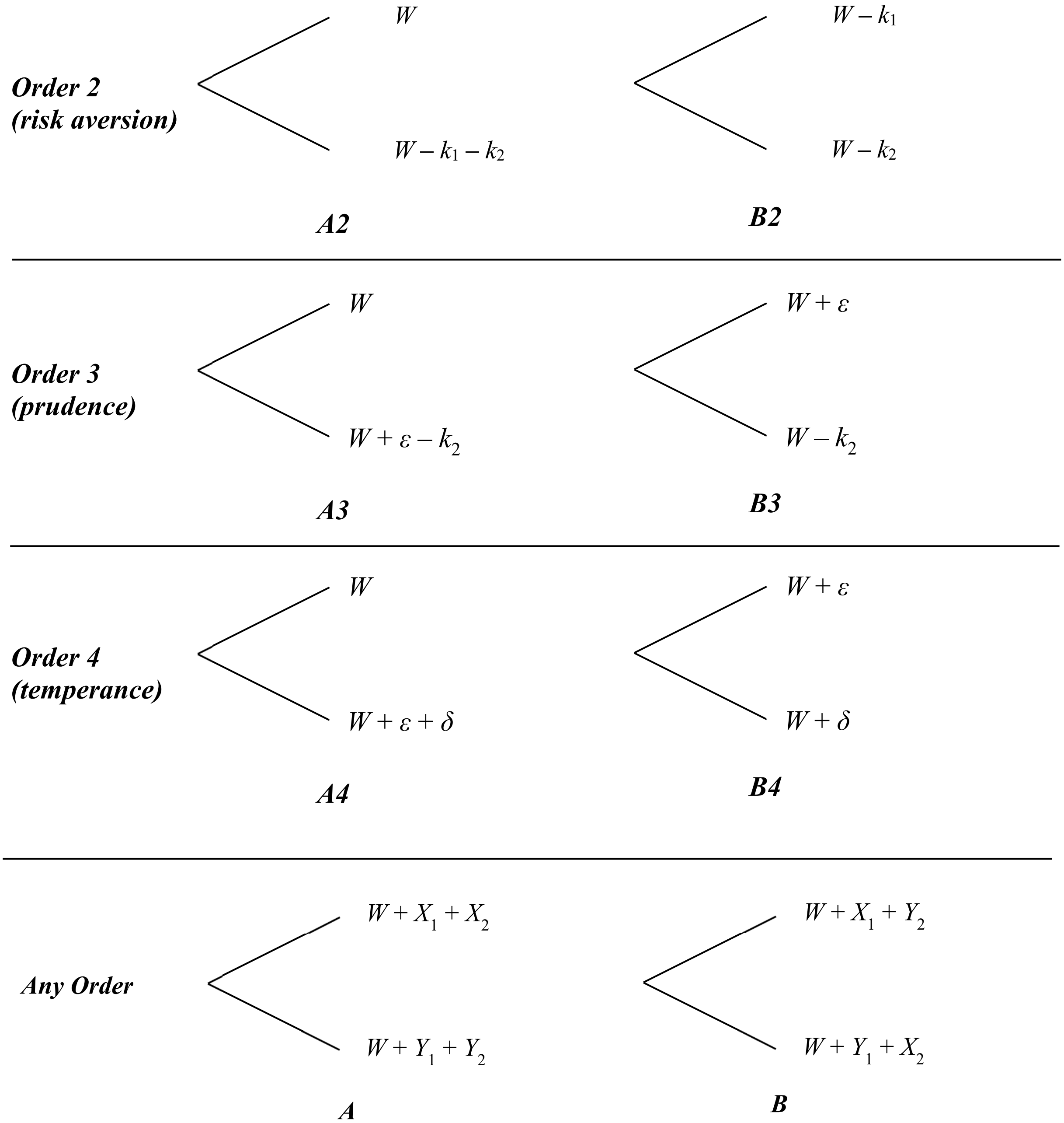
In the first row, risk apportionment of order 2 (risk aversion) is illustrated. A risk-averse individual prefers Lottery B2 over A2 because of the lower variance resulting in a disaggregation of the two sure losses k_1 and k_2 in Lottery B2. In other words, a lower variance is associated with a lower second-order risk. Vice versa, a risk-loving individual prefers Lottery A2.

The second row of Figure 1 shows risk apportionment of order 3 (prudence). Here k_1, a sure loss, is replaced by the zero-mean background risk ε. Following Eeckhoudt & Schlesinger (2006) prudence is defined as a preference for disaggregating a sure loss and an additional zero-mean risk. Hence, a prudent individual prefers Lottery B3 and an imprudent individual prefers Lottery A3.

The third row displays risk apportionment of order 4 (temperance). Here, the second sure loss k_2 is replaced by δ, the additional zero-mean risk that is independent of ε. In this case, temperance can be defined as a preference for disaggregating the two risks ε and δ (Eeckhoudt & Schlesinger, 2006). Therefore, a temperate individual prefers Lottery B4 over A4 and, vice versa, an intemperate individual prefers A4 over B4.

A general approach for orders higher than order 4 by Deck & Schlesinger (2014), based on the theoretical approach by Eeckhoudt et al. (2009), is shown in the last row of Figure 1. The approach assumes that the tasks consist of two random variables $[X_1, Y_1]$. Here, Y_1 has more n-th degree risk than X_1. Y_1 has more n-th degree risk than X_1 if the following two conditions are fulfilled: (1) X_1 and Y_1 have the same $n - 1$ moments ($n > 0$) and (2) if X_1 is n-th order stochastic dominant to Y_1. Besides that, $[X_2, Y_2]$ is a second pair of random variables, where Y_2 has more m-th degree risk than X_2. Here, all random variables are statistically independent of each other. Subjects which prefer lotteries with a lower $(m + n)$-th degree risk are "risk apportioning of order $m + n$". Subjects which are risk apportioning of order $m + n$ prefer lottery B over lottery A in Figure 1.

Figure 1: Risk apportionment up to order 4 and for any order as lottery preferences



3. Experimental design

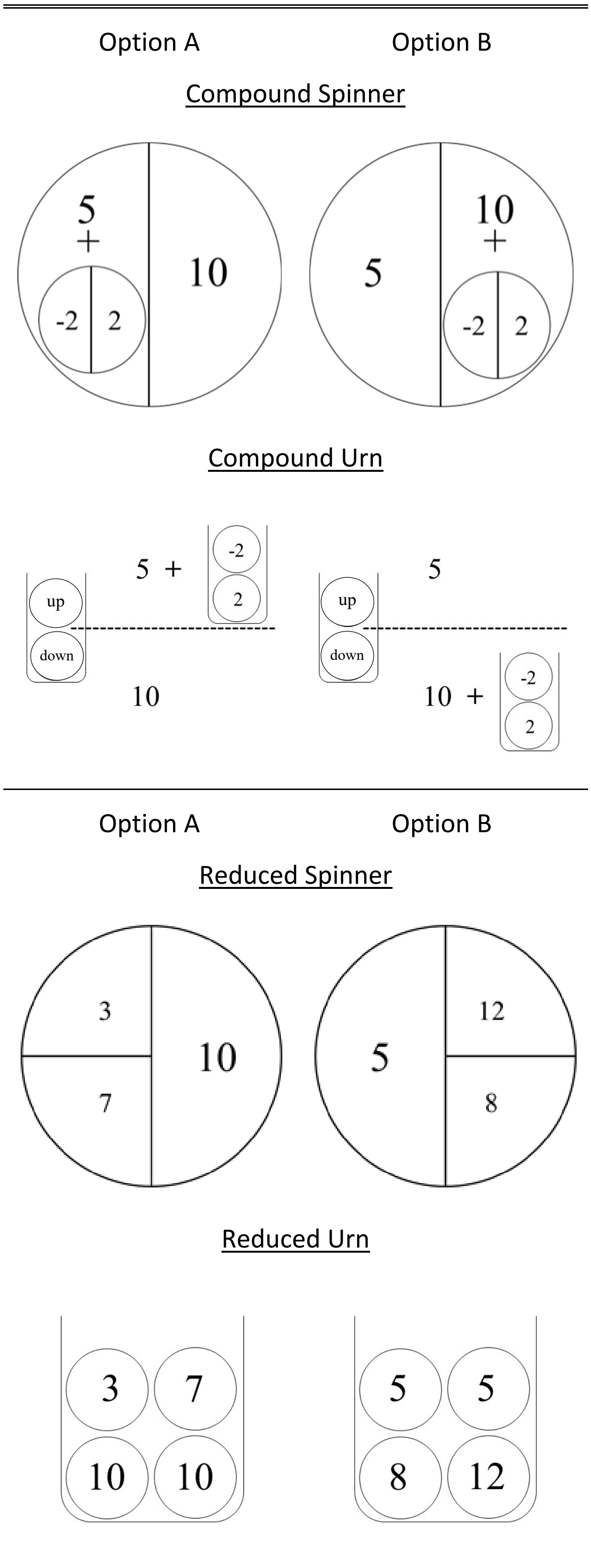
Elicitation method

The general experimental design and the lottery parameters follow the elicitation method by Deck & Schlesinger (2014). It contains 38 tasks (3 in case of order 1 and 7 each in orders 2 to 6) and subjects choose between an Option A and an Option B. In contrast to Deck & Schlesinger (2014), I introduce a reduced framing and an additional way to display the lotteries to the subjects − the urn format. Figure 2 shows examples of a prudent task (order 3) as it is presented to the subjects, depending on the framings (compound and reduced) and display types (spinner and urn) I use in my experiment. In case of spinners, the probability of winning is represented by the share of the circle (like a wheel of fortune) and in the urns display format by the number of balls in them.

In Figure 2 "Compound Spinner" and "Compound Urn" − Option A − involves a 50% chance of winning 10 ECU (experimental-currency-units) or a 50% chance of winning 5 ECU. But when a subject receives the 5 ECU, it involves a second lottery which either results in a 2 ECU win or 2 ECU loss, which is added to or subtracted from the 5 ECU. In "Reduced Spinner" and "Reduced Urn" − Option A− participants can win 5 – 2 = 3 ECU with a probability of 25%, 5 + 2 = 7 ECU with a probability of 25%, and 10 ECU with a probability of 50%. So, the reduced framing can be derived by multiplying out the probabilities of the potential outcomes.

Using the notation from Section 2, where W is an individual's initial wealth, k_2 is a fixed value, ε is a zero-mean background risk and $[x, y]$ denotes a lottery with a 50% chance of receiving x and a 50% chance of receiving y. In this example, the parameters of the task are $W = 10$ and $k_2 = 5$. The zero-mean background risk ε is represented by an additional lottery [-2, 2]. Therefore, the one lottery "Option A" corresponds to $[W - k_2 + \varepsilon, W]$ and the other lottery "Option B" to $[W - k_2, W + \varepsilon]$. Following Eeckhoudt & Schlesinger (2006) a prudent individual should prefer "Option B" over "Option A", independent of framing and lottery display type.

Figure 2: Examples of lotteries of order 3 (Task 11) as presented to participants



Experimental treatments and protocol

The economic laboratory experiment was conducted at the Laboratory for Experimental Economics (elfe) in Essen, Germany. All participants faced 34 tasks[2] in randomized order, and one of the tasks was randomly selected for payment[3]. In each task, the subjects had to choose between two lotteries, Option A or Option B. The arrangement of Option A and B was displayed randomly to the participants, meaning that Option A was randomly displayed on the left or right side of the screen and Option B vice versa. Table 1 shows my treatments as well as the lotteries` display type (spinner or urn) and framing (compound or reduced).

Table 1:Treatments

Treatment	Lotteries by Deck & Schlesinger (2014) (Order, S = Spinner or U = Urn, C = Compound or R = Reduced)
Spinner_C	1SC; 2SC; 3SC; 4SC; 5SC; 6SC
Urn_C	1UC; 2UC; 3UC; 4UC; 5UC; 6UC
Spinner_R	1SR; 2SR; 3SR; 4SR; 5SR; 6SR
Urn_R	1UR; 2UR; 3UR; 4UR; 5UR; 6UR

I use a between-subjects design and each subject only participated in one treatment. For recruiting the participants, I use ORSEE (Greiner, 2015); for programming my experiment z-Tree (Fischbacher, 2007). Overall, 143 student subjects took part. 36.4% were students of economics, 23.8% students of engineering and 39.8% students of other disciplines. They earned on average 25.41 Euro and a session lasted roughly two hours[4]. Participants were randomly assigned to one of the four treatments in each session by drawing a card from a stack of cards. After entering their respective cubical, subjects read the instructions and all remaining questions were answered in private. Before the actual tasks started, participants had to pass a test of understanding (containing four questions, see Appendix A1). In case participants had problems with a question, they were helped privately by one of the experimenters. Intermediate questions during the experiment were allowed and introduced by hand signals, questions and answers were handled privately. At the end of the experiment payments were given out in private.

[2] Unfortunately, due to a computer error I was not able to use one task in order 4 and 5 each and two tasks in order 6.

[3] This might add an additional compound layer to the lotteries. But I followed Deck & Schlesinger (2014) and used a random payment technique, which allows to compare my results with previous studies. In addition, as Azrieli et al. (2018) point out, the random payment technique "is essentially the only incentive compatible mechanism".

[4] The sessions were conducted as the first part of another experiment. Here only this first part is analyzed.

Before and after the task, the participants answered four questions. The following two questions were asked before the lottery task, but after the subjects read the instructions: "*What do you think, how confident will you be with your choices?*" and "*What do you think, how well did you understand the instructions?*". After finishing the lottery tasks, the subjects had to answer the two final questions: "*How understandable were the lotteries?*" and "*How confident are you with your decisions?*". Participants answered the questions by rating them with school grades (A to F).

4. Results

Subject pool and summary statistics

Table 2 summarizes the demographics of the subject pool I used in my experiment. The share of female participants is slightly above 50% in **Spinner_C** and **Urn_C,** but the differences between the four treatments are not significant (p =1, Fisher's exact test).

Table 2: Summary statistics

				Demographics		Course of studies	
Treatment	Display Type	Framing	N	Female	Age (SD)	Econ.	Eng.
Spinner_C	Spinner	Compound	35	51.4%	24.514 (5.198)	22.9%	31.4%
Urn_C	Urn	Compound	36	52.8%	23.333 (2.449)	41.7%	19.4%
Spinner_R	Spinner	Reduced	36	50.0%	23.917 (2.116)	38.9%	22.2%
Urn_R	Urn	Reduced	36	50.0%	24.333 (3.538)	41.7%	22.2%

Note: N is the number of participants and SD is the standard deviation.
In course of studies "Econ." represents economics and "Eng." Engineering,
the remaining participants are enrolled in other disciplines.

The observed differences regarding the average subjects' age are statistically insignificant ($p \geq 0.185$, two-sided Mann-Whitney U test). The same holds true for the share of participants studying economics ($p \geq 0.129$, Fisher's exact test) or engineering ($p \geq 0.285$). To provide a robustness check of my results, I add the subjects' age and gender to OLS regressions (see Appendix A2 for details).

Analyses of individual behavior

In this subsection the individual behavior is analyzed by comparing the four treatments (**Spinner_C, Spinner_R, Urn_C** and **Urn_R**) with each other. I measure if subjects exhibit a tendency for *n*-th order risk-loving behavior in each treatment and test whether participants' behavior differs between the treatments. I, then, pool my four treatments by lottery framing (**Compound** vs **Reduced**) and display type (**Spinner** vs **Urn**). My goal for the latter step is to measure the sole influence of the lottery framing and display type respectively. Finally, I investigate how the subjects rate the lotteries by school grades before and after the tasks and the time they need to make their decisions.

Higher-order risk preferences across treatments − In each task, subjects were able to choose between a risk-loving and a risk-averse choice. The number of choices differs between the orders. There are three choices in order 1, seven in orders 2 & 3, six in orders 4 & 5 and five in order 6. Like Deck & Schlesinger (2014), I use the number of risk-loving choices in each order as a measure of *n*-th order risk aversion: the more *n*-th order risk-loving choices a subject selects, the lower is her degree of *n*-th order risk aversion. In general, I assume that all subjects prefer more money over less, as measured by the tasks in order 1. That is the case for the vast majority of participants (98.6%). Only two subjects[5] choose an option with a lower payoff in the **Spinner_C** treatment once. Yet, this share is not statistically different when comparing **Spinner_C** with any other treatment (p = 0.239, Fisher's exact test).

Firstly, I investigate whether the participants exhibit a tendency for *n*-th order risk-loving behavior in each treatment separately. Table 3 summarizes the average number and median of *n*-th order risk-loving choices in each treatment separated by order 1 to 6. In addition, it shows p-values of two-sided Wilcoxon signed-rank tests against the median that I would expect due to random behavior by the subjects (H_0 WSR test). I, therefore, use this test strategy to measure a tendency for risk-loving or risk-averse behavior in each order.

Testing against random behavior reveals that in all treatments up to order 5, except in the **Spinner_R** treatment, I can (weakly) significantly reject random behavior by the participants ($p \leq 0.088$, two-sided Wilcoxon signed-rank test). The participants display a tendency for *n*-th order risk aversion up to order 5, apart from order 3 in **Urn_R**. Here, the subjects exhibit 3-rd order risk-loving (imprudent) behavior due to the higher number of 3-rd order risk-loving choices.

I assume that subjects stated their *n*-th order risk preferences in a nonrandom way in all four treatments up to order 5 (except order 4 in **Spinner_R**). They dislike risk in any order with order 3 in **Urn_R** treatment being the only exception. In this instance, participants prefer the 3-rd order risk-loving option,

[5] All my results reported in this paper are robust when I drop these two subjects from my analysis.

an indicator of imprudent behavior. In order 6, I can only reject random behavior in **Spinner_R**. Actually, such random behavior comes as no surprise, as the lotteries in order 6 are quite complex, even in case of reduced framing.

Table 3: n-th order risk-loving choices across treatments

Order	1	2	3	4	5	6
# of choices	3	7	7	6	6	5
H_0 WSR test	1.5	3.5	3.5	3	3	2.5
Spinner_C						
Mean	0.057	1.229	1.429	1.914	2.429	2.143
Std. Dev.	0.236	1.682	1.596	1.704	1.290	1.438
Median	0	1	1	2	2	2
p-value	**0.000**	**0.000**	**0.000**	**0.001**	**0.021**	0.145
Urn_C						
Mean	0.000	1.111	1	2.278	2.167	2.361
Std. Dev.	0.000	1.785	1.219	1.632	1.444	1.355
Median	0	0.5	1	2	2	2
p-value	**0.000**	**0.000**	**0.000**	**0.018**	**0.002**	0.590
Spinner_R						
Mean	0.000	1.472	2.889	2.917	1.833	1.889
Std. Dev.	0.000	1.765	2.095	1.381	1.384	1.282
Median	0	1	2	3	2	2
p-value	**0.000**	**0.000**	**0.088**	0.859	**0.000**	**0.012**
Urn_R						
Mean	0.000	1.222	4.111	2.444	1.583	2.194
Std. Dev.	0.000	1.476	1.894	1.698	1.273	1.369
Median	0	1	4.5	2	1	2
p-value	**0.000**	**0.000**	**0.063**	**0.072**	**0.000**	0.220

Note: Std. Dev. represents the standard deviation. p-values calculated by two-sided Wilcoxon signed-rank test (WSR) against H_0.

Secondly, I investigate differences in the share of *n*-th order risk-loving choices between each treatment separately. I test whether lottery framing, display type or both jointly influence individual risk-loving behavior in each order, respectively.

I start with lottery framings. Comparing the compound and reduced form of Spinner display types (**Spinner_C** and **Spinner_R)** reveals that participants choose highly significantly more often the 3-rd and 4-th order risk-loving option in **Spinner_R** ($p \leq 0.004$, two-sided Mann-Whitney *U* test). In case of order 5, they choose weakly significantly less often the risk-loving choice ($p = 0.054$). All other observed differences between **Spinner_C** and **Spinner_R** are insignificant ($p \geq 0.508$).

Investigating differences between **Urn_C** and **Urn_R** indicates that subjects choose highly significantly more often the 3-rd order risk-loving option and weakly significantly less often the 5-th order risk-loving option (p = 0.071) in **Urn_R** (p =0.000). All other differences between **Urn_C** and **Urn_R** are insignificant (p ≥ 0.511).

Considering differences between display types, a comparison of the reduced form of the two display types (**Spinner_R** and **Urn_R)** shows that subjects choose highly significantly more 3-rd order risk-loving options in **Urn_R** (p = 0.013). All other observed differences between these two treatments are insignificant (p ≥ 0.224). Finally, in case of the compound form of the display types (**Spinner_C** and **Urn_C),** I do not observe any significant differences (p ≥ 0.284). All findings are robust with regards to the subjects' gender and age (see Appendix A2 and A3 for the regression specification and additional OLS regressions).

In summary, my results of n-th order risk-loving choices between treatments reveal two things. (1) The majority of differences occur between the lottery framings, i.e., between **Spinner_C** and **Spinner_R** and between **Urn_C** and **Urn_R**. (2) When I consider the display types, comparing **Spinner_R** and **Urn_R** or **Spinner_C** and **Urn_C**, subjects only behave differently between **Spinner_R** and **Urn_R** in order 3. Stated differently, the display format does not influence a subject's n-th order risk-loving behavior much. This finding gives ample reason that lottery framing is the driving force of differences in n-th order risk-loving behavior.

Higher-order risk preferences across framings − To verify the finding that lottery framing influences subjects' behavior and display type does not, I pool my observations to compare both framings and both lottery display types separately. Therefore, I pool the two display type treatments depending on the lottery framing and the two framing treatments with regards to display type.

I start by comparing the aggregated **Compound** and **Reduced** treatments against each other. Again, I interpret the number of n-th order risk-loving choices as a measure of n-th order risk aversion (more n-th order risk-loving choices the lower is her degree of n-th order risk aversion).

Firstly, I explore whether the participants exhibit a tendency for n-th order risk-loving behavior in the pooled **Compound** and the pooled **Reduced** treatments. Table 4 displays the average number of n-th order risk-loving choices in the **Compound** and the **Reduced** treatments separated by orders. It shows the p-values of two-sided Wilcoxon signed-rank tests against the median I would expect under random behavior by the subjects (H_0 WSR test).

In case of **Compound** framing, I observe a clear non-random behavior of the subjects up to order 5 (p = 0.000, two-sided Wilcoxon signed-rank test). They prefer highly significantly less often the n-th order risk-loving choices and therefore exhibit a clear tendency for n-th order risk aversion.

Table 4: n-th order risk-loving choices across framings

Order	**1**	**2**	**3**	**4**	**5**	**6**
# of choices	3	7	7	6	6	5
H_0 WSR test	1.5	3.5	3.5	3	3	2.5
Compound						
Mean	0.028	1.169	1.211	2.099	2.296	2.254
Std. Dev.	0.167	1.724	1.423	1.666	1.367	1.391
Median	0	1	1	2	2	2
p-value	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.148
Reduced						
Mean	0	1.347	3.5	2.681	1.708	2.042
Std. Dev.	0	1.62	2.076	1.555	1.326	1.326
Median	0	1	4	3	1.5	2
p-value	**0.000**	**0.000**	0.986	0.146	**0.000**	**0.008**

Note: Std. Dev. represents the standard deviation. P-values calculated by two-sided Wilcoxon signed-rank test against H_0.

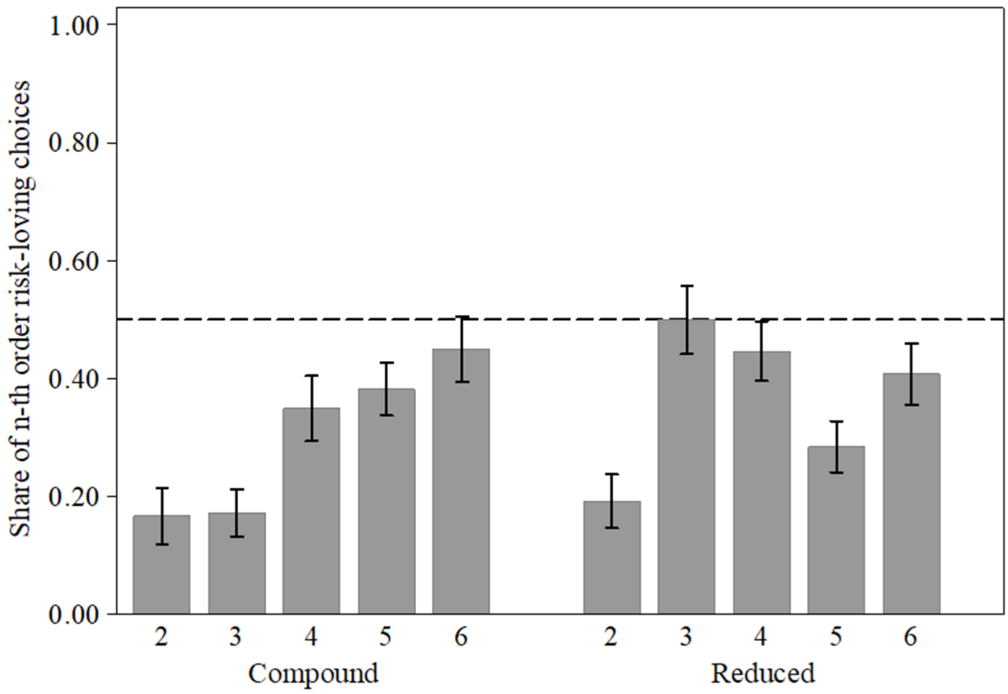
When facing the **Reduced** framing, the pattern is less clear. Participants highly significantly less often choose the *n*-th order risk-loving option in order 1, 2, 5 and 6 ($p \leq 0.008$). Yet, I cannot reject random behavior by the participants in order 3 and 4 ($p \geq 0.146$).

In summary, I observe that in pooled **Compound** framing, subjects stated their *n*-th order risk preferences in a nonrandom way. They dislike risk in every order up to order 5. But in **Reduced** framing, individuals' behavior is not that clear. They are neither risk-loving nor risk-averse in order 3 and 4.

Secondly, I explore differences in the share of *n*-th order risk-loving choices between the pooled **Compound** and pooled **Reduced** framings. I test whether lottery framing influences individual risk-loving behavior in each order. Figure 3 shows the average share of *n*-th order risk-loving choices as well as 90 percent confidence intervals. It compares both Framing treatments against each other, separated by order.

In order 3 and 4, the subjects choose (highly) significantly more often the *n*-th order risk-loving choice in **Reduced** framing ($p \leq 0.025$, two-sided Mann-Whitney *U* test) and in order 5 highly significantly less often ($p = 0.009$), instead. The behavior in order 2 and 6 is not significantly different ($p \geq 0.359$). All observations are robust when I add a female dummy and a subject's age as control variables in OLS regressions (see Appendix A3 for the regression results).

Figure 3: Share of n-th order risk-loving choices and 90 percent confidence intervals across framings



In summary, I observe a clear non-random pattern of risk-averse, prudent, temperate and edgy behavior in **Compound** lotteries. Yet, in **Reduced** lotteries, the pattern is less clear. I also observe evidence for a different behavior by the subjects due to the lottery framing. Subjects choose the *n*-th order risk-loving option more often in orders 3 and 4 in the **Reduced** framing and less often in order 5. I, therefore, find that the framing of the lotteries influences individual behavior. But the results should be interpreted with caution. I cannot reject random behavior by the participants in the **Reduced** framing.

Higher-order risk preferences across display types − In the second step, I compare the aggregated **Spinner** and **Urn** treatments against each other. My goal is to explore the effect of display type. I interpret the number of *n*-th order risk-loving choices as a measure of *n*-th order risk aversion.

First, I examine whether the subjects show a tendency for *n*-th order risk-loving behavior in the pooled **Spinner** and the pooled **Urn** treatments. Table 5 summarizes the results. Again, the table displays the average number of *n*-th order risk-loving choices in the pooled **Spinner** as well as the pooled **Urn** treatments, separated by order. It reports p-values of two-sided Wilcoxon signed-rank tests against the median, which would occur due to random behavior by the subjects (H_0 WSR test).

In both treatment pools, **Spinner** and **Urn**, participants highly significantly more often ($p \leq 0.006$, two-sided Wilcoxon signed-rank test) prefer the *n*-th order risk-averse choice. The only exception is order 6 in case of **Urn** ($p = 0.209$).

Table 5: n-th order risk-loving choices across display types

Order	**1**	**2**	**3**	**4**	**5**	**6**
# of choices	3	7	7	6	6	5
H_0 WSR test	1.5	3.5	3.5	3	3	2.5
Spinner						
Mean	0.028	1.352	2.169	2.423	2.127	2.014
Std. Dev.	0.167	1.716	1.993	1.618	1.362	1.357
Median	0	1	2	2	2	2
p-value	**0.000**	**0.000**	**0.000**	**0.006**	**0.000**	**0.005**
Urn						
Mean	0.000	1.167	2.556	2.361	1.875	2.278
Std. Dev.	0.000	1.627	2.226	1.656	1.383	1.355
Median	0	1	2	2	2	2
p-value	**0.000**	**0.000**	**0.001**	**0.003**	**0.000**	0.209

Note: Std. Dev. represents the standard deviation. P-values calculated by two-sided Wilcoxon signed-rank test against H_0.

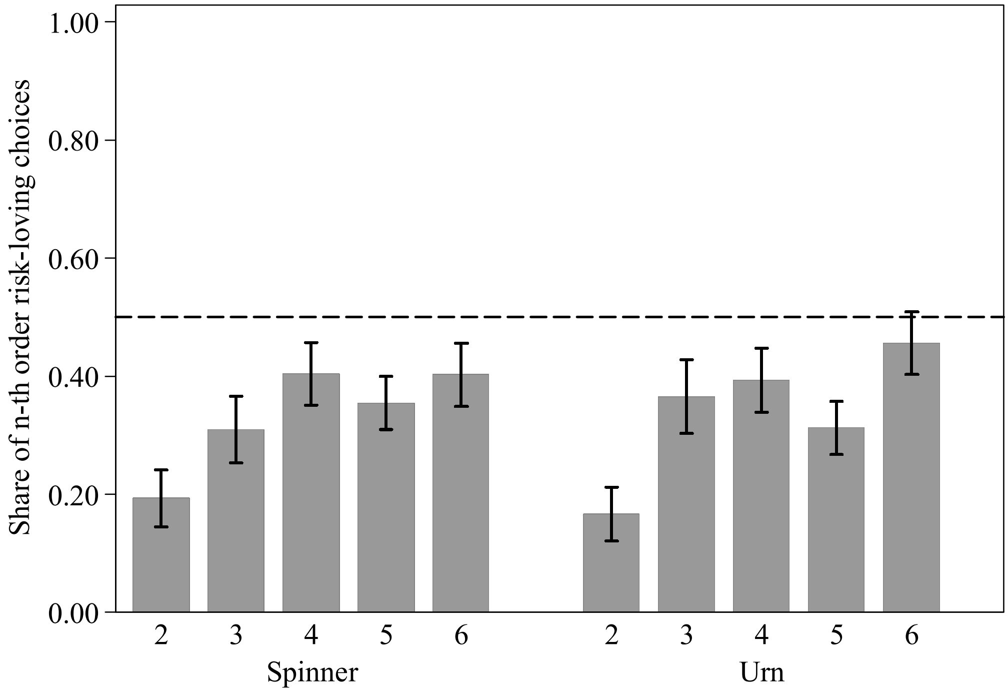
Consequently, I observe a non-random and a clear *n*-th order risk-averse behavior up to order 5 in both treatments. In case of my pooled **Spinner** treatments even up to order 6. Regardless of lottery display type, the subjects stated their *n*-th order risk preferences in a nonrandom way and dislike risk of any order.

Secondly, I examine differences in the share of *n*-th order risk-loving choices between the pooled **Spinner** and pooled **Urn** display treatments. Figure 4 displays the average share of *n*-th order risk-loving choices as well as 90 percent confidence intervals for both display type treatments separated by order.

Comparing the differences between the two display types reveals that all minor differences are not statistically significant ($p \geq 0.192$, two-sided Mann-Whitney *U* test). This observation is also confirmed by the OLS regressions (controlling for the subjects' age and gender) in Appendix A3.

In summary, I observe a non-random behavior and a clear *n*-th order risk-averse behavior up to order 5 in both treatments. I do not find evidence for a different behavior by the subjects due to the lottery display type. I, therefore, find that the display type of the lotteries does not influence individual *n*-th order risk-loving behavior.

Figure 4: Share of n-th order risk-loving choices 90 percent confidence intervals across display types



Potential differences in lottery evaluation and time needed by the subjects − In a final step, I gather more exploratory evidence about the subjects' behavior due to the four treatments. Therefore, I examine how the subjects rated the lotteries by school grades before and after the tasks. I also consider the time needed by the participants to make their decisions. I compare all my four treatments (**Spinner_C**, **Urn_C**, **Spinner_R** and **Urn_R**) separately.

To measure the confidence of the subjects before and after the lottery task as well as to investigate how understandable the instructions and the lotteries were, I used four questions. I asked the following two questions before the lottery task, but after the subjects read the instructions. These are #1 "*What do you think, how confident will you be with your choices?*" and #2 "*What do you think, how well did you understand the instructions?*". After completion of the tasks, I asked the final two questions: #3 "*How understandable were the lotteries?*" and #4 "*How confident are you with your decisions?*". The questions as well as the median grade given by the subjects are displayed in Table 6.

Overall, I observe a similar pattern with minor differences. Comparing the grades between **Spinner_C** and **Spinner_R** treatments reveals that subjects rated question #1 weakly significantly better (p = 0.095, two-sided Mann-Whitney *U* test) and question # 3 highly significantly better (p = 0.011) in the reduced framing. And comparing **Urn_C** and **Urn_R** treatments reveals that subjects rated question #3 highly significantly better (p = 0.006) in **Urn_R**. All other minor differences are insignificant (p ≥ 0.192).

Table 6: Median grades across treatments

#	Before	*Spinner_C*	*Urn_C*	*Spinner_R*	*Urn_R*
1	What do you think, how confident will you be with your choices?	B	B	B	B
2	What do you think, how well did you understand the instructions?	A	A	A	A
	After				
3	How understandable were the lotteries?	B	B	A	A
4	How confident are you with your decisions?	C	C	B-	C

Note: Questions are rated using school grades, A for "very good" to F for "unsatisfactory".

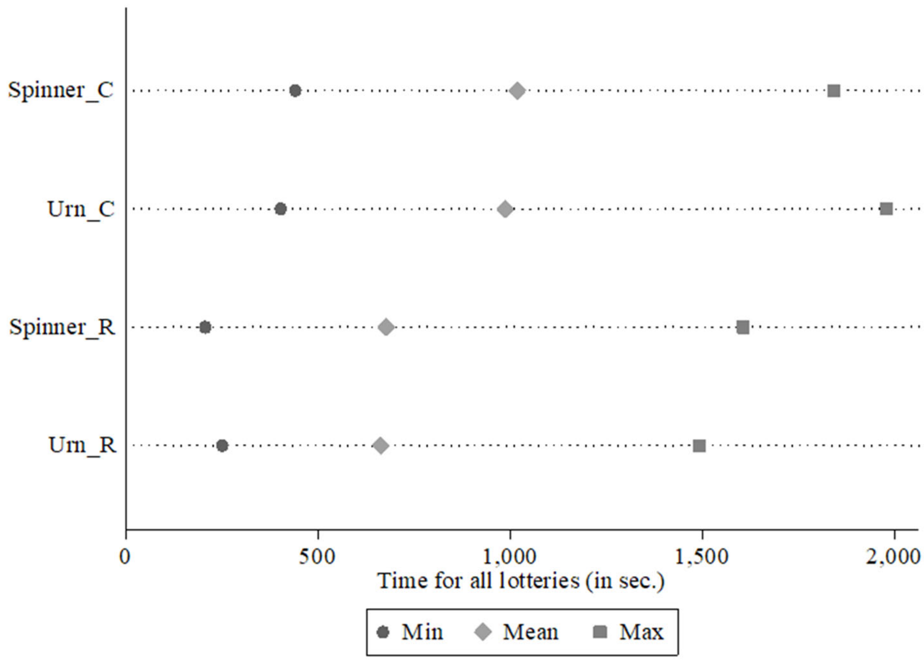
In a nutshell, subjects thought that they will be less confident when they are confronted with the compound framing with a spinner display format. They also think that the compound lotteries are less understandable in both display type formats.

In a next step, I analyze the time needed by the subjects to make their decisions. I investigate whether the subjects need more time in the more complex compound treatments compared to the reduced treatments. Figure 5 summarizes the average time (mean) as well as the minimum (min) and maximum (max) separated by treatment.

On average, the participants needed highly significantly ($p = 0.000$, two-sided Mann-Whitney *U* test) more time in **Spinner_C** than in **Spinner_R**. I observe the same pattern in the Urn treatments when I compare **Urn_C** and **Urn_R** ($p = 0.001$). Comparing **Spinner_C** and **Urn_C** as well as **Spinner_R** and **Urn_R** revels no significant differences ($p \geq 0.550$).

In summary, subjects needed more time for the compound- than for the reduced-framed lotteries, independent of the display type. This does not come as a surprise. The compound-framed lotteries (especially in higher orders) are more complex and harder to understand. But the extra time they needed is a good indicator that they understand the task and try to solve the decision problem they are facing.

Figure 5: Time needed for all lotteries across treatments



5. Conclusion

In this study, I analyze how lottery framing and lottery display type affect the degree of higher-order risk preferences. Beside risk aversion (2-nd order), I focus on prudence (3-rd order), temperance (4-th order), edginess (5-th order) and risk apportioning of order 6. Based on the elicitation method introduced by Deck & Schlesinger (2014), I explore differences by comparing reduced and compound lotteries and differences by comparing lotteries in an urn and in a spinner display format.

Overall, my findings show that the lottery framing influences individual behavior: Confronted with a spinner display format, subjects choose less prudent and temperate (3-rd and 4-th order) but more edgy (5-th order) options in a reduced lottery framing. This observation holds true for orders 3 and 5 when subjects are confronted with an urn display format. Comparing the differences emerging from the lottery display format reveals that only in order 3 subjects behave differently. They choose less prudent options due to an urn display format in a reduced framing. Put differently, the display format does not influence a subject's n-th order risk-loving behavior, but the lottery framing is the driving force of differences. These findings are confirmed when I pool my observations to compare both framings and both lottery display types separately.

My finding regarding the effect of lottery framing is confirmed by recent studies. Deck & Schlesinger (2018) compare subjects' behavior due to compound and reduced framing. They apply a spinner display format and use a within-subject design. They observe a significant framing effect: subjects are less temperate (4-th order) and more edgy (5-th order), but − in contrast to my study − slightly more prudent (3-rd order) due to a reduced framing. Using a within-subject design, Haering et al. (2020) observe that the framing influences individuals' *n*-th order risk-loving behavior, too. They compare compound with reduced lotteries using a spinner display format. Their findings confirm that subjects choose the 3-rd and 4-th order risk-loving option less often in compound lotteries. But they do not observe significant differences in order 5. Maier & Rüger (2012) study higher-order risk preferences using reduced lotteries only. In their study the share of prudent and temperate subjects is on average lower than in most studies using compound lotteries. But the authors do not directly compare lottery framings.

In addition, Haering et al. (2020) shed some light into the driving factors behind these differences in *n*-th order risk-loving behavior due to lottery framing. They show that subjects' reasoning for a prudent and temperate choice is the maximization of the smallest potential payoff when facing compound lotteries. This finding gives ample reason that subjects do not value compound and reduced lotteries in the same way (Trautmann & van de Kuilen, 2018) and might fail to reduce compound lotteries by themselves in a proper way (see, e.g., Starmer & Sugden, 1991). This might lead to a different behavior by subjects depending on the lottery framing in the context of higher-order risk preferences.

As, to my knowledge, I am the first to use different display types in one study, a verification of my finding is not straightforward. Yet, a comparison of two recent studies using a spinner display type (Deck & Schlesinger, 2018 and Haering et al., 2020) with two studies using an urn-style display type (Bleichrodt & van Bruggen, 2018 and Heinrich & Mayrhofer, 2018) reveals an ambiguous picture. The papers using a spinner design both observe that the majority of subjects exhibit prudent and temperate behavior. The papers using an urn-style display type observe inconsistent results. Heinrich & Mayrhofer (2018) find that the majority of subjects can be classified as prudent and temperate, whereas Bleichrodt & van Bruggen (2018) classify only slightly above half of the subjects as prudent and only less than half as temperate. This gives ample reason that my observation of a non-existing display type effect should be interpreted with caution. Though, it cannot be ruled out that there are other differences between these studies that influence individual behavior.

Overall, my results contribute to the understanding of higher-order risk preferences measured in the lab. I enrich the growing literature by being the first to analyze both, lottery framing and display type, in a between-subject design up to order 6. My findings can help researchers when designing new experiments on individual behavior with a focus on higher-order risk preferences.

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Appendix

A1: Test of understanding

The test is translated from German. The questions were the same in all treatments, but the graphic presented varied depending on the treatment. Participants had to choose one of the answers. The correct answer is marked in bold.

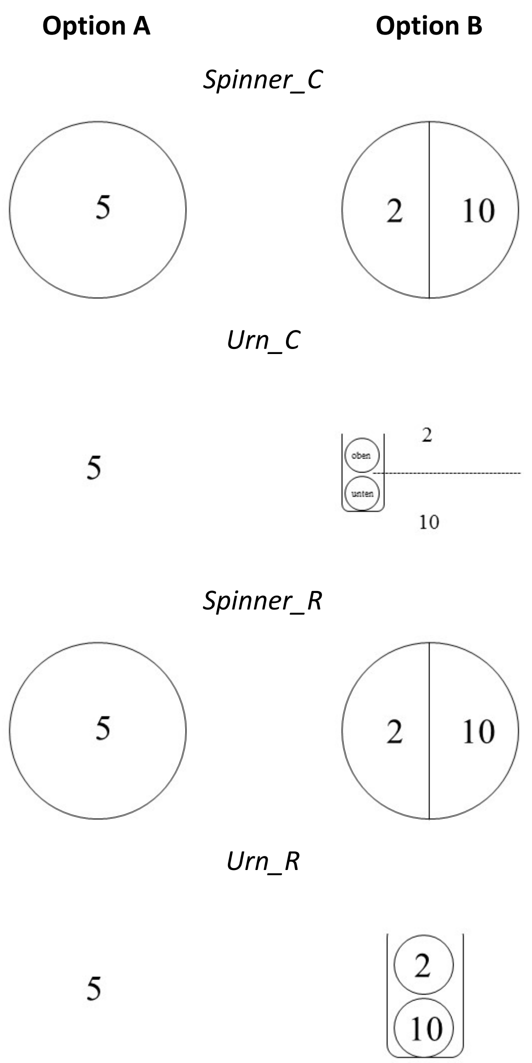
<u>Page 1</u>

Question 1: If you were to observe the following choices and selected Option A, you would receive...

Answers 1: "2" or "**5**" or "10"

Question 2: If you were to observe the following choices and selected Option B, you would receive...

Answers 2: "5" or "**2 or 10, each with an equal chance**"



Page 2

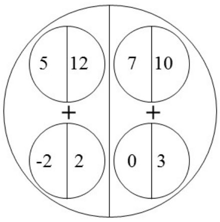
Question 3: If you were to select the following lottery, the smallest amount of money you could earn is...

Answers 3: "-2" or "0" or "**3**"

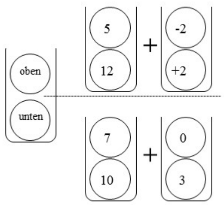
Question 4: If you were to select the following lottery, the largest amount of money you could earn is...

Answers 4:"13" or "**14**" or "17"

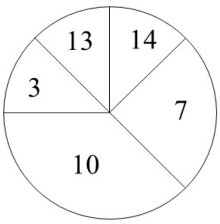
Spinner_C



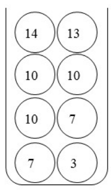
Urn_C



Spinner_R



Urn_R



A2: Summary of variables and specification regression

Table A1: Summary of variables

Variable	Description
y_i :	
Order n	Subject's number of *n*-th order risk-loving choices in order *n*
$\boldsymbol{\Gamma}'_i$:	
Urn_C	Dummy variable indicating "Urn Compound" treatment
Spinner_R	Dummy variable indicating "Spinner Reduced" treatment
Urn_R	Dummy variable indicating "Urn Reduced" treatment
Compound	Dummy variable indicating both "Compound" treatments
Spinner	Dummy variable indicating both "Spinner" treatments
$\boldsymbol{X}'_{it}$:	
Female	Dummy variable indicating female subjects
Age	The subjects' age

I estimate an OLS regression to investigate differences in higher-order risk preferences across my four treatments using the following equation:

$$y_i = \beta_0 + \boldsymbol{\Gamma}'_i\tau + \boldsymbol{X}'_i\gamma + \varepsilon_i \tag{1.1}$$

In equation 1.1 y_i represents an individual's number of risk-loving choices within one order *n*. Vector $\boldsymbol{\Gamma}'_i$ contains Urn_C_i, $Spinner\_R_i$ and Urn_R_i which are dummy variables indicating a subjects' treatment or the dummy indicator $Compound_i$ or $Spinner_i$ respectively in case of pooled analysis. The vector $\boldsymbol{X}'_i$ contains additional explanatory variables to consider potential effects of individual's demographics (*Female, Age*). To avoid problems due to a correlation between the error terms ε_i between subjects in a specific session (heteroscedasticity), I use robust standard errors.

A3: Regression results

Table A2: OLS regression number of n-th order risk-loving choices

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	O2	O2	O3	O3	O4	O4	O5	O5	O6	O6
Urn_C	-0.117	-0.076	-0.429	-0.472	0.363	0.340	-0.262	-0.255	0.218	0.193
	(0.411)	(0.407)	(0.338)	(0.359)	(0.396)	(0.400)	(0.325)	(0.331)	(0.332)	(0.336)
Spinner_R	0.244	0.255	1.460^{***}	1.448^{***}	1.002^{***}	0.989^{***}	-0.595^{*}	-0.593^{*}	-0.254	-0.263
	(0.409)	(0.403)	(0.441)	(0.445)	(0.369)	(0.371)	(0.317)	(0.322)	(0.324)	(0.326)
Urn_R	-0.006	-0.007	2.683^{***}	2.683^{***}	0.530	0.525	-0.845^{***}	-0.846^{***}	0.052	0.051
	(0.376)	(0.378)	(0.415)	(0.419)	(0.404)	(0.406)	(0.304)	(0.306)	(0.333)	(0.333)
Female		-0.452		0.438		-0.074		-0.092		0.187
		(0.284)		(0.291)		(0.273)		(0.228)		(0.229)
Age		0.030		-0.032		-0.021		0.005		-0.020
		(0.039)		(0.037)		(0.042)		(0.032)		(0.026)
p-values										
Urn_C vs Spinner_R	0.390	0.422	0.000	0.000	0.075	0.072	0.319	0.314	0.131	0.148
Urn_R vs Spinner_R	0.515	0.493	0.010	0.009	0.198	0.204	0.426	0.427	0.330	0.315
Urn_C vs Urn_R	0.774	0.859	0.000	0.000	0.672	0.636	0.071	0.072	0.605	0.660
N	143	143	143	143	143	143	143	143	143	143
AIC	558.356	558.914	567.095	567.930	545.685	549.334	495.586	499.379	498.084	500.938
BIC	570.207	576.691	578.946	585.707	557.536	567.111	507.437	517.156	509.935	518.715

Note: Constant not reported, robust standard errors in parentheses, asterisks indicate the significance level: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A3: OLS regression number of n-th order risk-loving choices

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	O2	O2	O3	O3	O4	O4	O5	O5	O6	O6
Compound	-0.178	-0.162	-2.289***	-2.302***	-0.582**	-0.586**	0.587**	0.591**	0.212	0.204
	(0.280)	(0.278)	(0.297)	(0.296)	(0.270)	(0.270)	(0.225)	(0.226)	(0.227)	(0.228)
Female		-0.452		0.441		-0.075		-0.092		0.188
		(0.283)		(0.300)		(0.273)		(0.228)		(0.228)
Age		0.030		-0.021		-0.027		0.007		-0.021
		(0.039)		(0.035)		(0.043)		(0.032)		(0.026)
N	143	143	143	143	143	143	143	143	143	143
AIC	554.853	555.413	573.061	574.458	544.192	547.649	492.902	496.666	495.478	498.289
BIC	560.779	567.265	578.987	586.310	550.117	559.500	498.828	508.518	501.404	510.141

Note: Constant not reported, robust standard errors in parentheses, asterisks indicate the significance level: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A4: OLS regression number of n-th order risk-loving choices

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	O2	O2	O3	O3	O4	O4	O5	O5	O6	O6
Compound	0.185	0.171	-0.387	-0.381	0.061	0.070	0.252	0.250	-0.264	-0.255
	(0.280)	(0.277)	(0.353)	(0.354)	(0.274)	(0.276)	(0.230)	(0.231)	(0.227)	(0.228)
Female		-0.455		0.397		-0.086		-0.081		0.191
		(0.282)		(0.355)		(0.278)		(0.232)		(0.228)
Age		0.029		-0.008		-0.025		0.003		-0.019
		(0.039)		(0.040)		(0.043)		(0.032)		(0.026)
N	143	143	143	143	143	143	143	143	143	143
AIC	554.819	555.374	621.811	624.466	548.795	552.312	498.427	502.289	494.993	497.824
BIC	560.745	567.226	627.736	636.317	554.721	564.163	504.352	514.140	500.919	509.675

Note: Constant not reported, robust standard errors in parentheses, asterisks indicate the significance level: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.