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Beyond Risk Aversion - eliciting higher order risk preferences

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Contents

Abstract

Eliciting higher order risk preferences such as prudence, temperance and edginess is most commonly done with the use of compound lotteries. This thesis builds on the current research done in eliciting the same preferences with the use of reduced form lotteries. It introduces a modified version of a reduced form in the form of a dot plot, which captures more characteristics of the underlying distribution than existing versions of other researchers. Direct comparison between both versions is made and results show that violations of reduction axiom are present, thus the usage of reduced lotteries is suggested when eliciting higher order risk preferences.

Section 1: Introduction

Risk preferences are an important concept in finance and microeconomics as they help explain how people make decisions in risky environments. Preferences such as risk aversion and risk seeking and their policy implications have been vastly researched but more recently, higher order of risk attitudes have been gaining attention too. These preferences are relevant for many fields of research such as "income inequality aversion" (Atkinson (1970); Shorrocks & Foster (1987)), portfolio choice (Wolfstetter (1999)), bidding and auctions (Eso & White (2004); White (2008)) and rent seeking (Treich (2010)).

By higher order risk attitudes researchers refer to prudence, temperance, edginess and risk preference of order 6. First researched formally by Kimball (1990), they extend the analysis of risk aversion and risk seeking. Using the definitions of Eeckhoudt & Schlesinger (2006), prudence is the "preference for disaggregation of a sure loss and the addition of a zero-mean random risk", temperance is the "preference for disaggregation of the two independent zero-mean random risks"[1], edginess is defined as the preference of adding an additional independent zero-mean risk to disaggregated sure loss and background risk and risk preference of order 6 is the preference of adding an additional zero-mean risk to disaggregated two independent zero-mean risks. Under expected utility, each of these preferences are represented by the derivatives of the utility function, risk aversion being

[1] Kimball (1993) uses the term "mutually aggravating" for those two risks.

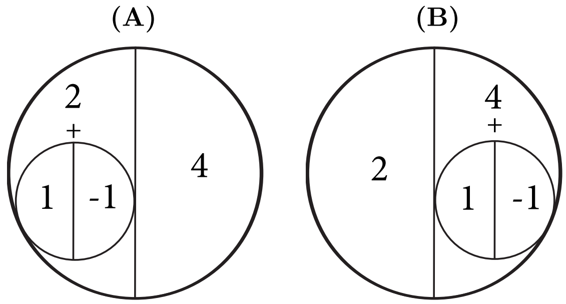
the second derivative, prudence - the third, temperance - the fourth, edginess - the fifth and order 6 being the sixth.

Some of those risk preferences have a practical definition too. One example is precautionary savings, researched first by Kimball (1990). The author finds that individuals increase their savings in the first period of a two-period model when they expect an uncertain income in the second period. Based on those findings, Gollier (2001) define prudence as the preference of having higher savings when a zero-mean risk is added that cannot be insured against and Menezes, Geiss, & Tressler (1980) give another definition of prudence as an "aversion to downside risk". As for temperance, Noussair, Trautmann, & Kuilen (2014) show that temperance is the preference of investing the precautionary savings in less risky assets in the presence of future income risks given. However, such a definition only applies for risk averse individuals. For risk lovers, those savings would be invested in more risky assets. Because of such patterns, mixed-risk preference framework is developed.

The mixed-risk preference framework, first defined by Deck & Schlesinger (2014), can be justified both theoretically (see Caballe & Pomansky (1996) for mixed risk preferences definitions and Menegatti (2014); Mayrhofer (2017) for a proof of the underlying theoretical relationship under expected utility) and empirically (Crainich, Eeckhoudt, & Trannoy (2013)). Within that framework, mixed risk averse individuals dislike risks for every order of risk preference, whereas mixed risk lovers dislike it only for odd orders of risk preference, such as temperance and risk preference of order 6, but like it for even orders. Thus, mixed risk averse individuals are also prudent, temperate, edgy and have a risk apportionment of order 6, whereas mixed risk loving are prudent, intemperate, edgy and have anti-risk apportionment of order 6. Such a relationship shows the need to further research higher order risk preferences because of how useful they are in improving our understanding on how the decision making under risk works.

Empirically, researchers use preferences over lotteries with uncertain outcomes to elicit risk preferences. For example, the research of Deck & Schlesinger (2014) uses lotteries for choices under risk in a compound form. The usage of such an experimental design relaxes the expected utility assumption, which is beneficial because the empirical findings often show that this assumption is often violated. The main assumption of such a research is that the utility function is at least 6 times differentiable so that all six orders can be measured. An example of their task design is given in Fig. 1-1.

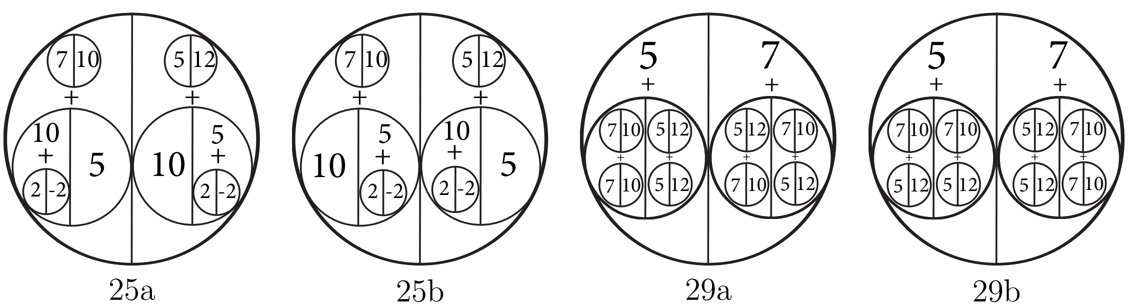
Figure 1-1: (Deck & Schlesinger, 2014)'s Task 14, a 3rd order task



In this example, a vertical line represents a 50% split in probability, i.e. in **A** outcome 4 has 50% chance of occurring, while the left side is a lottery on its own - outcome 1 and 3 each have an overall chance of 25%. In **B** outcome 2 has 50% chance and outcomes 3 and 5 each have 25% chance. This means that subjects choosing between option **A** and **B** are actually choosing where to attach the lottery {1, -1} to the good outcome 4 (showing prudence) or to the bad outcome 2 (showing imprudence).

The construction of higher order risk preferences tasks in is done similarly - by adding lotteries, representing the zero-mean risk, over other lotteries. However, tasks for each order higher than third have different ways of construction. To illustrate, an example is given in Fig. 1-2. Task 25 is constructed by combining tasks of order 2 and 3, whereas Task 29 is combining order 1 and 4. Even though both tasks elicit the same order of risk preference (i.e. edginess), their design differ. Another noticeable aspect of the task design is that the difficulty is higher than tasks eliciting prudence.

Figure 1-2: (Deck & Schlesinger, 2014)'s Task 25 (2+3) and Task 29 (1+4), fifth order tasks



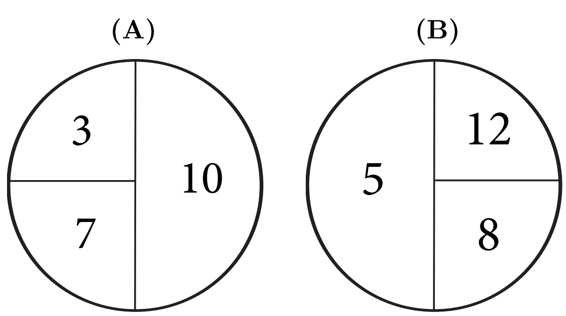
Deck & Schlesinger (2014) find that for higher than fourth order risk preferences, subjects do not have a strong preference towards the choices given. There is a possibility that by framing choices as a compound lottery, subjects find these choices too difficult at higher orders and thus choose at random. This has been a motivation for some researchers to develop different ways of presenting the task choices. For example, Maier & Rüger (2012) use a reduced form of the lotteries in Eeckhoudt & Schlesinger (2006). The final outcomes of each task are presented in a table with each outcome in a separate cell and subjects have to choose their preference between two of such tables. An example is given in Table 1.1. Thus, the probability of occurring of each outcome is equal to the number of cells in which that outcome appears divided by the total number of cells in that table. In order for a subject to know the probability of each outcome, they would have to calculate it on their own as no explicit measurement is shown. Moreover, the design does not reflect graphically the overall distribution of the final outcomes in terms of absolute distance between each outcome. This increases the difficulty of the tasks because it requires the subjects to put extra effort in order to make a decision.

Table 1.1: (Maier & Rüger, 2012)'s reduced form task eliciting prudence

Option A					Option B				
Outcome	1	2	3	4	Outcome	1	2	3	4
Points	6	10	10	10	Points	8	8	8	12

More recently, Haering, Heinrich, & Mayrhofer (2017) use Deck & Schlesinger (2014)'s framework and introduce another design of the reduced form. The researchers present each task as a pie chart, reflecting the fact that each outcome to have different probability, depicted as the share of outcome in the pie chart. An example is shown in Fig. 1-3. Their design is better than Maier & Rüger (2012) in terms of showing the final probabilities for each outcome but what is left for the subject is to visualize the absolute differences between the final outcomes of each option.

Figure 1-3: Reduced form of (Deck & Schlesinger, 2014)'s Task 11, as used by Haering et al. (2017)



This thesis introduces a modified reduced form that intends to overcome the difficulties concerning the framing of tasks eliciting risk preferences. It is based on Deck & Schlesinger

(2014)'s framework and does not only show the probabilities for each outcome but also the whole distribution of outcomes by presenting it graphically in a dot plot graph, resembling a probability distribution function that could be easily understood by the subjects. Ebert (2013) shows that any two choices in tasks eliciting a certain risk attitudes differ only with respect to one of the central moments of two underlying distributions therefore, using the modified reduced form creates a way to choose between different central moments.

On this matter, Camerer & Ho (1994) introduce a weak version of an independence axiom that would be sufficient for assuming no differences between choices in compound forms and reduced forms of lotteries. In order to assume independence of the way the task is presented, the observed behavior should not violate the compound-betweenness and reduction axioms.

The compound-betweenness axiom states that if A ≻ B then A ≻ (p, A; 1-p, B) ≻ B, for ∀ p ∈ (0, 1) and the reduction axiom states that (p, A; 1-p, B) ~ pA + (1-p)B. This means that subjects should not only follow continuity condition but also be able to reduce compound lotteries to simple lotteries correctly.

Empirically, Luce (1990) do not find violations of compound-betweenness axiom even when independence is violated therefore, difference should come from violation of the reduction axiom. In the context of this thesis, this means that comparison between the modified reduced form introduced here and the compound form of Deck & Schlesinger (2014) would result in estimating the extent of the violation of the reduction axiom. Such violations would potentially explain the weak preferences found by researchers on higher than fourth order risk preference. Thus, if subjects do not reduce lotteries properly but have more clear preferences when making decisions under the reduced form, then compound forms would not be suitable for estimating higher order risk preferences. This introduced the main hypothesis of this thesis, i.e. the reduced form captures higher order risk preferences better.

The following section 2 reviews empirical results of the current research on the topic, section 3 outlines the experimental design, section 4 presents the methodology and results of testing the hypothesis in this thesis and section 5 conclude and discuss the results. All additional information is contained in the Appendix.

Section 2: Literature review

Deck & Schlesinger (2010) first use choice-based design with a compound form lotteries to elicit higher order risk preferences and they find the majority of subjects being prudent (61%)[2] and temperate (38%). Their findings for prudence are replicated by other researchers using choice-based method as well - Ebert & Wiesen (2011) find 65.1% of subjects being prudent, Noussair et al. (2014) find between 67.6% and 89% depending on the sample, Deck & Schlesinger (2014) find 76.5% and Baillon, Schlesinger, & van de Kuilen (2018) find 70.8%. As for the temperance, the results are more inconsistent. Baillon et al. (2018) find 57.2% of subjects to be temperate, while the rest of the researchers find temperate behavior in between 58% (Noussair et al. (2014)) and 79.9% (Deck & Schlesinger (2014)). A common result for the research on higher order risk preferences is that temperance is less prevalent and pronounced than prudence.

Another method of eliciting risk preferences is by determining the risk premia. Using this method, Ebert & Wiesen (2014) find positive required premium for prudence tasks in 88% of the subjects and 75% for temperance tasks. Heinrich & Mayrhofer (2018) use the same methodology and find 96% prudent and 87% temperate subjects.

Using the reduced forms discussed in section 1, researchers confirm the findings for prudence. Maier & Rüger (2012) find 60% of subjects being prudent and Haering et al. (2017) find between 75.4% and 77% depending on the country. Deck & Schlesinger (2018) use similar reduced form as Haering et al. (2017) and 77% of their sample are prudent. However, the results for temperance are still conflicting, ranging from 47% for Deck & Schlesinger (2018) to between 63.5% and 71.1% for Haering et al. (2017).

For higher order risk preferences, modest edginess is found by Deck & Schlesinger (2014) and Haering et al. (2017), both significant. For order 6, the research up to date has only found marginally significant evidence in favor of risk apportionment of order 6 (i.e. anti-apportionment of order 6 was less prevalent).

This thesis contributes to the existing literature by introducing a modified version of a reduced form lotteries but also by replicating existing research using limited incentives.

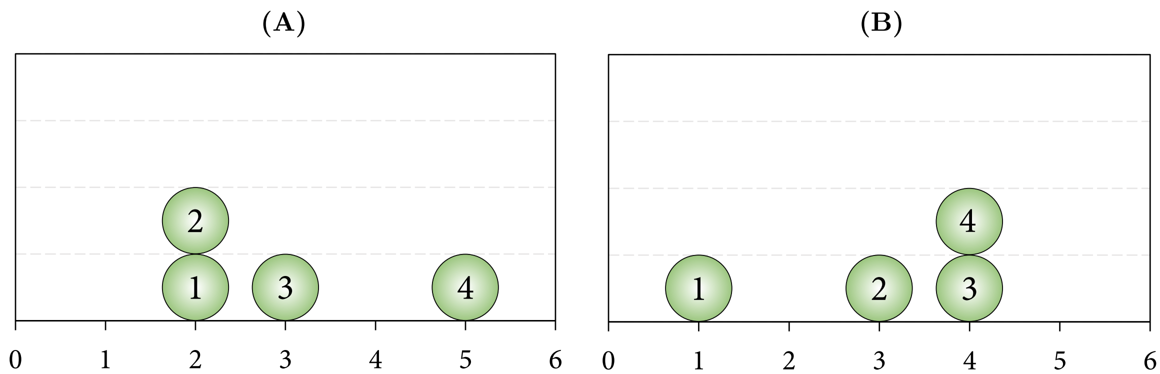
[2] All the results shown in this section are the mean number of tasks consistent with a specific risk preference as a percentage of the total number of tasks

Section 3: The experiment

3.1 General setup

The tasks in the experiment are presented in a dot plot - the y-axis represents the probability of each outcome and the x-axis - all the outcomes. Each ball on the plot represents a probability of $1/n$, n ($n \in \mathbb{N}$) being the order of risk preference. Stacked in a vertical way, one can see the probability of each outcome. An example is given bellow.

Figure 3-1: Reduced form of (Deck & Schlesinger, 2014)'s Task 14, a third order task



In this example, the experimenter has a bag of four numbered balls from 1 to 4 and randomly picks one of them. The outcome for the subject depends on the number of that ball - the higher the number, the higher the outcome. In option **A** of the given example, if the experimenter picks a ball with a **2** on it, the subject will receive 2 points. If it is a **4**, they will receive 5 points. In other words, they have a 50% chance of getting 2 points, 25% of receiving 3 and 25% chance of getting 5 points, which is reflected on the y-axis, i.e. the height of the numbered balls. The reduced form shows clearly the difference in the outcome distribution of the specific order of risk preference. In the figure one can see that the mean and the variance is the same for choice **A** and choice **B** but they differ in their skewness. Thus, subjects have to choose their preference between a positive and negative skewed distribution. A prudent subject would prefer option **B**.

The tasks for higher order risk preferences are designed in a similar way. For example, for the third order tasks, the difference between the two options comes from the skewness, keeping the mean and the variance the same, for the fourth it is the kurtosis that creates the difference between the two options, keeping all other characteristic of the distribution the same and so on. The number of balls in the experimental design increases as the order of risk preference that is elicited increases and is thus equal to $2^{(n-1)}$. In this thesis, risk preferences are considered from the fourth to the sixth order, i.e. the maximum number of balls is 32. Figures 3-2, 3-3 and 3-4 show examples.

Figure 3-2: Reduced form of (Deck & Schlesinger, 2014)'s Task 19, a fourth order task

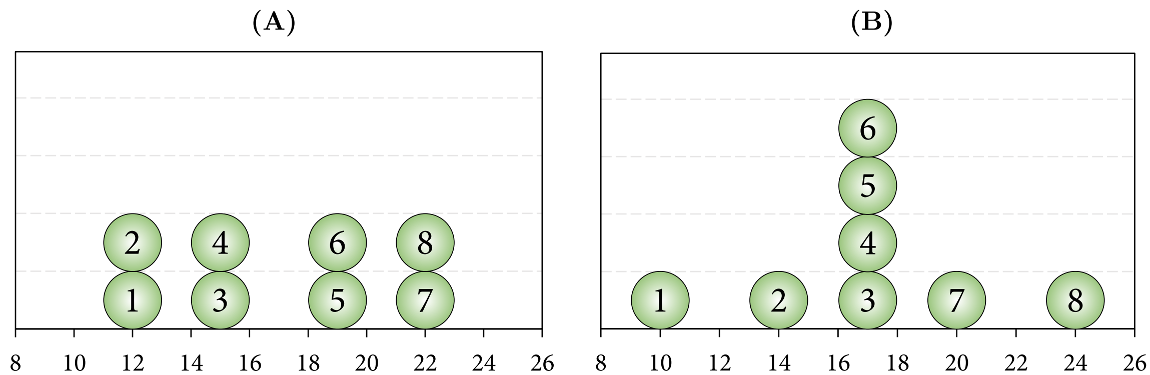


Figure 3-3: Reduced form of (Deck & Schlesinger, 2014)'s Task 29, a fifth order task

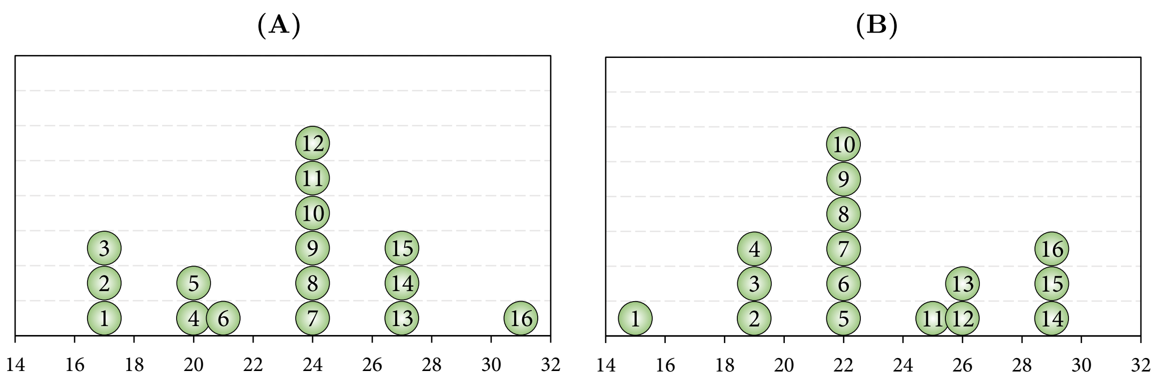
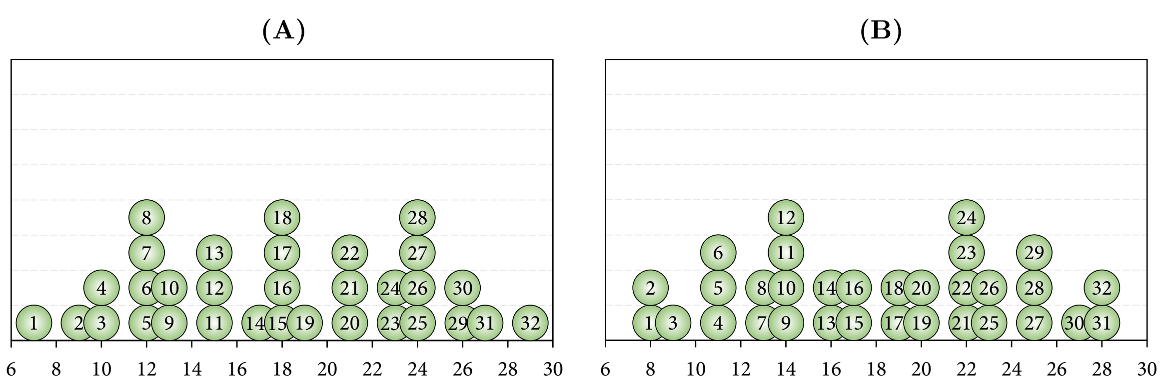


Figure 3-4: Reduced form of (Deck & Schlesinger, 2014)'s Task 34, a sixth order task



3.2 Tasks

The experimental framework is provided by Deck & Schlesinger (2014). The authors have constructed 38 different tasks that elicit risk attitudes up to sixth order risk preference, uncovering risk attitudes by asking subjects to make a choice between two lotteries. The way the research question will be investigated in this thesis is by using their choice list to conduct a decision-making experiment, similar to what the authors have already conducted. This allows for replication of their results, as well as further research on this topic.

In order to decrease the duration of the experiment to minimize fatigue, 24 tasks are given to the subjects instead of 38 as in the original framework, having 8 tasks for each of the 3 orders elicited. 10 out of those 24 are the same as in Deck & Schlesinger (2014), while the rest are constructed by simple arithmetical manipulations (addition, subtraction, multiplication and division). The way those manipulations is done makes sure that the final outcomes in the experiment are not decimals as well as that the reduced form design is clear enough in terms of balls overlapping in the dot plot. The choice of these 10 tasks is done in such a way that the task pool consists of only 2 types of constructions. This simplifies the task pool and the subject's decision making, especially in the compound form. An overview of all tasks can be seen in table 3.3. The way the tasks is presented to the subject is by randomization while keeping each 8 tasks together. Additionally, the location (left or right) of the options A and B is randomized. This way any order effect is minimized.

The choice to include only 3 orders of risk preference in the experimental design[3], each being elicited by 8 tasks, is done to decrease the probability of randomness causing a strong risk preference as compared to the current research done (e.g. Noussair et al. (2014) use 5 tasks and Deck & Schlesinger (2014) use 7 with various types of constructions for each order[4]), while keeping the experiment short due to low incentives. Using similar task list in this thesis is not ideal since it increases the complexity of the tasks, which is not compensated by the incentives structure. A strong risk preference here is defined by either the subject being consistent in all of the tasks eliciting a particular preference by allowing the subject to have one mistake. With 7 tasks, a Binomial distribution shows a probability

[3]It should be noted, however, that tasks testing for monotonicity, risk aversion and prudence (i.e. first, second and third order risk preference) is included in instructions to facilitate subjects' understanding.

[4]Construction here refers to the construction explained in Section 2.

of about 12.5% of a subject misclassified as having a strong risk preference, i.e. the subject being consistent in all questions or all questions except for one, while the same probability is about 7% for 8 tasks. This helps to capture random decision-making easier, which is beneficial for this thesis because using low incentives together with complex tasks is likely to result in more randomness than what other researchers have found.

3.3 Experimental design

With subjects performing multiple tasks, wealth effects might become an issue. To overcome this, this thesis uses a random lottery incentive, which picks randomly one task to be actually paid. According to Cox, Sadiraj, & Schmidt (2015) this is the only incentive compatible payoff structure for most of the existing models. The expected payoff of the experiment is €6.56 and only one subject was paid for their participation.

To test the hypothesis of this thesis, an online experiment is conducted, using the platform Qualtrics. The instructions can be found in the Appendix. The majority of the subject pool consisted of undergraduate and graduate students from Erasmus University Rotterdam but there are also students from other universities in Bulgaria, United Kingdom, Germany and Spain, leading to a predominantly European sample.

Half of the sample, called the *Treatment* group, is randomly selected to make the experiment in the modified reduced form and the other half, the *Control* group, makes the experiment in the compound form. This creates a *between*-subject experimental design. A *within*-subject design would require less subjects and it would limit the group differences (see MacKenzie (2013) for details) but in the case of this thesis the incentives structure (the probability of actually being paid is less than 1%) and randomization done over a sample of university students makes a *between*-subject design more appropriate since fatigue is minimized from the number of tasks and the groups can be assumed to be heterogeneous. Conducting a *within*-subject design in this case would double the number of tasks for each subject, further decreasing the incentives for subjects to put the same effort as they would have put if they were to do the experiment in a lab settings.

Table 3.1: Task list used in this thesis

Task[a]	Order[b]	Construction[b]	Option A[c]	Option B[c]	Exp. payoff[d]
1 (18)	4	2+2	[[14, 20] + [14, 20], [10, 24] + [10, 24]]	[[10, 24] + [14, 20], [14, 20] + [10, 24]]	€8.50
2 (18, x*0.5*)	4	2+2	[[7, 10] + [7, 10], [5, 12] + [5, 12]]	[[5, 12] + [7, 10], [7, 10] + [5, 12]]	€4.25
3 (18,-*5*)	4	2+2	[[9, 15] + [9, 15], [5, 19] + [5, 19]]	[[5, 19] + [9, 15], [9, 15] + [5, 19]]	€7.25
4 (18, -*9*)	4	2+2	[[5, 11] + [5, 11], [1, 15] + [1, 15]]	[[1, 15] + [5, 11], [5, 11] + [1, 15]]	€6.25
5 (19)	4	2+2	[[7, 10] + [7, 10], [5, 12] + [5, 12]]	[[5, 12] + [7, 10], [7, 10] + [5, 12]]	€4.25
6 (19, -*4*)	4	2+2	[[3, 6] + [3, 6], [1, 8] + [1, 8]]	[[1, 8] + [3, 6], [3, 6] + [1, 8]]	€3.25
7 (21)	4	2+2	[[1, 16] + [1, 16], [5, 12] + [5, 12]]	[[5, 12] + [1, 16], [1, 16] + [5, 12]]	€4.25
8 (21, x*2*)	4	2+2	[[2, 32] + [2, 32], [10, 24] + [10, 24]]	[[10, 24] + [2, 32], [2, 32] + [10, 24]]	€8.50

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[a] Task number in parenthesis is the corresponding task in Deck & Schlesinger (2014) and its modification, if applicable, in italics.

[b] Order denotes the order of risk preference that is being elicited by the given task. Construction refers to how the task is being constructed in terms of lower order tasks.

[c] $[x_i, x_j]$ denotes a lottery of having a 50% chance of winning x_i and 50% chance of winning x_j.

[d] Expected payoff is calculated by taking into account that 1 point = €0.25.

Table 3.1: (continued)

Task	Order	Construction	Option A	Option B	Exp. payoff
9 (25)	5	2+3	$[[7, 10] + [5, 10 + [2, 2]],$ $[5, 12] + [5 + [2, 2], 10]]$	$[[7, 10] + [5 + [2, 2], 10]],$ $[5, 12] + [5, 10 + [2, 2]]$	€4.00
10 (25, x*2*)	5	2+3	$[[14, 20] + [10, 20 + [4, 4]],$ $[10, 24] + [10 + [4, 4], 20]]$	$[[14, 20] + [10 + [4, 4], 20]],$ $[10, 24] + [10, 20 + [4, 4]]$	€8.00
11 (25, x*3*)	5	2+3	$[[21, 30] + [15, 30 + [6, 6]],$ $[15, 36] + [15 + [6, 6], 30]]$	$[[21, 30] + [15 + [6, 6], 30]],$ $[15, 36] + [15, 30 + [6, 6]]$	€12.00
12 (26)	5	2+3	$[[2 + 8, 4] + [10, 20 + [4, 4]],$ $[2, 4 + 8] + [10 + [4, 4], 20]]$	$[[2 + 8, 4] + [10, 20 + [4, 4]],$ $[2, 4 + 8] + [10 + [4, 4], 20]]$	€5.50
13 (26, x*0.5*)	5	2+3	$[[1 + 4, 2] + [5, 10 + [2, 2]],$ $[1, 2 + 4] + [5 + [2, 2], 10]]$	$[[1 + 4, 2] + [5, 10 + [2, 2]],$ $[1, 2 + 4] + [5 + [2, 2], 10]]$	€2.75
14 (27)	5	2+3	$[[20 + 30, 40] + [5, 10 + [2, 2]],$ $[20, 40 + 30] + [5 + [2, 2], 10]]$	$[[20 + 30, 40] + [5 + [2, 2], 10],$ $[20, 40 + 30] + [5, 10 + [2, 2]]$	€13.13
15 (28)	5	2+3	$[[5, 12] + [5, 10 + [2, 2]],$ $[1, 16] + [5 + [2, 2], 10]]$	$[[5, 12] + [5 + [2, 2], 10]],$ $[1, 16] + [5, 10 + [2, 2]]$	€4.00
16 (28, x*2*)	5	2+3	$[[10, 24] + [10, 20 + [4, 4]],$ $[2, 32] + [10 + [4, 4], 20]]$	$[[10, 24] + [10 + [4, 4], 20]],$ $[2, 32] + [10, 20 + [4, 4]]$	€8.00

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Table 3.1: (continued)

Task	Order	Construction	Option A	Option B	Exp. payoff
17 (32)	6	3+3	[[5 + [2, 2], 10]] + [5 + [2, 2], 10]], [5, 10 + [2, 2]] + [5, 10 + [2, 2]]	[[5 + [2, 2], 10]] + [5, 10 + [2, 2]], [5, 10 + [2, 2]] + [5 + [2, 2], 10]]	€3.75
18 (32, x*2*)	6	3+3	[[10 + [4, 4], 20]] + [10 + [4, 4], 20]], [10, 20 + [4, 4]] + [10, 20 + [4, 4]]	[[10 + [4, 4], 20]] + [10, 20 + [4, 4]], [10, 20 + [4, 4]] + [10 + [4, 4], 20]]	€7.5
19 (32, *+5*)	6	3+3	[[10 + [7, 7], 15]] + [10 + [7, 7], 15]], [10, 15 + [7, 7]] + [10, 15 + [7, 7]]	[[10 + [7, 7], 15]] + [10, 15 + [7, 7]], [10, 15 + [7, 7]] + [10 + [7, 7], 15]]	€5
20 (33)	6	3+3	[[5 + [2, 2], 10]] + [10 + [4, 4], 20]], [5, 10 + [2, 2]] + [10, 20 + [4, 4]]	[[5, 10 + [2, 2]] + [10 + [4, 4], 20]], [5 + [2, 2], 10]] + [10, 20 + [4, 4]]	€5.63
21 (33, x*2*)	6	3+3	[[10 + [4, 4], 20]] + [20 + [8, 8], 40]], [1020 + [4, 4]] + [20, 40 + [8, 8]]	[[10, 20 + [4, 4]] + [20 + [8, 8], 40]], [10 + [4, 4], 20]] + [20, 40 + [8, 8]]	€11.25
22 (33, *+5*)	6	3+3	[[10 + [7, 7], 15]] + [15 + [9, 9], 25]], [10, 15 + [7, 7]] + [15, 25 + [9, 9]]	[[10, 15 + [7, 7]] + [15 + [9, 9], 25]], [10 + [7, 7], 15]] + [15, 25 + [9, 9]]	€6.88
23 (34)	6	3+3	[[10 + [4, 4], 20]] + [2 + [1, 1], 4]], [10, 20 + [4, 4]] + [2, 4 + [1, 1]]	[[10 + [4, 4], 20]] + [2, 4 + [1, 1]], [10, 20 + [4, 4]] + [2 + [1, 1], 4]]	€4.5
24 (34, x*2*)	6	3+3	[[20 + [8, 8], 40]] + [4 + [2, 2], 8]], [20, 40 + [8, 8]] + [4, 8 + [2, 2]]	[[20 + [8, 8], 40]] + [4, 8 + [2, 2]], [20, 40 + [8, 8]] + [4 + [2, 2], 8]]	€9

Section 4: Results

The total number of subjects participating in the experiment is 155, with 78 having the confound form and 77 the reduced form. Firstly, the aggregate behavior is analyzed, then the behavior of the two groups is compared.

4.1 Aggregate behavior

To analyze the aggregate behavior, subjects have to be classified as having a particular risk preference versus being neutral. As the median number of answers is 4, allowing for a deviation of 1 question, a neutral subject towards a particular risk preference can be defined as having 3, 4 or 5 number of tasks answered in a consistent way. The rest of the subjects can be classified as having a particular risk preference[5]. The following table presents the results of this thesis.

	Intemp.	Temp.	Non-edgy	Edgy	Anti-order 6	Order 6
Reduced form	42.1%	32.9%	9.2%	38.2%	19.7%	23.7%
Compound form	16.9%	26%	19.5%	27.3%	14.3%	20.8%

In the reduced form, there are noticeably more intemperate subjects than temperate, which is not the case for the compound form. For edginess and risk preference of order 6, the pattern for both forms is the same, even though with the reduced form less subjects can be classified as neutral. A potential explanation for the differences in temperance could be that the reduced form makes subjects more willing to take risks because they can see more clearly the best outcomes and compare those between the two choices, which is consistent with the findings of Camerer & Ho (1994) that reduced forms induce a more risk-seeking behavior.

Since there is no reason to believe that subjects differ in the incentives and environmental effects across treatments, classifying more subjects with a particular risk preference is a clear indication that the reduced form captures better risk preferences of higher order. To

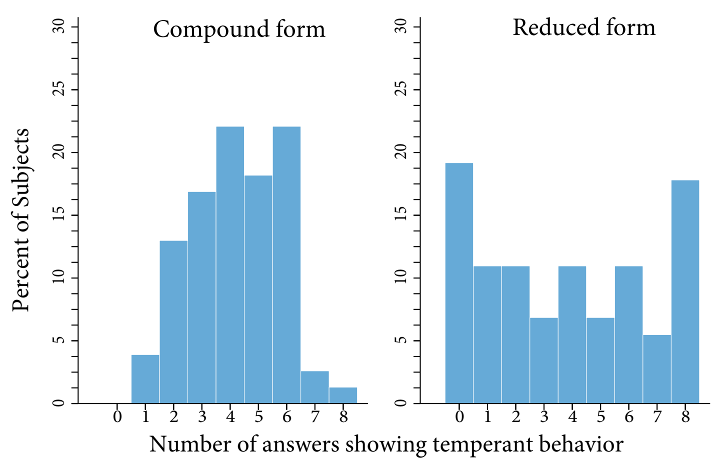
[5] This classification includes not only subjects who have strong preference but also subjects that cannot be classified as neutral.

test this, next subsection focuses on group comparison using graphical representations and non-parametric tests.

4.2 Group comparison

Looking at the histograms for temperance in picture 4-1, one can discern a clear difference in the distributions of the two groups. For the reduced form group, the dispersion of the answers given by subjects is higher. There is also observable clusters of number of answers at the tails for the reduced form, an indication that the reduced form captures strong risk preferences better. Chi-squared test shows that for subjects performing tasks in the reduced form, their number of tasks showing temperate behavior is statistically different than the median ($\mathcal{X}^2 = 158.75$, $p - value < 0.001$), however, for compound form this difference is statistically insignificant ($\mathcal{X}^2 = 49.0$, $p - value = 0.993$). Direct comparison between the groups using Mann-Whitney U test shows no significant differences in the mean number of answers ($p - value = 0.198$). The difference in the groups, however, is captured by a robust tests for equality of variances ($p - value < 0.001$), confirming the dispersion differences seen from the histograms.

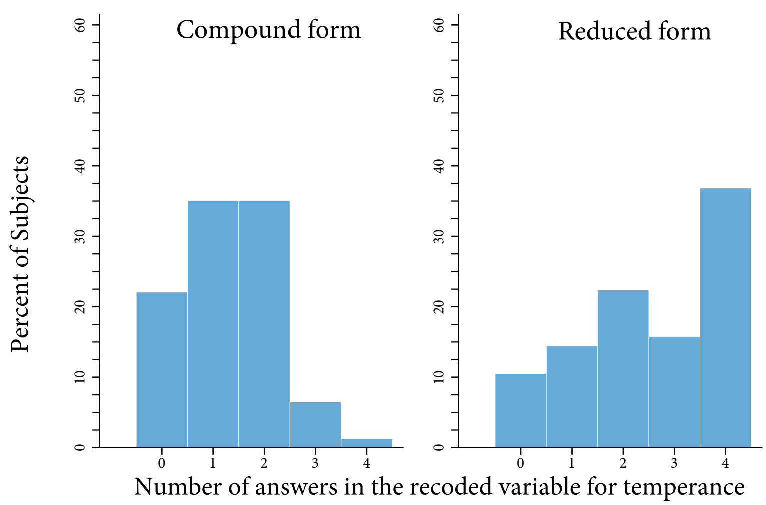
Figure 4-1: Histogram of tasks eliciting temperance



To see more clearly the differences in the distributions in capturing a strong risk preference, the variable $temperance_i$ (number of questions an individual has answered in temperate way) is recoded to have a value of 0 when the number of questions is equal to 4 (the median), 1 for (3 and 5), 2 for (2 and 6), 3 for (1 and 7) and 4 for (0 and 8). This shows differences in consistency of answers between the groups, i.e. how well the design performs in terms of distance from the median number of answers.

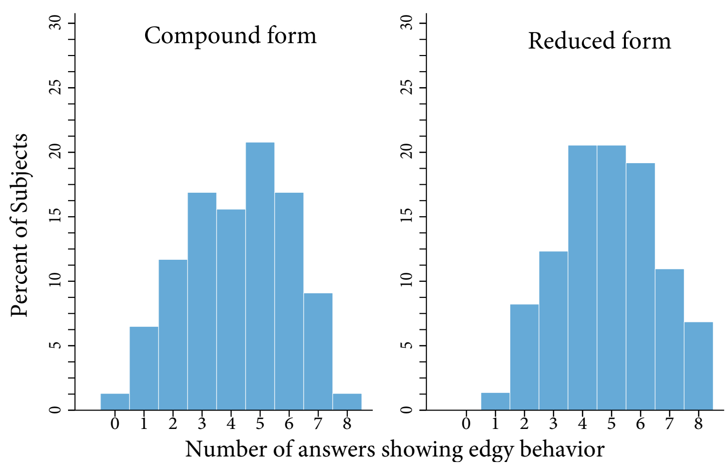
A histogram of the recoded variable (fig. 4-2) shows significantly more number of answers are further away from the median the reduced form than the compound form, reflecting the dispersion seen from the original variable for temperance. Less than 10% of the subjects in the compound form had a strong preference, whereas in the reduced form it is higher than 50%, both of which are higher the benchmark for the Binomial distribution to consider it random. However, Mann-Whitney U test rejects that the two recoded variables for the two groups are the same ($p - value < 0.001$). This means that even if part of the sample randomized their answers, there were subjects with strong preference not by chance as well, and significantly more so with the reduced form.

Figure 4-2: Histogram of recoded temperance



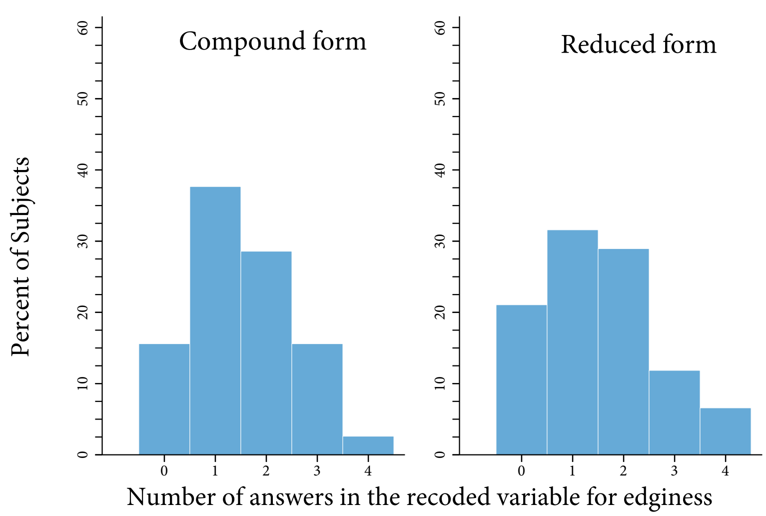
Looking at fifth order risk preference (edginess), fig. 4-3 shows that the histogram for the reduced form is slightly more shifted to the right than that of the compound form, confirming the observation made in section 4.1. Chi-squared test cannot rejects any differences from the median ($p - value = 0.696$ for the reduced form and $p - value = 0.83$ for the compound form). Mann-Whitney U test, however, confirms the group differences by rejecting that the two groups are similar ($p - value = 0.0382$). The robust tests for equality of variances rejects differences in their variances ($p - value = 0.33$).

Figure 4-3: Histogram of tasks eliciting edginess



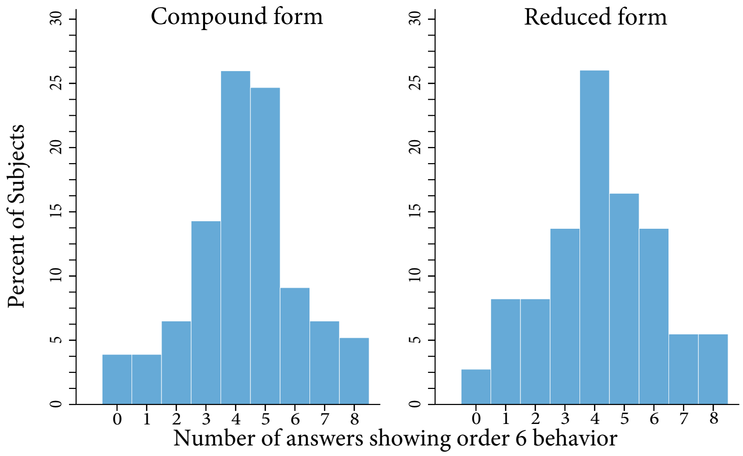
The recoded variable for edginess is constructed the same way as temperance (see fig. 4-4). The histogram shows that the reduced form induces more number of answers the furthest away from the median, indicating that a strong preference is captured better with the reduced form. However, Mann-Whitney U test fails to reject any statistically significant differences between the two recoded variables.

Figure 4-4: Histogram of recoded edginess



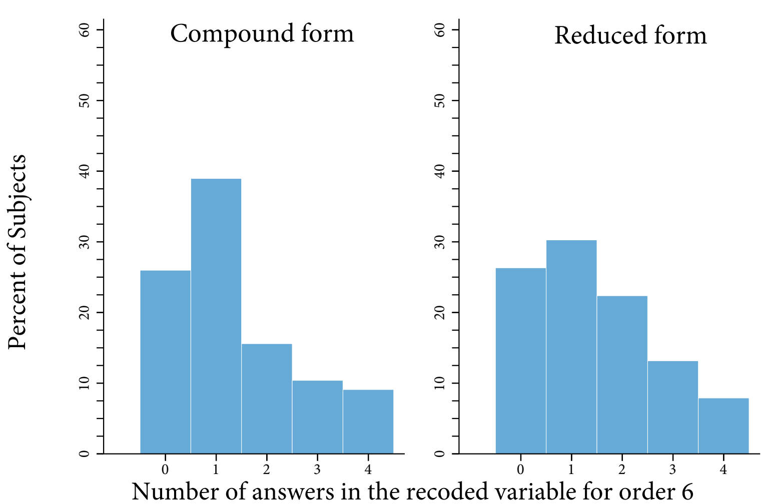
The sixth order risk preference is where one can see more similarities between the distribution of the answers. The observed distribution follow more closely random behavior than lower orders, as seen in fig. 4-5. None of the non-parametric tests can reject that the two groups are different in their order 6 risk preferences. Chi-squared test shows a $p - value = 0.665$ for the reduced form and $p - value = 0.799$ for the compound form. Mann-Whitney U test has a $p - value = 0.6166$ and the robust tests for equality of variances results in $p - value = 0.659$.

Figure 4-5: Histogram of tasks eliciting order 6



Recoding the variable $order6_i$ the same way as temperance shows only slight differences in the percentage of subjects with a strong risk preference (combining values 3 and 4) - 19.5% for compound form versus 21% for the reduced form, shown to be insignificant by Mann-Whitney U test ($p - value = 0.723$).

Figure 4-6: Histogram of recoded order 6

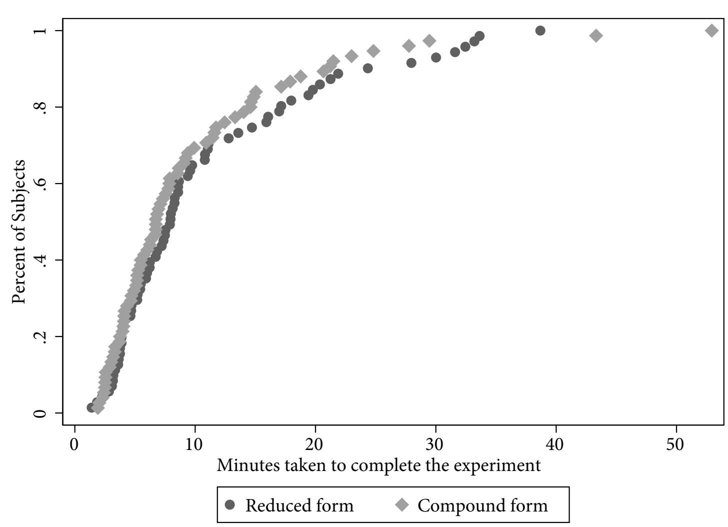


The comparison between the two ways of presenting the lottery choices is in conflict with what Haering et al. (2017) have found. They observe behavior consistent with mixed risk-aversion to be more prevalent with compound form and no differences in mixed risk-seeking. The results of this thesis, however, shows that any risk preference other than non-edginess (which is not expected by mixed risk preferences) are captured more with the reduced form (see section 4.1), which leads to the conclusion that any mixed-risk preferences are captured better with the reduced form as there is no reason to believe a higher number of people are risk seeking in any of the two groups.

4.3 Timing of the experiment

A potential effect that would cause differences between the groups is also the effort each subject made during the experiment. The best estimate available for that is the time spend doing the experiment. Fig. 4-7 represents the cumulative distribution of the time taken on the experiment. Excluded are 4 observations that show a significantly higher than 1 hour for the duration of the experiment.[6]

Figure 4-7: Cumulative distribution of the duration of the experiment



The graph shows that subjects generally spend more time with the reduced form, which

[6]Those observations come from subjects who did the experiment but forgot to submit it and did so after contacting them via e-mail.

might indicate that they spend more effort in their decision-making. However, a Mann-Whitney U test rejects that hypothesis with $p - value = 0.20$. Of interest is also whether subjects spend more time on individual tasks but Mann-Whitney U test rejects any differences across orders of risk preference and the framing of the tasks. It should be noted that generally subjects spend half the time on individual tasks as compared to Deck & Schlesinger (2014) for both groups. This strengthens the validity of the violation in the reduction axiom, i.e. subjects often fail to reduce complex compound forms and given little incentives would spend less time on individual decisions and also potentially explains why the results of this thesis are not in line with what Deck & Schlesinger (2014) find with the compound form. Reduction of the lotteries does not change the time individuals spend on each task but after considering the results from this thesis, it helps to elicit risk attitudes better.

Section 5: Conclusion and Limitations

This thesis introduces a modified reduced form for testing any order of risk preference. The design introduced is tested against the most commonly used way of testing for risk preferences - compound form. The results show violations of the reduction axiom, which is in favor of the hypothesis of this thesis that a reduced form is more suitable for testing higher orders risk preferences. This leads to the conclusion that a reduced form is more appropriate for task eliciting higher than third order risk attitudes due to violations of the reduction axiom, keeping in mind the potential overestimation of intemperance due to higher degree of risk taking in reduced forms.

The research of this thesis are useful in future research on the topic as it may provide a better way of eliciting higher risk attitudes. However, one should keep in mind the limitations of this research. Those include a small sample with little incentives and environmental effects. Future research with larger samples, real incentives and lab settings would make any claims made in this thesis more robust.

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Appendix

Compound form

Introduction

This is an online experiment in decisionmaking. Depending on your decisions and chance you can earn money, which will be paid to you by bank transfer in case you are selected for payment.

Experimental Procedure, general setup

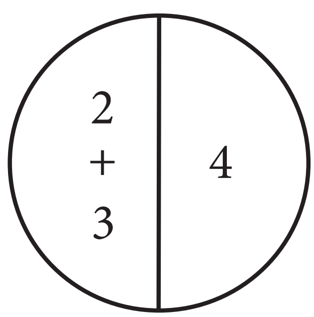
The experiment consists of 24 rounds. In each round you will have to select your preference between two choices A and B. Each choice consists of different lotteries, and then randomization will determine the outcome in points.

1 point = 0.25 euro cents.

The expected earnings are about 7 euro but you could earn as high as 20 euro depending on your choice and chance.

Design

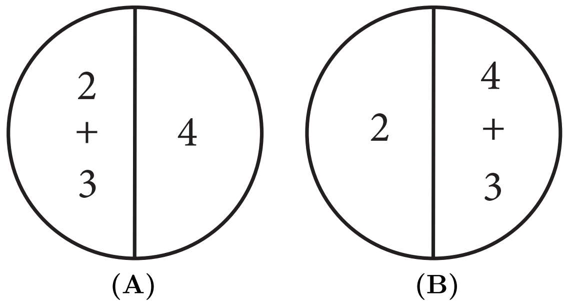
In each round, the outcomes are presented in a cyrcle. Dividing the cyrcle into two parts means that the probability is split in half. Below an example is given:



In this example, there is a 50% chance of getting 2+3 points and 50% chance of getting 4 points. The outcome is determined by the computer.

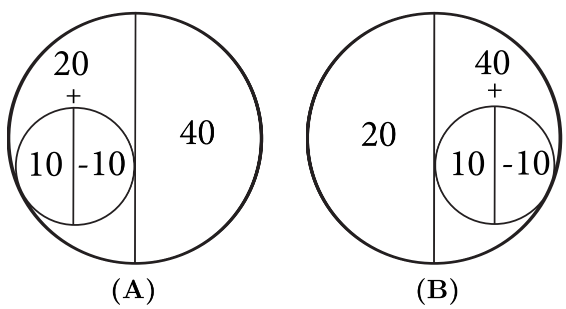
Periods

During the experiment, you will be given a choice between two different lotteries like so:



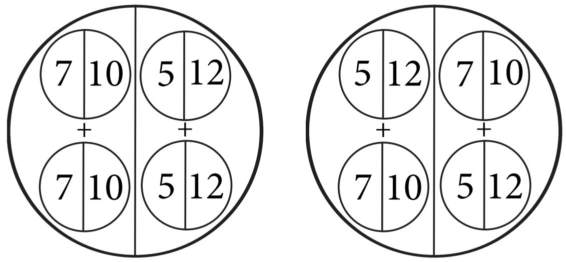
Looking at this example, the choice between A and B depends on where you would like to add the amount of 3 - to 2 or to 4.

During the experiment, you will encounter more difficult tasks than this example. For instance, the amount added could itself be a lottery. Consider the example:



Here the choice is whether to add the lottery of 50% chance of gaining 10 points and 50% chance of losing 10 points to 20 or to 40.

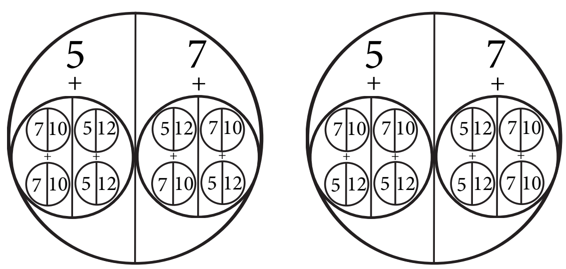
Some choices include adding lotteries to lotteries such as the next example.



(A) **(B)**

In this example, you will have to choose how to distribute the lottery of getting 7 or d 10 with 50% chance and the lottery of getting 5 or 12 with 50% chance. Choosing option A would mean that the computer would run with 50% chance twice the lottery of getting 7 or 10 and with 50% chance twice the lottery of getting 5 or 12. Option B mixes those lotteries.

During the experiment, you will be given complicated choices such as:



(A) **(B)**

Payment

One participant of this experiment will be paid for real. In order to participate in that lottery you should leave your email address on the next page. If you wish not to do so, leave it blank.

If you are selected, your payment is determined in the following way. At the end of the experiment, the experimenter will randomly select 1 out of all 24 rounds to be considered as your final outcome. In that selected round, depending on your choice, the computer will randomly select the outcome paid for real depending on the lotteries involved in the task.

Reduced form

Introduction

This is an online experiment in decisionmaking. Depending on your decisions and chance you can earn money, which will be paid to you by bank transfer in case you are selected for payment.

Experimental Procedure, general setup

The experiment consists of 24 rounds. In each round you will have to select your preference between two choices A and B. Each choice consists of different lotteries and randomization determines the outcome in points at the rate:

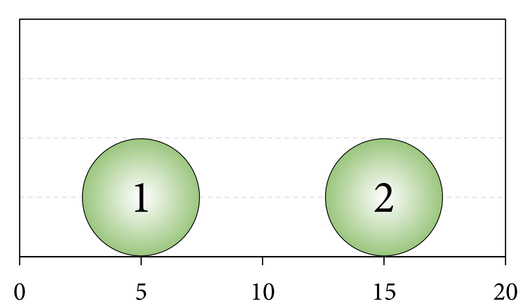
1 point = 0.25 euro cents.

The expected earnings are about 7 euro but you could earn as high as 20 euro depending on your choice and chance.

Design

In each round, there are certain maximum number of balls, numbered 1, 2 and so on. The higher the number on the ball in a specific round, the higher the outcome that is associated with it. Some outcomes might be more probable than others, which will be indicated as having more numbered balls associated with that outcome, i.e. a longer column of balls on one outcome. In this experiment, the maximum number of balls that you will see is 32. A summary of that relationship will be provided in a graphical form.

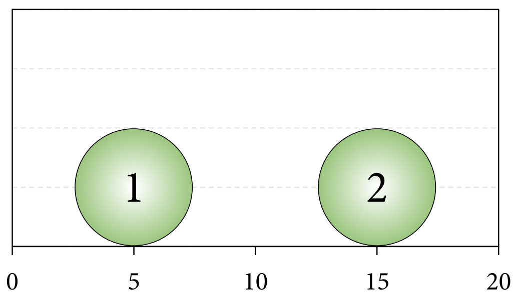
To understand the design let us look at a basic example. The outcomes and their chance of occurring is presented in the following way:



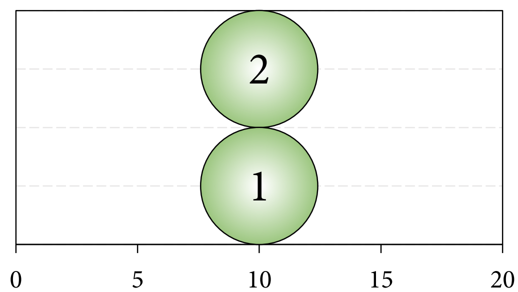
In this example, the experimenter has a bag of two numbered balls and randomly takes out one of them. The outcome for you depends on the number of the ball that is taken out. For example, if the experimenter takes out a ball with a 2 on it, you receive 15 points. If it was a 1, you would have received 5 points. In other words, you have 50% chance of getting 5 and 50% chance of getting 15, which is reflected by the height of the balls.

Periods

During the experiment, you will be given a choice between two different distributions like so:



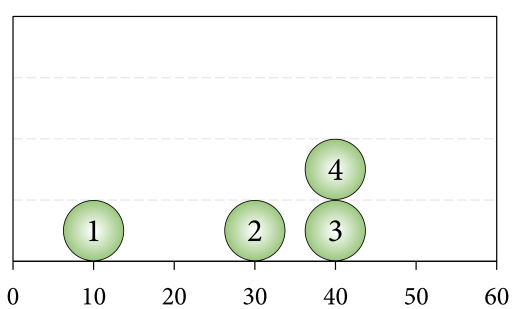
(A)



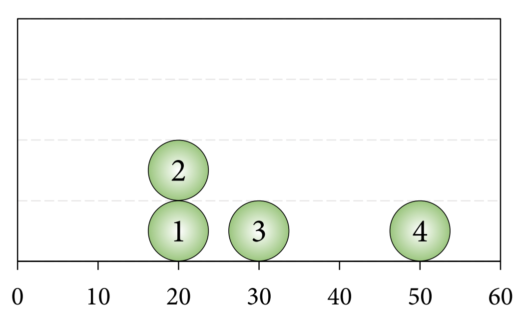
(B)

Looking at this example, if you choose B, you have 100% chance of getting a 10 because 2 out of 2 balls indicate an outcome of 10. Likewise, if you choose A, what you get depends on which number the experimenter takes out.

During the experiment, you will encounter more difficult tasks than this example. For instance:



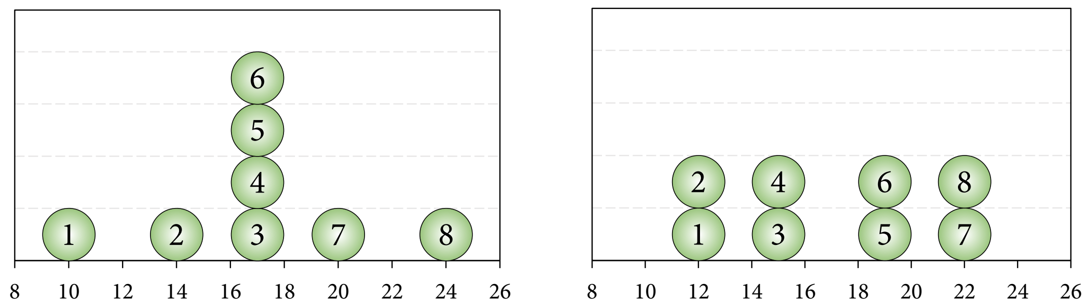
(A)



(B)

In this example, choice A has a larger probability of receiving 40 (50%) but also 25%

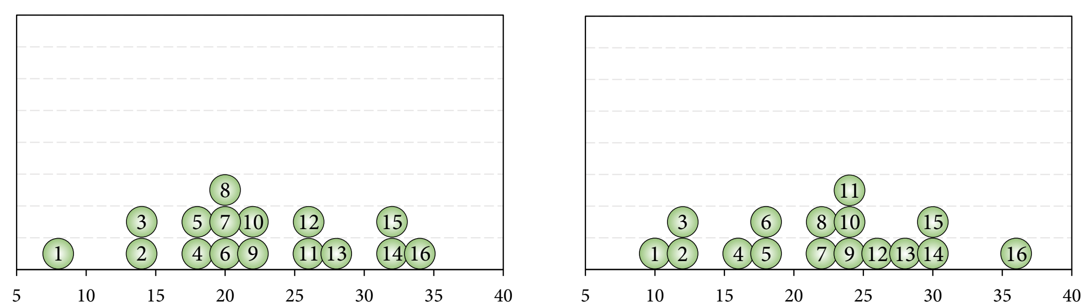
probability of receiving 10 and 30, whereas in choice B, the largest probability is of receiving 20 (50%) but also 25% probability of receiving higher than that (25% of 30 and 25% of 50). More complicated tasks include higher number of balls. For example:



(A) **(B)**

In this example, choice B has the highest probability of receiving 17 as there are 4 out of 8 numbered balls all indicating a gain of 17, i.e. 17 has a 50% chance. Choice A has 25% chance of receiving 12, 15, 19 and 22.

With more complicated examples having more numbered balls, there could be several outcomes that have high probabilities and several that have low. Consider the example.



(A) **(B)**

Here 24 has the highest probability in option A but 20 has the highest probability in option B. The rest of the outcomes have lower probability but different distribution with respect to points.

Payment

One participant of this experiment will be paid for real. In order to participate in that lottery you should leave your email address on the next page. If you wish not to do so, leave it blank.

If you are selected, your payment is determined in the following way. At the end of the experiment, the experimenter will randomly select 1 out of all 24 rounds to be considered as your final outcome. In that selected round, depending on your choice, the computer will randomly select the outcome paid for real depending on the lotteries involved in the task.