Consistency of Higher Order Risk Preferences

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Abstract:

Risk aversion (a 2nd order risk preference) is a time-proven concept in economic models of choice under risk. More recently, the higher order risk preferences of prudence (3rd order) and temperance (4th order) also have been shown to be quite important. While a majority of the population seems to exhibit both risk aversion and these higher-order risk preferences, a significant minority does not. We show how both risk-averse and risk-loving behaviors might be generated by a simple type of basic lottery preference for either (1) combining "good" outcomes with "bad" ones, or (2) combining "good with good" and "bad with bad" respectively. We further show that this dichotomy is fairly robust at explaining higher order risk attitudes in the laboratory. In addition to our own experimental evidence, we take a second look at the extant laboratory experiments that measure higher order risk preferences and we find a fair amount of support for this dichotomy. Our own experiment also is the first to look beyond 4th order risk preferences and we examine risk attitudes at even higher orders.

Keywords: risk apportionment, mixed risk aversion, mixed risk loving, prudence, temperance, edginess, laboratory experiments
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1. INTRODUCTION

The risk attitude of an economic agent has long been expressed as simply being risk averse or risk loving (or neither). How we characterize risk aversion can depend upon model specifics, but typically is consistent with an aversion to mean-preserving spreads. Of course, any measures of the intensity of risk aversion truly are model-specific, such as the widely-used utility-based measures of Arrow (1965) and Pratt (1964). In a similar vein, an individual's (or corporation's) "risk profile" typically is just a metric of how much risk an agent is willing to take, as if "risk" were some kind of homogeneous mass. All of these notions deal with only so-called "second-order effects." But risk comes in many forms.

Recent attention has been given to the fact that one's behavior towards risk depends upon more than just risk aversion. The early expected-utility models of precautionary saving by Leland (1968), Sandmo (1970) and Dréze and Modigliani (1972), which were later re-analyzed by Kimball (1990), all showed how the attribute of "prudence" (a 3rd order effect) can affect such decision making. Even more recently, temperance (a 4th order effect) has become integrated into decision models (see, for example, Gollier (2001)).[1]

Across a wide array of settings a majority of people have been found to exhibit risk aversion; but the minority who are risk loving often only receive passing attention. Except for the occasional attempt to explain risk-loving behavior, an abundance of papers simply include an assumption of risk aversion. Although higher order risk attitudes are less-well understood, researchers have mostly found evidence for prudence and, to a lesser degree, for temperance as well. But again, individuals who do not follow the majority are largely ignored.

Beyond the 4th order, not much at all has been done to examine how these preferences affect decision making. Whether or not theoretical research in this direction is even warranted might depend in part on whether such attitudes are empirically relevant. This paper helps to answer the latter question by examining both 5th and 6th order attitudes in a laboratory setting in addition to reexamining lower order attitudes.

Our motivation in this paper is to examine another framework for viewing risk behavior. In particular, Eeckhoudt, Schlesinger and Tsetlin (2009) propose a method for viewing aversion to higher degree risks as a type of lottery preference for combining relatively good outcomes with relatively bad outcomes; as opposed to the alternative of combining "good with good" and "bad with bad." The particulars of such lottery preference are spelled out below, but Eeckhoudt et al. (2009) pay no real attention to risk lovers.

A recent paper by Crainich, Eeckhoudt and Trannoy (2013) attempts to remedy this situation by examining risk lovers. In particular, they apply the analysis from Eeckhoudt et al. (2009), but

[1] The paper by Noussair et al. (2014) provides a good summary of the many ways prudence, and to a lesser extent temperance, has been applied to many types of economic problems, such as auctions, bargaining, ecological discounting, precautionary saving and rent-seeking contests.

with the assumption that risk lovers prefer to combine "good with good" and "bad with bad." In particular, Crainich et al. (2013) apply their analysis to 3rd and 4th order risk attitudes to show that risk lovers also *can be* both prudent and intemperate. However, as Ebert (2013) comments, neither prudence nor intemperance *needs* to follow from risk-loving behavior.

Whether or not risk lovers actually do tend to exhibit this type of behavior would seem to be an empirical question. Although Crainich et al. (2013) restrict their theoretical analysis to expected utility, there is no compelling argument to do so, as we explain below. Moreover, although their theoretical analysis only goes up to 4th order risk attitudes, the analysis can easily be extended to risk attitudes of any arbitrary order *n*.

This paper both generalizes the theoretical underpinnings of Crainich et al. (2013) and tests the results using controlled experiments. In the laboratory, respondents stated their preferences for 38 pairs of lotteries. The lotteries were designed to test for risk attitudes (a.k.a. "risk preferences") of orders 2-6.[2] In this manner we were able to see evidence to support a hypothesis that can be derived from Eeckhoudt et al. (2009) and Crainich et al. (2013). Namely, that lottery preference for either combining "good with bad" or for combining "good with good" more basically describes risk-averse behavior or risk-loving behavior respectively. In particular, we find two distinct patterns of behavior:

> *Risk averters are "mixed risk averse:" they dislike an increase in risk for every degree n*
>
> *Risk lovers are "mixed risk loving:" they like risk increases of even degrees, but dislike increases of odd degrees*

Thus, both risk averters and risk lovers agree on their risk attitudes of odd orders, such as for 3rd order prudence. But risk averters and risk lovers disagree on their risk attitudes of even orders. For example, at the 4th order, risk averters are temperate but risk lovers are intemperate. Mimicking the terminology of Caballé and Pomansky (1995), who use "mixed risk aversion" for the first pattern of behavior within the confines of expected utility, Crainich et al. (2013) use the terminology "mixed risk loving" to characterize the second pattern of behavior. It also should be noted that, although Caballé and Pomansky (1995) characterize mixed risk aversion in terms of utility functions, they never address the question of whether or not this trait is commonly exhibited by risk averse individuals.

Our evidence provides a fair amount of support for the above hypothesis of two distinct patterns of behavior. Since risk lovers seem to follow this consistent pattern (mixed risk loving), it might help to explain their behavior in situations where risk loving alone does not appear to be sufficient. For example, Golec and Tamarkin (1998) find that betting on "long shots" in a horse

[2] We also test preferences being *monotonic* in wealth, which is a first-order risk attitude.

race is consistent with both risk-averse and risk-loving behavior, both of which can be consistent with a preference for less third-degree risk.[3]

In our experiment, risk aversion, prudence and temperance seem to be the more frequent risk attitudes for orders 2-4. This evidence agrees with the handful of experimental evidence to date: (Tarazona-Gomez (2004), Ebert and Wiesen (2011), Ebert and Wiesen (2012), Noussair, Trautmann and van de Kuilen (2014) and Maier and Rüger (2012)). Only one paper to date, Deck and Schlesinger (2010), shows some other trait (intemperance) to be more prevalent, but only modestly so.

To the best of our knowledge, our paper is also the first to make any experimental attempt at determining risk attitudes for orders higher than 4. Our results for 5^{th} order attitudes also support the above-mentioned patterns, although the support is weaker. Likewise, 6^{th} order attitudes are weakly consistent, but behavior at this order is approaching random choices. Thus, although we can theoretically consider risk preferences for any arbitrary order *n*, restricting any analyses within economic applications to only the first four orders seems a reasonable approximation. We attribute this phenomenon to the ever increasing complexity involved with deciphering increasingly higher degrees of risk.

The theoretical model that we set up describes preferences over particular 50-50 lotteries pairs. This simple approach stems from the earlier work of Eeckhoudt and Schlesinger (2006), as adapted by Eeckhoudt et al. (2009). Although not constrained to expected-utility theory (EUT), we show how our results are consistent with expected utility models: both for risk averters and for the less-examined case of risk lovers.[4] We explain how the evidence might be used to support (or not support) other preference models as well.

We start in the next section by introducing the basic theoretical lottery-preference framework for risk attitudes of orders 2-4: risk aversion, prudence and temperance; and we next extend the analysis to any arbitrary order *n*, paying particular attention to the 5^{th} and 6^{th} orders. Since expected utility is still quite prevalent in much of the literature, especially the literature with applications of higher order risk attitudes, we next explain the theory of how each of the different order risk attitudes works within an expected utility framework. The following two sections present our experimental design and our experimental results, which are shown to add support to the hypothesis of two dichotomous behavior patterns. Finally, we discuss the consistency of our experimental results with both expected utility and with a few non-expected utility models of choice behavior, as well as add a few closing remarks.

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[3] Golec and Tamarkin (1998) use moment-based preferences, which are consistent with our results, as we explain later in the paper.

[4] A look at the seminal papers by Pratt (1964) and Arrow (1965), for example, show typical detailed analyses of risk-averse behaviors, but no regard for how the many theorems and other results might apply to risk lovers. Some extensions are relatively trivial, but others can be quite perplexing.

2. RISK AVERSION, PRUDENCE AND TEMPERANCE

Eeckhoudt and Schlesinger (2006) and Eeckhoudt et al. (2009) introduced a canonical method for classifying risk attitudes, based upon a simple set of lottery preferences. Here we present a brief summary of these risk attitudes, starting with the well-known second-order attitude of risk aversion. We assume throughout that all individuals prefer more wealth to less. Since only binary lotteries with equal probabilities are considered in this paper, we will write $[x, y]$ to denote a lottery with a 50-50 chance of receiving either outcome x or outcome y, where it is understood that both x and/or y might themselves be lotteries.

Risk aversion (2nd order risk apportionment)

Consider an individual with an initial wealth $W > 0$.[5] Let $k_1 > 0$ and $k_2 > 0$. Consider the two 50-50 lotteries $A_2 \equiv [W, W - k_1 - k_2]$ and $B_2 \equiv [W - k_1, W - k_2]$. To avoid bankruptcy issues, we assume that all variables are defined so as to maintain a strictly positive total wealth. An individual is *risk averse* if and only if lottery B_2 is preferred to lottery A_2 for all possible values of W, k_1 and k_2. The reader can easily verify that the characterization above coincides with a dislike for mean-preserving spreads (see Rothschild and Stiglitz (1970)), as well as with a concave utility function within EUT. Eeckhoudt and Schlesinger (2006) describe the preference for B_2 over A_2 as a preference for "disaggregating the harms." The "harms" are the losses of k_1 and k_2. Since they extend this idea to higher-order preferences, they generically label this second-order risk attitude as "risk apportionment of order 2." We note here that a *risk lover* would have exactly the opposite lottery preference. In other words, someone who always prefers the lottery A_2 over lottery B_2 is a risk lover.

This preference is shown graphically as a probability tree in Figure 1, where the branches each have a probability of $p = \frac{1}{2}$. In Figure 1, we let ε and δ represent two generic "harms." Here, each harm is the loss of a fixed amount of money $\varepsilon \equiv -k_1$ or $\delta \equiv -k_2$.

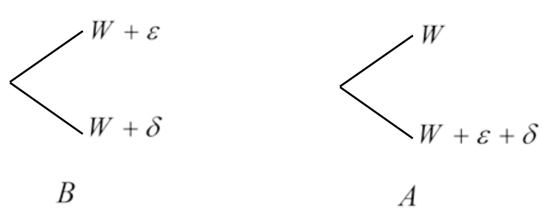

Figure 1: Risk apportionment as lottery preference

5 We note here that initial wealth can also be random, so long as it is statistically independent of any random additions to wealth. This is in the exact same spirit as Pratt and Zeckhauser (1987). To keep the story somewhat simpler, we assume that initial wealth is an arbitrary, but fixed, constant.

Prudence (*3rd order risk apportionment*)

To define the third-order risk attitude of *prudence*, Eeckhoudt and Schlesinger (2006) replace one of the "harms" of a sure loss with a zero-mean random variable. Let $\varepsilon \equiv \tilde{\varepsilon}$ now be any zero-mean random variable.[6] In other words, replace the "harm" $\varepsilon \equiv -k_1$ with the "harm" $\varepsilon \equiv \tilde{\varepsilon}$. Define $A_3 \equiv [W, W + \tilde{\varepsilon} - k_2]$ and $B_3 \equiv [W + \tilde{\varepsilon}, W - k_2]$. Prudence is defined as a preference for lottery B_3 over lottery A_3 for every arbitrary W, $k_2 > 0$ and zero-mean $\tilde{\varepsilon}$. This lottery preference is equivalent to a convex marginal utility in expected-utility models, $u''' > 0$. In addition this same lottery preference for B_3 is a preference for decreases in downside risk, as defined by Menezes, Geiss and Tressler (1980), which is itself equivalent to a preference for a decrease in 3rd degree risk, as defined by Ekern (1980). An individual who has the opposite preference, who always prefers A_3 to B_3, is classified as *imprudent*.

Temperance (*4th order risk apportionment*)

To define the fourth-order risk attitude of *temperance*, now replace the sure loss of $-k_2$ with a second zero-mean risk $\tilde{\delta}$, where the distribution of $\tilde{\delta}$ is assumed to be statistically independent to that of $\tilde{\varepsilon}$.[7] Someone who is temperate will always prefer lottery $B_4 \equiv [W + \tilde{\varepsilon}, W + \tilde{\delta}]$ to lottery $A_4 \equiv [W, W + \tilde{\varepsilon} + \tilde{\delta}]$, whereas someone who is intemperate will always prefer A_4 to B_4. For a risk averter, zero is preferred to either $\tilde{\varepsilon}$ or $\tilde{\delta}$. Thus, Eeckhoudt and Schlesinger (2006) describe temperate behavior as a preference for "disaggregating the harms." Alternatively, suppose that the risk $\tilde{\varepsilon}$ already appears in one state of nature. A temperate individual would prefer to receive an unavoidable second risk $\tilde{\delta}$ in the state of nature where there is no risk, as opposed to the same state of nature with $\tilde{\varepsilon}$. Kimball (1993) refers to the two harms, $\tilde{\varepsilon}$ and $\tilde{\delta}$, in this setting as being "mutually aggravating."

3. HIGHER-ORDER RISK ATTITUDES

Here we present a more general approach that derives from Eeckhoudt et al. (2009). Consider the pair of random variables $\{\tilde{X}_1, \tilde{Y}_1\}$. We assume that the random variable $\tilde{Y}_1$ has more n^{th} degree risk than $\tilde{X}_1$.[8] Also consider a second pair of random variables $\{\tilde{X}_2, \tilde{Y}_2\}$ and assume that

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6 The terminology "prudence" is due to Kimball (1990), who examined precautionary effects within an expected-utility framework.

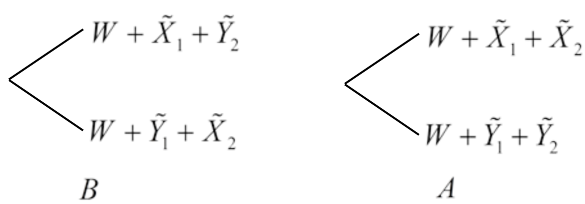
7 The terminology "temperance," to the best of our knowledge, was first coined by Kimball (1992), and its usefulness in analyzing background risks was examined by Gollier and Pratt (1996) and by Eeckhoudt et al. (1996).

8 Random variable $\tilde{Y}$ is said to have more first-degree risk than $\tilde{X}$ if $\tilde{X}$ dominates $\tilde{Y}$ via first-order stochastic dominance. $\tilde{Y}$ is said to have more n^{th}-degree risk than $\tilde{X}$, $n > 1$, if $\tilde{X}$ dominates $\tilde{Y}$ via n^{th}-order stochastic dominance and these random variables have the same first n-1 moments. See Ekern's (1980). An increase in 2nd-

the random variable $\tilde{Y}_2$ has more m^{th} degree risk than $\tilde{X}_2$. We also assume that all of the above random variables are statistically independent of one another. The main result in Eeckhoudt et al. (2009) is the following:

Theorem (Eeckhoudt, Schlesinger and Tsetlin, 2009): *Given* $\{\tilde{X}_1, \tilde{Y}_1\}$ *and* $\{\tilde{X}_2, \tilde{Y}_2\}$ *as described above, the 50-50 lottery* $[W+\tilde{X}_1+\tilde{X}_2, W+\tilde{Y}_1+\tilde{Y}_2]$ *has more* $(m+n)^{th}$ *degree risk than the lottery* $[W+\tilde{X}_1+\tilde{Y}_2, W+\tilde{Y}_1+\tilde{X}_2]$.

Someone who dislikes the lotteries with more $(m+n)^{\text{th}}$ in the Theorem is labeled as "risk apportionate of order $m+n$." For someone who is risk apportionate of orders m and n, both of the $\tilde{X}_i$ random variables are relatively "good" and both of the $\tilde{Y}_i$ random variables are relatively "bad." By starting with both m and n less than four and iterating on the process applied in the Theorem, we can define risk apportionment of any higher order.



<u>Figure 2</u>: Risk apportionment as combining "good" with "bad"

Risk apportionate of order $m+n$ is illustrated by always having a preference for lottery B over lottery A when considering the two lotteries shown in Figure 2, as described in the above Theorem.

For differentiable expected utility, "risk apportionate of every order" is equivalent to "mixed risk aversion," as defined by Caballé and Pomansky (1995), a point not made explicitly in Eeckhoudt et al. (2009).

Examples:

<u>Risk aversion</u>: Set $n = m = 1$, and define $\tilde{X}_1 = \tilde{X}_2 = 0$, $\tilde{Y}_1 = -k_1$ and $\tilde{Y}_2 = -k_2$.

<u>Prudence</u>: Set $n = 2$, $m = 1$, and define $\tilde{X}_1 = \tilde{X}_2 = 0$, $\tilde{Y}_1 = \tilde{\varepsilon}$ and $\tilde{Y}_2 = -k_2$.

<u>Temperance</u>: Set $n = 2$, $m = 2$, and define $\tilde{X}_1 = \tilde{X}_2 = 0$, $\tilde{Y}_1 = \tilde{\varepsilon}$ and $\tilde{Y}_2 = \tilde{\delta}$.

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degree risk also was analyzed by Rothschild and Stiglitz (1970), who referred to it as a "mean-preserving increase in risk."

The above examples show how our earlier descriptions can all be illustrated as particular applications of the above Theorem. Moreover, the Theorem allows us to provide alternative characterizations. For example, we can set n = 1, m = 3, and define $\tilde{X}_1 = 0$, $\tilde{Y}_1 = -k_1$, $\tilde{X}_2 = \tilde{\theta}$ and $\tilde{Y}_2 = \tilde{\delta}$, where $\tilde{\delta}$ has more 3rd degree risk than $\tilde{\theta}$, which provides an alternative characterization of temperance.

The fifth-order attitude of *edginess*[9] can be characterized by setting $\tilde{X}_1 = 0$, $\tilde{Y}_1 = -k_1$, $\tilde{X}_2 = \tilde{\theta}$ and $\tilde{Y}_2 = \tilde{\delta}$, where $\tilde{\delta}$ has more 4th degree risk than $\tilde{\theta}$; or by setting $\tilde{X}_1 = \tilde{\varepsilon}_1$, $\tilde{Y}_1 = \tilde{\varepsilon}_2$, $\tilde{X}_2 = \tilde{\theta}_1$ and $\tilde{Y}_2 = \tilde{\theta}_2$, where $\tilde{\varepsilon}_2$ has more 2nd degree risk than $\tilde{\varepsilon}_1$ and $\tilde{\theta}_2$ has more 3rd degree risk than $\tilde{\theta}_1$.

To obtain *risk apportionment of order 6*, we can once again apply the Theorem and Figure 2 and choose any positive integers n and m with $n+m$ = 6. This gives us three different ways to construct lotteries characterizing risk apportionment of order 6 (with $n+m$ equaling either 1+5, 2+4 or 3+3). Risk apportionment of order 6 follows from a preference for lottery *B* over *A* in any of the above settings. The opposite preference (for *A* over *B*) will be called *anti-risk apportionment of order 6*. Of course, we need not stop at 6 and the Theorem can be used to define any arbitrarily high order of risk apportionment.

4. MIXED RISK LOVERS vs. MIXED RISK AVERTERS

Recall that mixed risk aversion can be described as preference for combining good with bad. From our previous analysis and from an inspection of the Theorem, it follows easily that risk apportionment of order n is consistent with this preference for combining good with bad. To the extent that combining good with bad is an inherent trait of risk preferences, the risk averse individual will also be prudent, temperate, edgy and satisfy risk apportionment of order 6.

On the other hand, mixed risk loving behavior shows a preference for combining good with good and combining bad with bad. Using the Theorem, it follows that someone who is mixed risk loving -- that is, who always prefers combining good with good -- will satisfy risk apportionment of order n for all n that are odd (e.g. prudence and edginess), but will satisfy anti-risk apportionment of order n for all n that are even (e.g. risk loving, intemperance, anti-risk apportionment of order 6).

Eeckhoudt and Schlesinger (2006) show that risk apportionment of order n holds for an individual with EUT preferences if and only if $\operatorname{sgn} u^{(n)}(t) = (-1)^{n+1}$, where the notation $u^{(n)}$

[9] The terminology “edginess” is from Lajeri-Chaherli (2004), who uses this property to examine whether or not the trait of prudence is maintained in the presence of an independent background risk.

denotes the n^{th} derivative of the utility function u.[10] If the above condition holds for all n, marginal utility is said to be completely monotone.[11] Note that most commonly used utility functions, such as those exhibiting constant absolute risk aversion (CARA) and those exhibiting constant relative risk aversion (CRRA), satisfy this condition for risk averse people. As one example of a fairly common utility function without this property, consider the quadratic utility function $u(t) = t - \beta t^2$, with the assumption that $t < (2\beta)^{-1}$, so that u is everywhere increasing. This utility exhibits risk apportionment of orders 1 and 2 only. For higher orders, such an individual is indifferent between lotteries B and A

Risk lovers need not be mixed risk lovers, as pointed out by Ebert (2013). Likewise, Caballé and Pomansky (1995) do not address the issue of whether or not risk averters are also mixed risk averse. These are empirical issues that we address in our experiment. But, if a risk loving individual is indeed mixed risk loving, her utility will satisfy the property that $u^{(n)}(t) > 0, \forall t$.

Our characterizations of mixed risk aversion and mixed risk loving are summarized in Table 1. Recall that we assume that everyone prefers more wealth to less, $u' > 0$.

Table 1: Projected higher order risk attitudes

MIXED RISK AVERSE **Prefer combining good with bad**	**MIXED RISK LOVING** **Prefer combining good with good**
Risk averse $(u'' < 0)$	*Risk loving* $(u'' > 0)$
Prudent $(u''' > 0)$	*Prudent* $(u''' > 0)$
Temperate $(u^{(4)} < 0)$	*Intemperate* $(u^{(4)} > 0)$
Edgy $(u^{(5)} > 0)$	*Edgy* $(u^{(5)} > 0)$
Risk apportionate of order 6 $(u^{(6)} < 0)$	*Anti-risk apportionate of order 6* $(u^{(6)} > 0)$

5. EXPERIMENTAL DESIGN

A total of 150 participants were recruited from the University of Arkansas Behavioral Business Research Laboratory's database of volunteers.[12] Subjects were recruited for a 45 minute session and received a $5 participation payment in addition to their salient earnings, which averaged $20.92 (minimum was $1 and maximum was $92).

Upon entering the laboratory, participants were seated at a computer terminal that was visually isolated from the other participants. Participants proceeded to read computerized directions and

[10] Of course, since we assume that more wealth is desirable, we also have $u' > 0$. For 2nd and 3rd derivatives, we will also use the more common notations u'' and u'''.

[11] See Pratt and Zeckhauser (1987) for other economic significances of this property.

[12] The majority of the people in the database are undergraduates in the business school, but some are undergraduates in other colleges and others are not undergraduate students. None of the participants recruited for this study had participated in any previous related study.

answer a series of comprehension questions, both of which are included in Appendix A. After any remaining questions were answered, the participant began making the 38 choice tasks that comprised the experiment.

The choice tasks that the participants encountered are shown in Table 2. Each task involved a binary comparison of fixed amounts of money and 50-50 lotteries. The 50-50 lotteries were presented to the subjects as circles divided in half with a vertical line to represent that each outcome was equally likely, as shown in Figure 3 below. The payoffs for each 50-50 lottery were shown in the corresponding half of the circle and were some combination of cash amounts and additional 50-50 lotteries. This technique is intended to facilitate participant understanding. This presentation admittedly also facilitates viewing the problem as "combining good with bad" or "combining good with good," rather than presenting the lotteries in a reduced form, which might obfuscate this interpretation.[13]

Table 2: Choice Tasks

Task	Order	Construction	Option A	Option B
1	1	-	$20	$20 + $10
2	1	-	$2	$2 + $5
3	1	-	[$2 + [$10, $20], $20]	[$25, $27 + [$-1, $1]]
4	2	-	[$5, $10 + $5]	[$5 + $5, $10]
5	2	-	[$2, $4 + $8]	[$2 + $8, $4]
6	2	-	[$10, $15 + $5]	[$10 + $5, $15]
7	2	-	[$2, $4 + $3]	[$2 + $3, $4]
8	2	-	[$20, $40 + $30]	[$20 + $30, $40]
9	2	-	[$4, $10]	$7
10	2	-	[$1 | $19]	$10
11	3	-	[$5 + [$-2, $2], $10]	[$5, $10 + [$-2, $2]]
12*	3	-	[$10 + [$-4, $4], $20]	[$10, $20 + [$-4, $4]]
13	3	-	[$5 + [$-4, $4], $10]	[$5, $10 + [$-4, $4]]
14	3	-	[$2 + [$1, $-1], $4]	[$2, $4 + [$1, $-1]]
15	3	-	[$20 + [$10, $-10], $40]	[$20, $40 + [$10, $-10]]
16	3	-	[$8 + [$2, $-2], $10]	[$8, $10 + [$2, $-2]]
17	3	-	[$12 + [$1, $-1], $14]	[$12, $14 + [$1, $-1]]
18	4	2+2	[[$14, $20]+[$14, $20], [$10, $24]+[$10, $24]]	[[$10, $24]+[$14, $20], [$14, $20]+[$10, $24]]

[13] The paper by Maier and Rüger (2012) does just the opposite and present lotteries for risk attitudes of orders 2-4 only in a reduced form. Their basic results do not differ from the other experiments to date, each of which presents the choices as compound lotteries. Only the "intemperance" result of Deck and Schlesinger (2010) appears to be an outlier, which could potentially (since they do not account for risk aversion) stem from a disproportionate number of risk lovers in their sample.

19	4	2+2	[[$7, $10]+[$7, $10], [$5, $12]+[$5, $12]]	[[$5, $12]+[$7, $10)], [$7, $10]+[$5, $12]]
20	4	2+2	[8B + 7B, 8A + 7A]	[8A + 7B, 8B + 7A]
21	4	2+2	[[$1, $16]+[$1, $16], [$5, $12]+[$5, $12]]	[[$5, $12]+[$1, $16], [$1, $16]+[$5, $12]]
22	4	1+3	[$14 + 12A, $24 + 12B]	[$14 + 12B, $24 + 12A]
23	4	1+3	[$7 + 11A, $12 + 11B]	[$7 + 11 B, $12 + 11A]
24	4	1+3	[$1 + 11A, $18 + 11B]	[$1 + 11B, $18 + 11A]
25	5	2+3	[[$7, $10] + 11B, [$5, $12] + 11A]	[[$7, $10] + 11A, [$5, $12] + 11B]
26	5	2+3	[[$10, $4] + 12B, [$2, $12] + 12A]	[[$10, $4] + 12A, [$2, $12] + 12B]
27	5	2+3	[[$50, $40] + 11B, [$20, $70] + 11A]	[[$50, $40] + 11A, [$20, $70] + 11B]
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]]
29	5	1+4	[$5 + 19A, $7 + 19B]	[$5 + 19B, $7 + 19A]
30	5	1+4	[$1+[[$10, $4]+[$7, $10], [$2, $12]+[$5, $12]], $4+[[$2, $12]+[$7, $10], [$10, $4]+[$5,$12]]]	[$1+[[$2, $12]+[$7, $10], [$10, $4]+[$5,$12]], $4+[[$10, $4]+[$7, $10], [$2, $12]+[$5, $12]]]
31	5	1+4	[$1 + 20A, $20 + 20B]	[$1 + 20B, $20 + 20A]
32	6	3+3	[11A + 11A, 11B + 11B]	[11A + 11B, 11B + 11A]
33	6	3+3	[11A + 12A, 11B + 12B]	[11B + 12A, 11A + 12B]
34	6	3+3	[12A + 14A, 12B + 14B]	[12A + 14B, 12B + 14A]
35	6	3+3	16A + 16A, 16B + 16B]	16A + 16A, 16B + 16B]
36	6	2+4	[[$8, $12] + 19B, [$5, $15] + 19A]	[[$5, $15] + 19B, [$8, $12] + 19A]
37	6	2+4	[[$8, $12] + [[$2, $12] + [$7,$10], [$10,$4] + [$5, $12]], [$5, $15] + [[$10, $4] + [$7,$10], [$2,$12] + [$5, $12]]	[[$5, $15] + [[$2, $12] + [$7,$10], [$10,$4] + [$5, $12]], [$8, $12] + [[$10, $4] + [$7,$10], [$2,$12] + [$5, $12]]
38	6	2+4	[[$2, $4] + 20B, [$5, $1] + 20A]	[[$5, $1] + 20B, [$2, $4] + 20A]

In this table [X,Y] denotes a lottery where there is a 50% chance of receiving X and a 50% chance of receiving Y. “Task” is simply our internal task reference number and table entries of the form #A and #B denote the content of Option A and Option B, respectively for Task #. “Order” refers to the risk-order being tested. “Construction” refers to the *m* and *n* chosen for decomposing $(m+n)^{th}$ order risk, as in section 3 above. Task 12 is marked with an * because the graphic files used in the experiment had an error for Task 12 resulting in the subjects observing two identical choices. Therefore, Task 12 is excluded from all analysis.

The first 3 tasks are designed to verify that participants understand the task under our assumption that they prefer more money to less. For example, Option B of Task 3 is a 50-50 lottery where one would receive either $25 or $27 plus or minus $1 with equal chance. Because the best outcome from Option A is less than the worst outcome from Option B, monotonicity alone is sufficient for one to prefer Option B to Option A. The remaining tasks measure risk apportionment of orders 2 – 6. Figure 3 shows some of the higher order choice tasks as they were presented to the subjects. While all the subjects observed the same tasks in a within subjects design, the order of the tasks was randomized for each person.[14] Which option was listed on the left was also randomized and whatever option was listed on the left was labeled as "Option A" for the participant. In our descriptions here, the label Option B is always used in a manner consistent with the previous part of the paper, i.e. the preferred choice of a mixed risk averter. The preferred choice of a mixed risk lover varies. For example, in Task 11 (see Figure 3), we see that mixed risk lover also prefers Option B, since it mixes the "good" zero-mean lottery [-2,+2] with the good outcome of $10.

After the participant completed all the choice tasks, one was randomly selected and the participant was paid based upon their choice for that task. This procedure was done to eliminate potential wealth effects that might lead participants to change their behavior over the course of the study if earnings were cumulative.[15] The experimenter approached the participant with a physical spinner to determine the outcome of each lottery. The spinner is a device found in many children's games and available at most educational supply stores. It consists of a metal arrow attached to the center of a square piece of plastic. The arrow is attached in such a way that it will freely move in a circle when pushed. On the plastic was a drawing of a large circle with the diameter shown, similar to the images shown in Figure 3. Note that more complicated tasks required multiple spins. For example, Task 20 requires 3 spins. Participants were allowed to perform the spin themselves so long as the arrow "goes around several times before stopping." Once the payment amount was determined, the experimenter recorded the payoff and the participant's sex, paid the participant, and dismissed him or her from the lab.

6. EXPERIMENTAL RESULTS

The results are presented in two parts. First, we look at aggregate behavior by task order; i.e. aggregate behavior for all of the tasks associated with a specific order of risk preference. Second we look at individual behavior across task orders.

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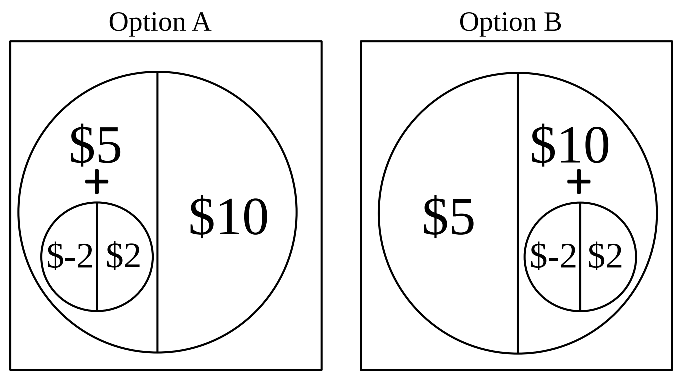
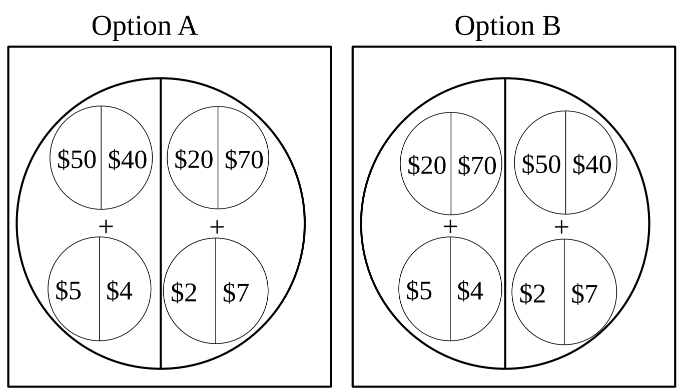
[14] In other words, each of the 150 participants had a randomized ordering of the 38 tasks. Task order was not strongly correlated with behavior for any task.

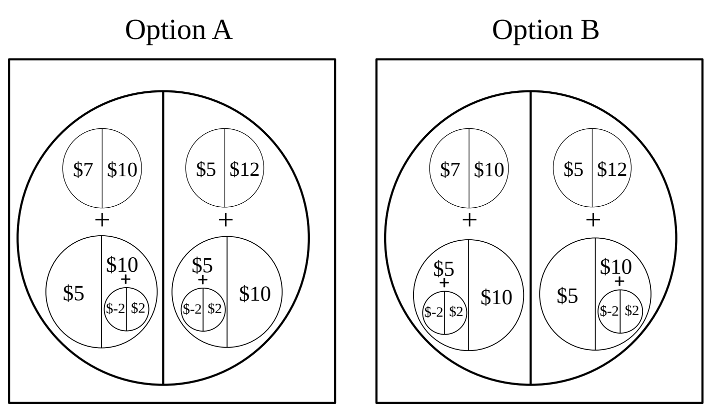
[15] A pay one randomly procedure is incentive compatible under EUT and other models where the independence axiom holds. However, this procedure creates a confound for models such as cumulative prospect theory. While some previous experimental work has suggested subjects look at each task is isolation (e.g. Starmer and Sugden (1991) and Laury (2005)), recent work Cox et al. (2013) considers several payoff procedures both theoretically and behaviorally. Cox et al. (2013) argue the only payoff procedure that is incentive compatible with all established models is to have a single paid task, which prohibits within subject ceteris paribus comparisons.



Task 11, a 3rd Order Task



Task 20, a 4th Order (2+2) Task



Task 25, a 5th Order (2+3) Task

Figure 3: Sample Tasks as Presented to Participants

6.1 *Aggregate Behavior*

As all participants faced multiple tasks for each order of risk preference, we can count the number of times a participant selected Option A in each order. Figure 4 shows the distribution of the number of Option A choices participants made for 1st – 6th order tasks. The solid line indicates the frequency with which a given number of A choices would be expected to occur if each participant made a random choice on each task. Table 3 provides statistical analysis of behavior on tasks of each order, with the unit of observation being the subject.

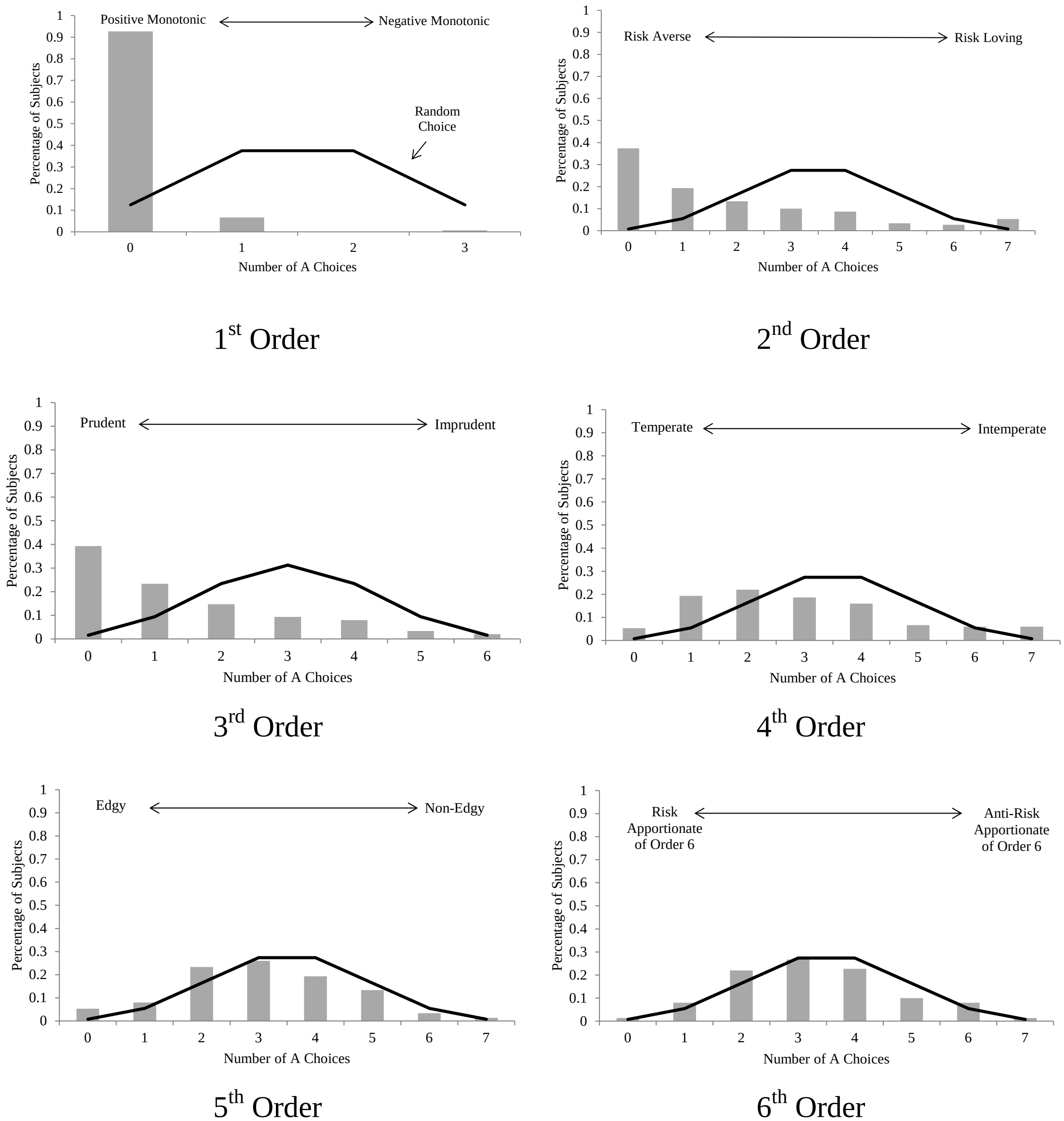


Figure 4: Distributions of Participant Behavior for Each Order

Based on the data summarized in Figure 4 and Table 3, we conclude that participants understand the experiment interface and prefer more money to less, with over 92% never selecting the lower payoff Option A on 1st order tasks. All of our results are qualitatively unchanged, if the participants who did not always select option A on 1st order tasks are excluded. Of those few that did select the lower payoff on a 1st order task, only one subject did so more than once.

Table 3: **Statistical Analysis of Behavior of the 150 Subjects by Task Order**

Order	1st	2nd	3rd	4th	5th	6th
Ho: for Mean and Median test	1.5	3.5	3	3.5	3.5	3.5
Observed Mean of A Choices (Standard Error)	0.09 (0.03)	1.81 (0.17)	1.41 (0.13)	2.95 (0.15)	3.06 (0.12)	3.3 (0.12)
p-value for t-test	<0.001	<0.001	<0.001	<0.001	<0.001	0.095
Observed Median of A choices	0	1	1	3	3	3
p-value for Wilcoxon Signed Rank test	<0.001	<0.001	<0.001	<0.001	<0.001	0.061
p-value for chi-square test of Random Behavior	<0.001	<0.001	<0.001	<0.001	<0.001	0.051

Consistent with the large volume of previous lab experiments, the participants are overwhelmingly risk averse in aggregate as 80% of the people made 3 or fewer (out of 7) Option A choices on 2nd order tasks.[16] The average number of risk loving choices was only 1.81 (p-value < 0.001). A Wilcoxon Signed Rank test leads to the same conclusion and a chi-square test soundly rejects the null hypotheses that people are behaving randomly. Still, 30 of the 150 participants (20%) can be classified as risk loving, i.e. making 4 or more Option A choices.

Figure 4 and Table 3 also indicate that the participants were generally prudent, consistent with all of the other previous lab studies to date. The number of imprudent choices was less than what would occur by chance as confirmed by all three tests reported in Table 3. Indeed the strength of prudence (average of 1.41 choices out of 6) seems rather strong here. To the extent that both risk lovers and risk averters would be prudent, this result is to be expected and is consistent with Figure 4 where 63% of subjects make either 0 or 1 imprudent choices. As discussed in the introduction, most previous research has found respondents to be moderately temperate.[17] Our participants also exhibit modest although statistically significant temperance (average 2.95 out of 7). From Figure 4, it appears to be the case that too much weight is placed on both tails and too

[16] Of course, making even one risk-loving decision might disqualify an individual from being labeled as “risk averse.” We will adopt a stochastic type of labeling and refer to someone whose majority of choices is for Option B as being “risk averse.” In the next section, we also define a stronger measure, which labels individuals who make either 3 or 4 Option A choices as “risk neutral.” In Appendix B, we offer an even stricter classification. See Wilcox (2008) for a review of these stochastic labels.

[17] We should note that although Ebert and Wiesen (2011) do not claim to test for temperance per se, they show that a more negatively skewed zero-mean lottery in their 3rd order tasks would lead to more lottery *B* choices; but this is precisely the “good with bad” type of temperance preference that we describe for risk preference of order 4, with a 3+1 construction. Thus, their results also indicate temperate behavior in the aggregate.

little weight is placed in the center. This is the pattern that would occur, for instance, if some participants were exhibiting clear temperance or intemperance and others were simply randomizing. To the extent that risk lovers (a minority in the population) would be intemperate, we would expect that temperance is exhibited less frequently than prudence. Our result here -- that temperance is less prevalent than prudence (based on paired t-test with p-value <0.001) -- is consistent with this hypothesis.[18] Noussair, et al. (2014) and Ebert and Wiesen (2012) also show that prudence is exhibited more frequently than temperance.

Moving to the 5th and 6th order tasks, it appears this pattern of some participants exhibiting preferences while others choose randomly continues. Casual inspection of Figure 4 shows that odd orders (the left panels) and even orders (the right panels) both trend towards random behavior as the order increases. This is supported by the sequence of observed means and medians reported in Table 3 as well as the chi-square tests for random behavior. There is evidence of a slight, albeit significant, preferences for edginess (3.06 out of 7 edgy choices on average). If risk lovers agree with risk averters about 5th order attitudes, then we would expect most all participants to be edgy. Since 5th order tasks get to be quite a bit more complicated, our results might be interpreted as: many or most subjects choose randomly, but those that have a preference tend toward being edgy. For the 6th order tasks, there is only marginally significant evidence that people exhibit 6th order risk apportionment (3.3 out of 7 A choices on average). Again, this might be a case where now the complexity is such that most subjects are choosing randomly. If the risk averters who do have a preference are mostly choosing Option B and those who are risk loving mostly choosing Option A, this would again lend some support to Crainich et al. (2013).

In the laboratory, we also recorded the amount of time that subjects took to make each decision. The average time spent on 1st order tasks was 8.3 seconds, clearly sufficient to identify the option with the larger payoff. For orders 2-6, the average number of seconds increased with task order: 9.9, 13.4, 22.9, 27.7 and 30.7 seconds, respectively. While 30.7 seconds may not sound like a long time, it might seem longer if you stop to think about it for, say, a full 30.7 seconds.

That people spent more time on more complicated tasks and behavior still approaches randomness suggests to us that how deeply people think about uncertainty is limited and that the fifth or sixth order is pushing the upper bound.[19] Some of the participants asked for and received scratch paper. After the experiment, these subjects indicated that they wanted to calculate the means, at least for the simple problems. While a couple tried to calculate variances, none were

[18] This pattern is also consistent with behavior becoming more random as the order increases.

[19] This result could also be interpreted as the compensation was not worth the additional time (i.e. the additional effort). Perhaps even more time would have been used with higher stakes; however the average difference in time between task 7 and task 8, which was for ten times the stakes of task 7, was less than one second. We should also note that people might take more time and effort if 5th and 6th order risk preferences are required in real world decisions outside of a laboratory, although we are not aware of any theoretical decisions that depend decisively on such higher-order risk preference, with the possible exception of Lajeri-Chaherli (2004).

found to be calculating higher moments. Of course, they might have also been looking to simplify, if possible, our compound lotteries, which become more complex at higher orders.[20]

Before turning to individual behavior, we briefly report our (lack of) findings regarding gender and behavior. Specifically, we compared male and female behavior for each order. In no case did the behavior differ substantially by sex: chi-square tests fail to reject that the male and female distributions are the same at the 95% confidence level for each order. Further, the average percentage of A choices does not differ statistically for males and females on any order at the 0.05 significance level, although men appear to be nominally more risk taking than women.[21]

6.2 *Individual Behavior*

As described previously, an individual who is mixed risk averse would be temperate and should pick Option B on 6th order tasks. An individual who is mixed risk loving would be intemperate and pick Option A on 6th order tasks. However, both types of individuals should have monotonic preferences, be prudent (select Option B on 3rd order tasks), and be edgy (select Option B on 5th order tasks). More generally, these two groups should behave similarly on odd numbered tasks and behave differently on even numbered tasks. As a first step, we directly look for evidence that there is heterogeneity of (second order) risk types. In particular, we compare the observed sample variance across subjects to the variance that would be predicted if each subject selected A with a probability of 0.26, the overall observed frequency for 2nd order tasks. A chi-square test rejects the hypothesis that the sample and predicted variances are the same (p-value < 0.001) suggesting there are multiple subject types for second order tasks.[22]

To further explore this hypothesis, we examine risk averters and risk lovers separately using two different classification systems. Under the weak classification, a subject making four or more A choices on 2nd order tasks is considered risk loving (30 subjects) while those making three or fewer A choices are considered to be risk averse (120 subjects). Under the strict classification, those making three or four A choices are considered risk neutral (28 subjects) while only those with more extreme behavior are labeled as *strict risk averse* (105 subjects) or *strict risk loving* (17 subjects).[23]

[20] Huck and Weizsäcker (1999) examine deviations from maximizing the expected payoff and find that subjects care less about 2nd order risk when the tasks become more complex. This idea seems to also hold for higher orders.
[21] There were 70 females and 80 males in our sample. Males chose the risk-loving Option A 27% of the time on average for the second order tasks whereas women did so 24% of the time. This difference is not significant based upon a two sided t-test (p-value = 0.497). More detailed analysis is presented in Appendix B.
[22] The p-values for similar tests for the other orders are as follows: 1st order p-value < 0.001, 3rd order p-value < 0.001, 4th order p-value < 0.001, 5th order p-value = 0.005, and 6th order p-value = 0.030.
[23] Under this strict classification there is a 23% chance that a person choosing randomly would be classified as risk averse and the same chance they would be classified as risk loving. Therefore, in Appendix B, we replicate the analysis in Figures 5 and 6 and Table 4 with an even stricter threshold for classifying someone as risk averse or risk

Figures 5 and 6 replicate Figure 4, separating risk-averse participants (shown as white bars) from risk loving participants (shown as black bars) and risk neutral participants (shown as gray bars) for the weak and strict classifications respectively. The patterns revealed in Figures 5 and 6 follow the pattern predicted by Crainich et al. (2013) although behavior still appears to become more random as the order increases.

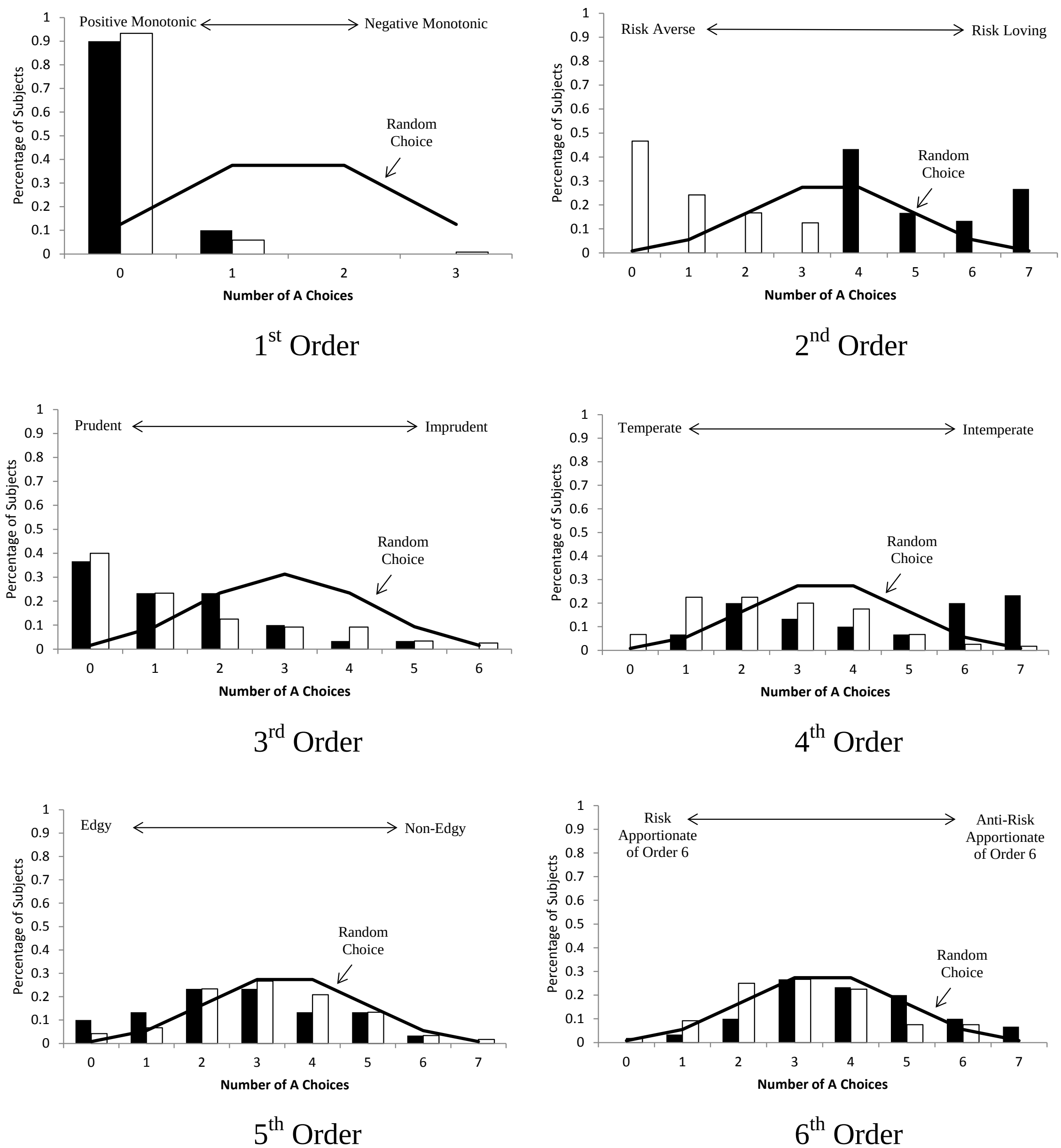


Figure 5: Distributions of Participant Behavior for Each Order by Weak Type [Weak Risk Averse (white) and Weak Risk Loving (black)]

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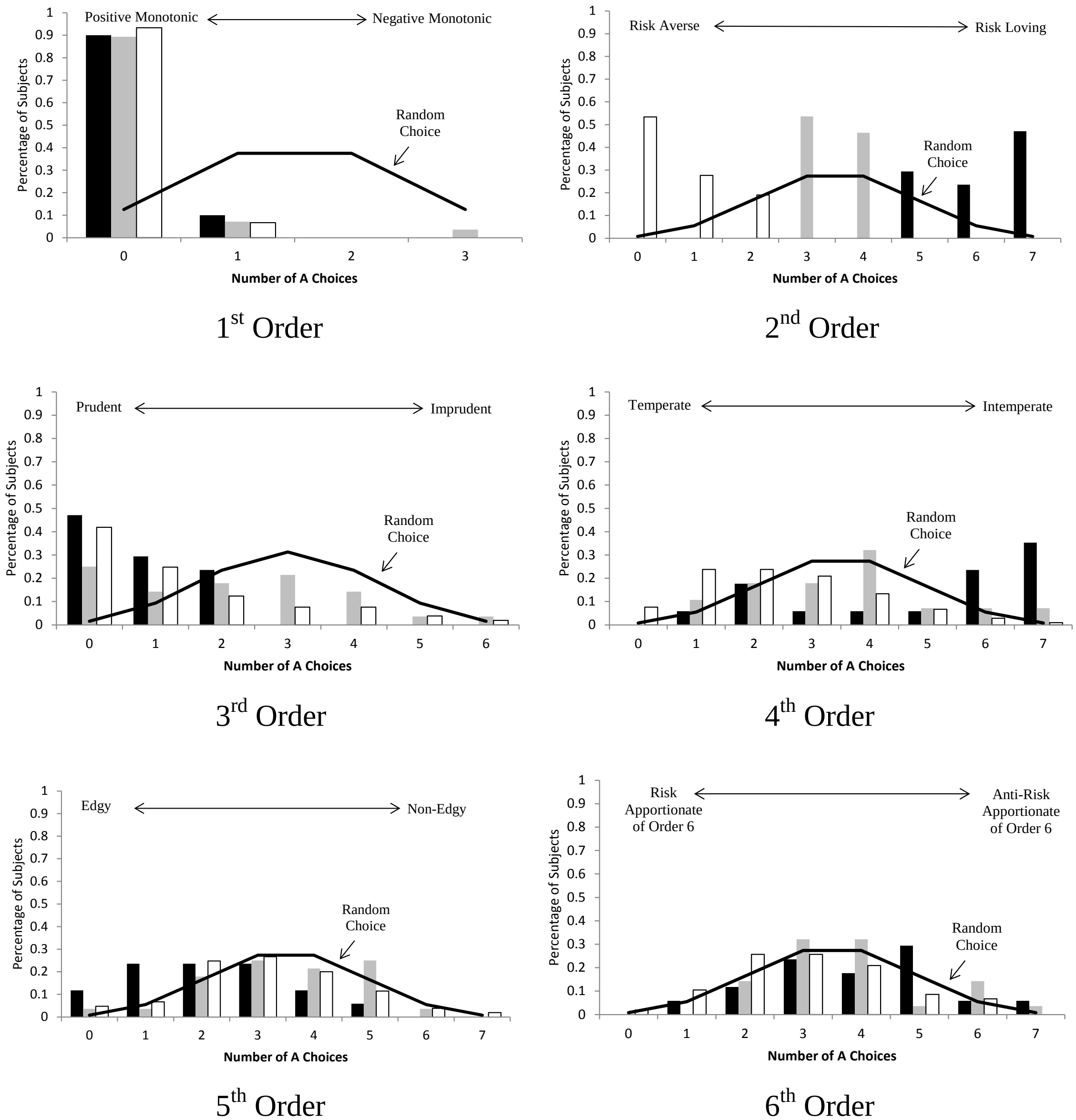
loving which reduces the probability of someone being classified as risk loving (risk averse) by chance to only 6%. The results are generally robust to this even stricter definition.



<u>Figure 6</u>: Distributions of Participant Behavior for Each Order by Strict Type [Strict Risk Averse (white), Risk Neutral (gray), and Strict Risk Loving (black)]

Table 4 summarizes statistical comparisons between subjects identified as risk lovers and those identified as risk averters. The results indicate that an alternating pattern is observed for the weak classification. Risk averters and risk lovers are not behaving in the same way on 4th order or 6th order tasks, but are behaving in the same way on 1st, 3rd and 5th order tasks. For the strict classification, the same pattern emerges expect that there is some evidence that the two groups differ on 5th order tasks although both are edgy.

Table 4: **Statistical Comparison of Risk Averse and Risk Loving Subjects**

Order		1st	3rd	4th	5th	6th
Prediction		Same	Same	Different	Same	Different
Observed Mean Number of A Choices	Risk Averse (n=120)	0.08	1.44	2.58	3.15	3.12
	Risk Loving (n=30)	0.10	1.3	4.43	2.7	4.03
p-value for t-test		0.813	0.661	<0.001	0.143	0.002
p-value for Mann-Whitney test		0.785	0.978	<0.001	0.179	0.004
p-value for chi-square test that		0.419	0.707	0.003	0.761	0.026
Observed Mean Number of A Choices	Strict Risk Averse (n=105)	0.07	1.33	2.45	3.10	3.06
	Strict Risk Loving (n=17)	0.06	0.76	5.00	2.18	3.94
p-value for t-test		0.904	0.150	<0.001	0.019	0.019
p-value for Mann-Whitney test		0.957	0.359	<0.001	0.026	0.031
p-value for chi-square test that		0.904	0.533	<0.001	0.346	0.057

F-tests for equal variances are not rejected at the 5% significance level and thus the t-tests for equal means used pooled standard errors.

Still stronger evidence for this relationship is found in Table 5, which reports the correlation in individual behavior between tasks of different orders. Specifically, Table 5 gives the correlation between the percentages of times a participant chose Option A on two different selected orders.[24] Given the underlying connection between tasks of different orders, we expect that an individual's choices will be positively correlated between even orders and between odd orders, but uncorrelated between even and odd orders. This is in fact the pattern that is observed.

[24] Appendix B provides additional analysis comparing behavior between two orders.

<u>Table 5</u>: Correlation of Individual Behavior Between Tasks of Different Orders

	% A Choices for 3^{rd} Order	% A Choices for 4^{th} Order	% A Choices for 5^{th} Order	% A Choices for 6^{th} Order
% A Choices for 2^{nd} Order	-0.048	**0.485****	-0.137	**0.259****
% A Choices for 3^{rd} Order	-	0.067	**0.261****	0.131
% A Choices for 4^{th} Order	-	-	0.001	**0.377****
% A Choices for 5^{th} Order	-	-	-	0.049

Analysis is based on all 150 subjects. * and ** indicate significance at the 5% and 1% significance levels, respectively. First order choices are omitted due to the limited variability in behavior.

As a final point, we look at the consistency of individual behavior on higher order tasks with multiple constructions. Fourth order tasks were constructed both as a combination of two 2^{nd} order tasks and as a combination of a 1^{st} and a 3^{rd} order task. Individual behavior was largely consistent between these two constructions (correlation = 0.311, p-value < 0.001).[25] Behavior was also weakly consistent between constructions for the more complicated 5^{th} order tasks and 6^{th} order tasks. Fifth order tasks were constructed as a combination of either 1^{st} and 4^{th} orders or of 2^{nd} and 3^{rd} orders (correlation = 0.161 and p-value = 0.024). Sixth order tasks were constructed as a combination of two 3^{rd} order tasks or a 2^{nd} and a 4^{th} order task (correlation = 0.185 and p-value = 0.012).

7. CONSISTENCY WITH OTHER LITERATURE

Most commonly used utility functions, such as those exhibiting either CARA or CRRA, have derivatives that alternate in sign, which as we have seen is equivalent to having risk apportionment of the various orders (risk aversion, prudence, temperance, etc.).[26] Thus, limiting economic models to such utility implies mixed risk aversion for all economic agents. Seldom

[25] This test considers the percentage of A choices that a subject made when facing a 4^{th} order task that was constructed by combining two 2^{nd} order tasks and the percentage of A choices the same subject made on 4^{th} order tasks that were constructed by combining a 1^{st} and a 3^{rd} order tasks. Subjects who are temperate should make few A choices regardless of construction while those who are intemperate should have a large percentage of A choices regardless of construction.

[26] One interesting exception is quadratic utility. We typically restrict the domain to coincide with an increasing function that is concave. But this utility yields neutrality for all risk orders higher than two. In other words, this individual would be indifferent to our *A* vs. *B* lottery choices for all orders three and higher.

used utility functions with all positive derivatives might be more appropriate for modeling the minority of mixed risk loving economic agents.

Although risk lovers might be in a minority, it is perhaps surprising that more attention has not been given to their potential behavior. Indeed, they do seem to be consistent in their higher order risk preferences, at least for the first several orders. Other papers to date have not explicitly tested for this consistency, although both Noussair et al. (2014) and Ebert and Wiesen (2012) find that prudence is more prevalent than temperance. To the extent that risk lovers are in the minority and they also exhibit prudence and intemperance, these results are consistent with our hypothesis. If the theory held perfectly, everyone would be prudent and the proportion that is temperate would equal the proportion that is risk averse.

Although Noussair et al. (2014) claim statistically significant positive pairwise correlations between risk aversion, prudence and temperance, a careful look at their evidence shows that these results are driven by their large on-line set of responders. Looking at their subsample of subjects who participated in the laboratory and who were later compensated, they actually find a strong positive correlation only between risk aversion and temperance as we would expect. There is no significant correlation between risk aversion and prudence; and although their correlation between prudence and temperance is positive, it is quite low (0.18) and significant only at a 10% level. Tarazona-Gomez (2004) also tests for the correlation between risk aversion and prudence and concludes that it is not statistically different from zero.

The paper by Maier and Rüger (2012) provides some additional supporting evidence for combining either “good with good” or “bad with bad.” In particular, they linearly regress their percent of Y choices on their percent of X choices, where X are particular n^{th} order task choices, $n = 2,3,4$ and Y are m^{th} order task choices, with $m < n$. For example, they regress the percent of risk averse choices ($m = 2$) made on the percent of prudent choices ($n = 3$) made for their participants. Although all of their slope coefficients are positive, their best fit ($R^2 = 0.5391$) is when Y is risk aversion and X is temperance, with a slope coefficient of 0.9062.

The paper by Crainich et al. (2013) limits itself to a description within the confines of expected utility theory. As we mentioned earlier, their hypothesis does not need to be so confined. For example, a careful look at each of our n^{th} order tasks, $n \geq 2$, reveals that the first n-1 moments are equal for both Option A and Option B. Moreover, Option A within our tasks always has a higher n^{th} moment than Option B. If we define a moment preference that is consistent with n^{th} degree risk, then someone who is risk apportionate (and thus always dislikes additional n^{th} degree risk) will prefer higher odd order moments and lower even order moments. This is the type of person who prefers to combine good with bad. The person who prefers combining good with good will have a preference for a higher n^{th} moment for every n.

Our experimental results are consistent with these types of moment preferences, at least for smaller orders. Likewise, our results do not necessarily rule out other types of non-EUT behavior, such as rank-dependent expected utility or prospect theory, although the implications of higher order preference for probability distortions remains open to future research.[27]

8. CONCLUDING REMARKS

Empirically investigating higher order risk preferences is an important area of research that is still in its infancy. In this paper we generalized Eeckhoudt et al. (2009) and Crainich et al. (2013) into a hypothesis about two distinct ways in which individuals view risk taking, which can be expressed as a basic type of lottery preference:

> *Risk averters are mixed risk averse*: *they dislike an increase in risk for every degree n*
>
> *Risk lovers are mixed risk loving*: *they like risk increases of even degrees, but dislike increases of odd degrees*

Since most studies find a majority of the population is risk averse, the second category above has not been studied much relative to the first category. Indeed, limited to experimental studies of higher orders of risk preference, only the first category above has been directly examined, except by perhaps noting correlations of higher attitudes with risk aversion.

The results of this paper add support to the nascent set of experimental results for the first category above. Most individuals do appear to be not only risk averse, but also prudent, temperate, edgy and, more generally, risk apportionate of order *n* for any *n*, as defined by Eeckhoudt and Schlesinger (2006). But those who are not do seem to fit nicely into our second category above.

Our evidence shows that risk lovers, just as risk averters, show a fair degree of consistency when it comes to higher order risk preferences. Moreover, we reexamine results from previous experiments to see if we can glean any support for this type of dichotomous behavior, and indeed we can. To the extent that risk lovers are also mixed risk lovers, we might be able to better explain certain types "risk loving behavior."

In this paper, our focus was: to what extent might higher-order behavior be characterized by a propensity for combining good with good? Examinations into higher order risk preferences to date, in addition to focusing on risk averters, have only gone as far as the 4th order. Very few results within expected-utility applications can be shown to also consider 5th order risk

[27] See, for example Deck and Schlesinger (2010) and Ebert and Wiesen (2012) for applications to Cumulative Prospect Theory (CPT). While we do not address framing issue here, the experiment by Maier and Rüger (2012), with CPT in mind, explicitly looks at the framing of lottery gains and losses for both prudence and for temperance and does not find much of an effect, if any. Support for prudence and weak support for temperance seems to prevail in both the domain of losses and the domain of gains, as well as in mixed domains.

attitudes[28], but until now, no one has tested for these higher orders. In this paper, we extend experimental tests to also consider both 5th order risk attitudes ("edginess") and 6th order risk attitudes. Although the patterns predicted in our dichotomy above seem to still hold, their significance is rather weak and behavior, at least with respect to our lottery choice, seems to become more and more random with higher orders.

Extensions of higher-order risk attitudes to various non-expected utility models are beginning to appear. For example, Kimball and Weil (2009) show that defining prudence in the temporal setting of Kreps and Porteus (1978) can be a bit tricky. A recent experiment by Bostian and Heinzel (2012) shows that subjects do tend to display this type of Kimball-Weil temporal prudence. In another extension, Baillon (2013) shows how one can apply the concepts of prudence and temperance to models of ambiguity aversion. The results presented in this paper will hopefully prove useful in such extensions.

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[28] See Lajeri-Chaherli (2004) as one example.

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APPENDIX A: Experiment Directions and Comprehension Quiz

The directions were computerized and self-paced as was the comprehension quiz. Italicized headings were not observed by the participants.

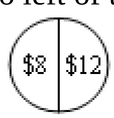
Page 1 of the Directions:

You are participating in a research study on decision making under uncertainty. At the end of the study you will be paid your earnings in cash and it is important that you understand how your decisions affect your payoff. If you have questions at any point, please let a researcher know and someone will assist you. Otherwise, please do not talk during this study and please turn off all cell phones.

Page 2 of the Directions:

In this study there is a series of 38 tasks. Each task involves choosing between Option A and Option B. Once you have completed these tasks, one of the thirty-eight tasks will be randomly selected to determine your payoff.

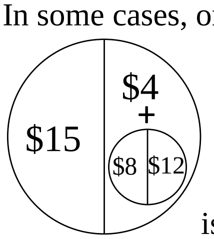
Page 3 of the Directions:

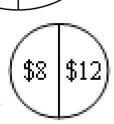
Each option will involve amounts of money and possibly one or more 50-50 lotteries represented as a circle with a line through the middle. A 50-50 lottery means there is a 50% chance of receiving the item to left of the line and a 50% chance of receiving the item to the right of the line. For example, 

is a 50-50 lottery in which you would receive either $8 or $12, each with an equal chance. To determine the outcome of any 50-50 lottery, we will use a spinner. You are welcome to inspect the spinner at any point.

Page 4 of the Directions:

In some cases, one of the items in a 50-50 lottery may be another lottery. For example,



is a 50-50 lottery where you receive either $15 or you receive $4 plus the 50-50 lottery 

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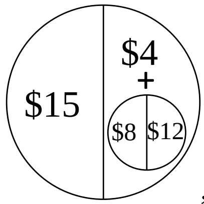
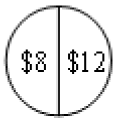
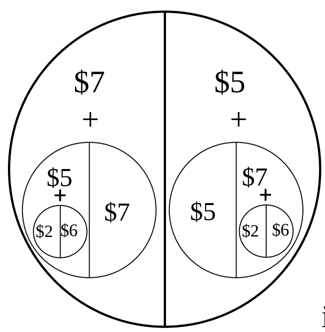
Page 5 of the Directions:

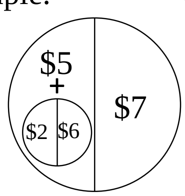
Continuing with the example, 

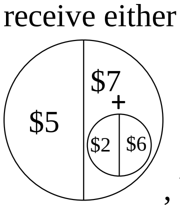
, there is a 50% chance that you would receive $15 in the big 50-50 lottery and that would be it. There is also a 50% chance that you would receive $4 + 

in the big 50-50 lottery. Conditional on this outcome for the big 50-50 lottery, you would then have a 50% chance of receiving an extra $8 and a 50% chance of receiving an extra $12 in addition to the $4. Therefore, the chance that you would end up with $4+$8 = $12 is 0.5 × 0.5 = 0.25 = 25%. The chance that you would end up with $4+$12 = $16 is 0.5 × 0.5 = 0.25 = 25%.

Page 6 of the Directions:

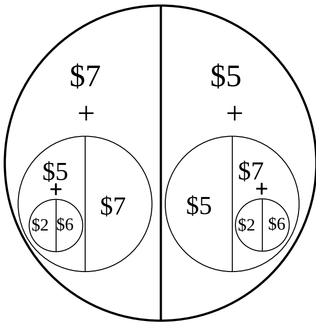
Let's look at a more complicated example. 

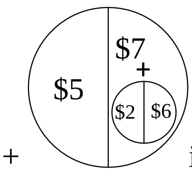
is 50-50 lottery where you receive either $7 plus the 50-50 lottery 

or you receive $5 plus the 50-50 lottery 

, both of which include an additional 50-50 lottery.

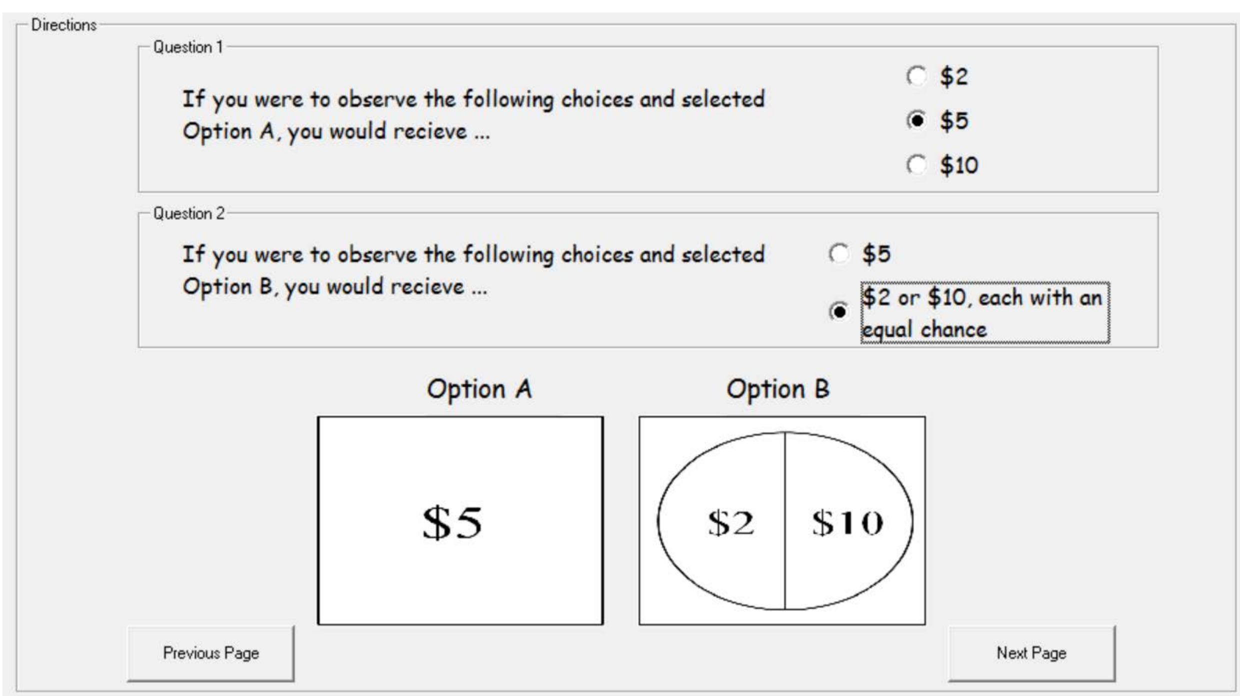
Page 7 of the Directions:

In 

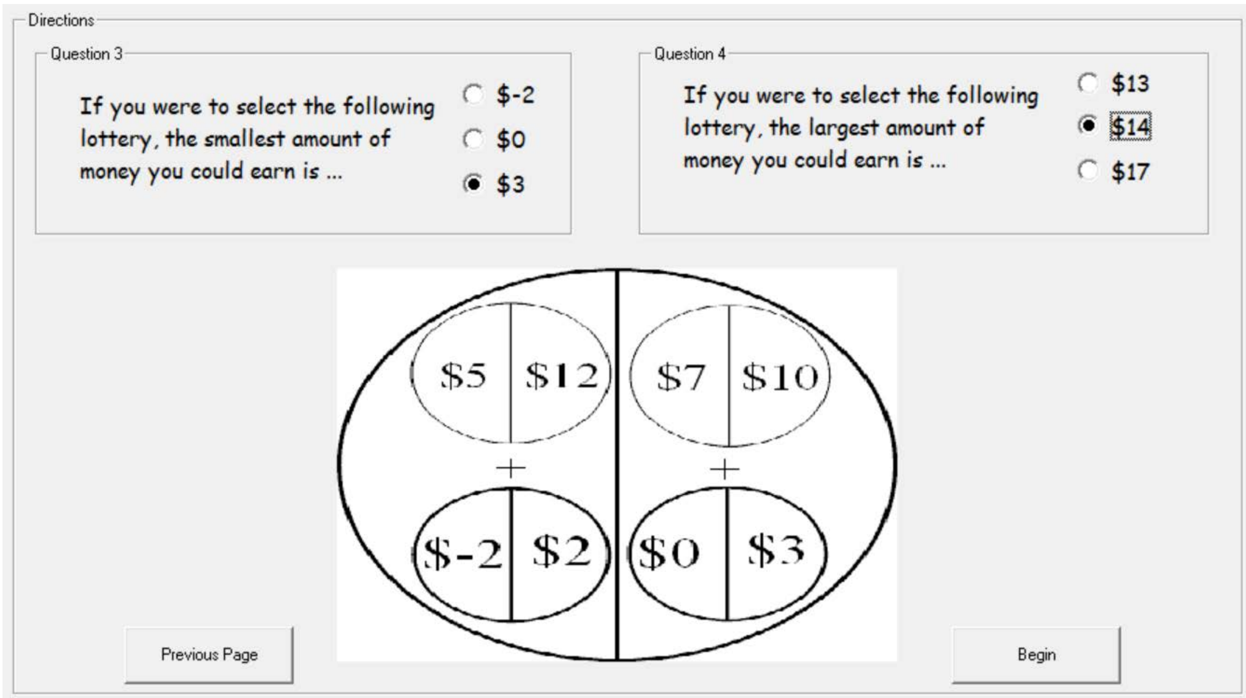
you could earn $10 if you get $5 + 

in the big lottery and then earn $5 in the second lottery. This occurs with a 0.5 x 0.5 = 25% chance. Alternatively, you could earn $14 with a 37.5% chance. Notice that you could earn $14 by 1) earning $7 (in the big lottery) + $5 (in the middle lottery) +$2 (little lottery) which happens with a 0.5 x 0.5 x 0.5 = 12.5% chance or 2) earning $7 (in the big lottery) + $7 (in the middle lottery) which happens with a 0.5 x 0.5 = 25% chance, or 3) earning $5 (in the big lottery) + $7 (in the middle lottery) +$2 (little lottery) which happens with a 0.5 x 0.5 x 0.5 = 12.5% chance. Finally there are two ways that you could earn $18 which occurs with a 0.5 x 0.5 x 0.5 + 0.5 x 0.5 x 0.5 = 25% chance.

Comprehension Quiz Screen 1 (with correct answers added):



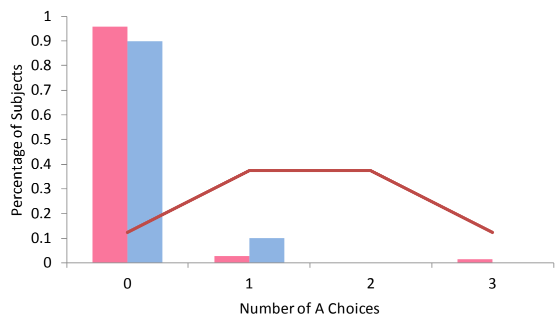
Comprehension Quiz Screen 2 (with correct answers added):



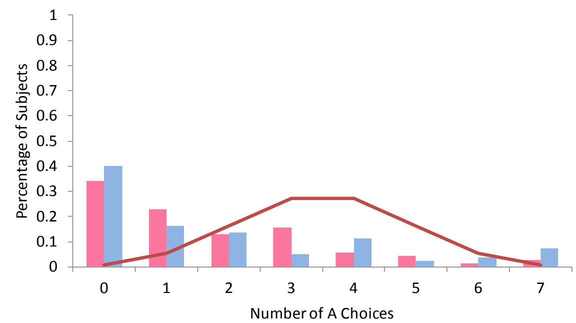
APPENDIX B: Further Analysis of the Experimental Data

Analysis of Experimental Data by Gender

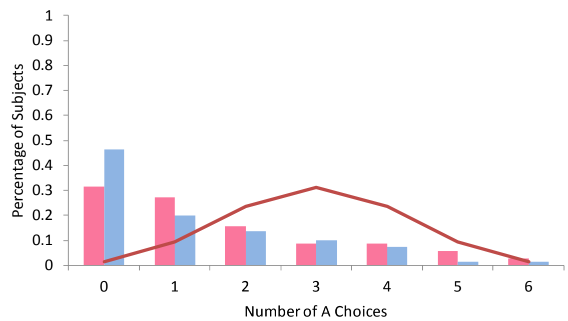
There were 70 females and 80 males in the sample. Figure B1 shows behavior by gender for tasks of each risk order. Data from male subjects are shown in blue and data from female subjects are shown in pink.



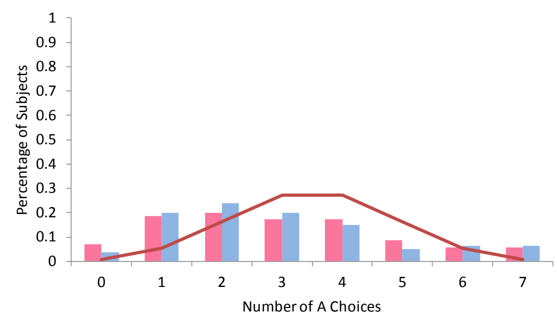
1st Order



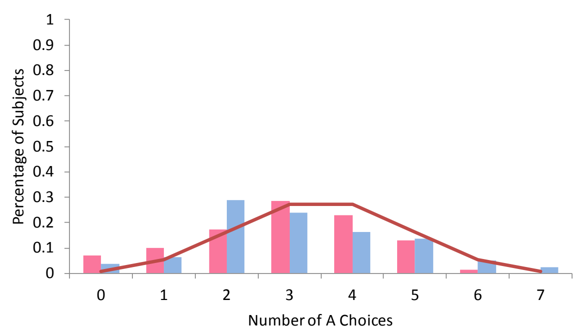
2nd Order



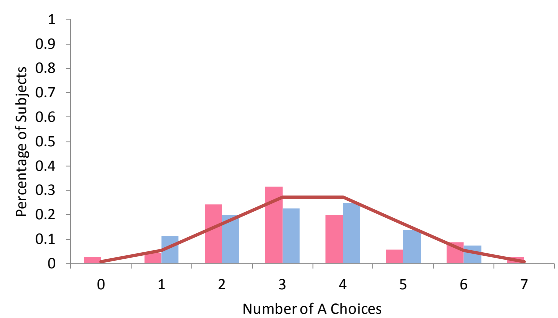
3rd Order



4th Order



5th Order



6th Order

<u>Figure B1</u>: Behavior by Males (blue) and Females (pink)

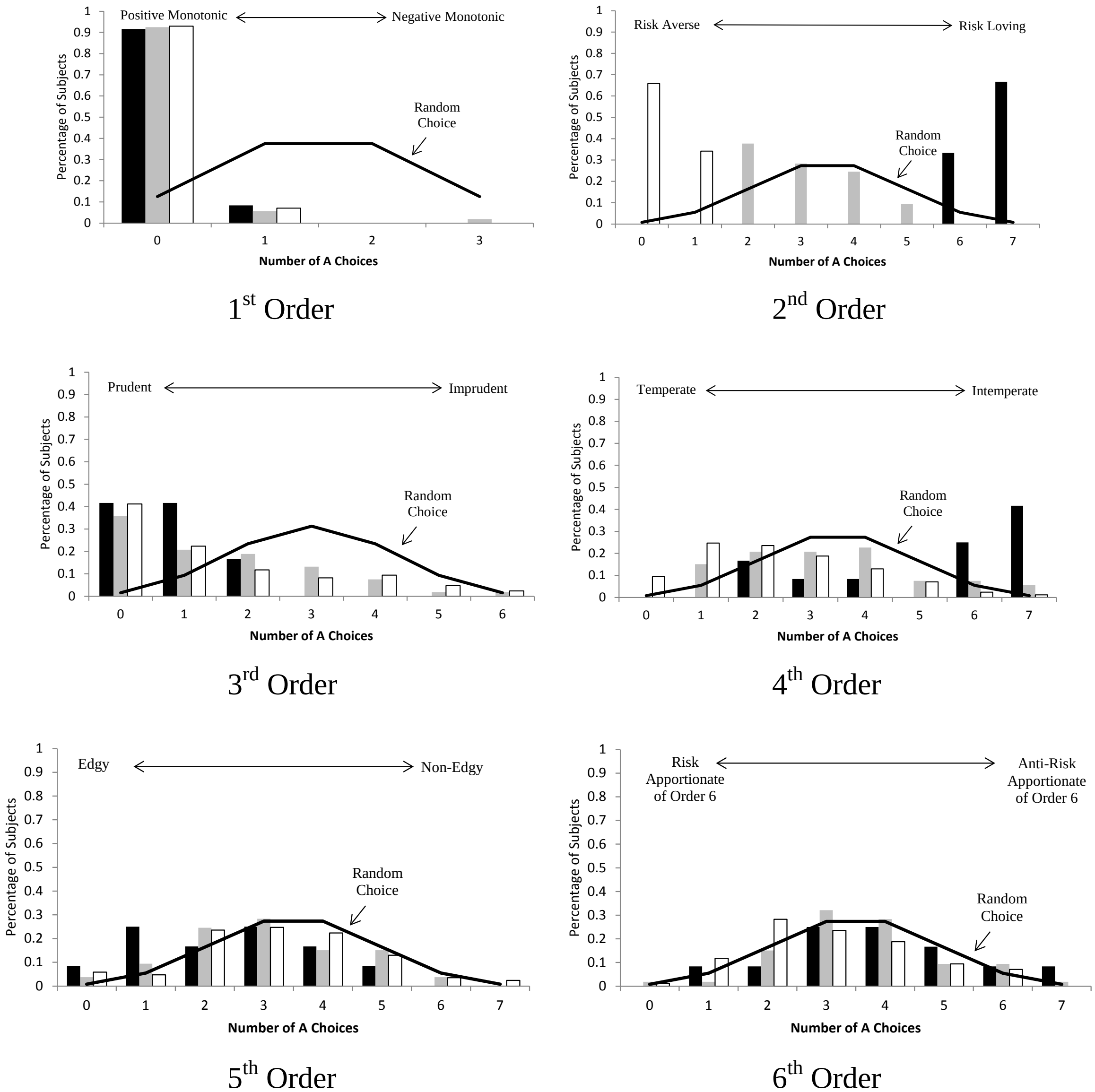
For each order, Table B1 reports p-values from both chi-squared tests that behavior is independent of gender and t-tests that average percentage of A choices is the same for males and females. None of the results indicate a significant deference by gender at the 5% level.

<u>Table B1</u>: Statistical Comparisons between Males and Females

Order	2nd	3rd	4th	5th	6th
Average Percentage A Choices by Males	27	20	42	45	48
Average Percentage A Choices by Females	24	27	42	42	47
p-value for t-test of no difference in percentage of A choices by gender	0.497	0.095	0.948	0.373	0.822
p-value for chi-squared test that the distribution of male and female choices are the same.	0.224	0.440	0.954	0.333	0.132

Analysis of Behavior under a Stricter Classification of Risk Averse and Risk Loving Subjects

In the main body of the paper, subjects who make 0, 1, or 2 risk averse actions are classified as Strict Risk Loving while those making 5, 6, or 7 risk averse actions are classified as Strict Risk Averse with all other subjects being classified as risk neutral. If subjects behaved randomly on each task then the chance of being classified as risk loving would be 23% and similarly there would be a 23% chance of being classified as risk averse. Here we consider an even stricter classification, which we term "Very Strict." A subject is Very Strictly Risk Averse (Loving) if the subject makes 0 or 1 (6 or 7) risk averse choices. If a subject behaved randomly then there is only a 6% chance the subject would be classified as risk loving or risk averse under this classification and thus one can consider these subjects as statistically significantly different from random choice. Of course, we would expect 6% of the 150 (= 9) subjects to be classified as risk loving (risk averse) if all of the subjects behaved randomly. From our data 85 subjects are Very Strictly Risk Averse and 12 are Very Strictly Risk Averse. Figure B2 replicates Figures 5 and 6 from the paper with the Very Strict classification. Table B2 extends Table 4 with this new classification. Ultimately, the general conclusions are the same regardless of which classification is used.



<u>Figure B2</u>: Distributions of Participant Behavior for Each Order by Very Strict Type [Very Strictly Risk Averse (white), Risk Neutral (gray), and Very Strictly Risk Loving (black)]

Table B2: Statistical Comparison of Risk Averse and Risk Loving Subjects

Order		1st	3rd	4th	5th	6th
Prediction		Same	Same	Different	Same	Different
Observed Mean Number of A Choices	Very Strict Risk Averse (n=120)	0.07	1.46	2.38	3.18	3.04
	Very Strict Risk Loving (n=30)	0.08	0.75	5.33	2.42	3.92
p-value for t-test		0.873	0.153	<0.001	0.109	0.053
p-value for Mann-Whitney test		0.945	0.377	<0.001	0.136	0.080
p-value for chi-square test that		0.817	0.576	<0.001	0.392	0.205

F-tests for equal variances are not rejected at the 5% significance level and thus the t-tests for equal means used pooled standard errors.

Further Examination of Behavior Between and Among Orders

The analysis presented in the paper and above in this appendix, classifies individuals based upon their preferences for second order risk. Under the assumption that people are mixed risk averse or mixed risk loving, one could use any even order to categorize people and conduct similar analysis to what we have reported. In the interest of brevity, we provide Table B3 which shows the frequency of subject classifications between any two orders. The classification used is “strict” in that someone is classified as (Anti-) Risk Apportionate of Order N if the individual selects A (B) for less than 35% of the tasks of order N. Table B4 reports chi-squared tests that behavior on tasks of one order is independent of behavior on tasks of the other order. The results generally confirm the conclusion that behavior is similar on odd order tasks and different on even order tasks. One should bear in mind that the tests reported in Table B4 include those subjects classified as being neutral whereas Table 4 in the paper only compares risk lovers and risk averters.

<u>Table B3</u>: Frequency of Behavioral Classification Between Two Orders

	Temperate	Neutral	Intemperate
Risk Averse	83	8	14
Neutral	16	6	6
Risk Loving	17	0	0

	Prudent	Neutral	Imprudent
Risk Averse	58	36	11
Neutral	8	14	6
Risk Loving	4	2	11

	Edgy	Neutral	Non-Edgy
Risk Averse	38	49	18
Neutral	7	13	8
Risk Loving	10	6	1

	Apportionate 6	Neutral	Anti-Apportionate 6
Risk Averse	40	49	16
Neutral	4	18	6
Risk Loving	3	7	7

	Prudent	Neutral	Imprudent
Temperate	57	37	22
Neutral	6	4	4
Intemperate	7	11	2

	Edgy	Neutral	Non-Edgy
Temperate	50	49	17
Neutral	3	6	5
Intemperate	2	13	5

	Apportionate 6	Neutral	Anti-Apportionate 6
Temperate	38	56	22
Neutral	2	10	2
Intemperate	7	8	5

	Edgy	Neutral	Non-Edgy
Prudent	30	30	10
Neutral	11	28	13
Imprudent	14	10	4

	Apportionate 6	Neutral	Anti-Apportionate 6
Prudent	29	33	8
Neutral	15	28	9
Imprudent	3	13	12

	Apportionate 6	Neutral	Anti-Apportionate 6
Edgy	18	26	11
Neutral	23	34	11
Non-Edgy	6	14	7

<u>Table B4</u>: p-values for Chi-Squared Test of Classification Independent Between Orders

	3rd Order	4th Order	5th Order	6th Order
2nd Order	0.013	<0.001	0.140	0.018
3rd Order	-	0.276	0.019	0.441
4th Order	-	-	0.057	0.002
5th Order	-	-	-	0.746

Analysis is based on all 150 subjects. First order choices are omitted due to the limited variability in behavior.