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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 such higher-order risk preferences, a significant minority does not. Rather than simply dismissing this behavior, we show how both risk-loving as well as risk-averse 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." 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 is the first to look beyond 4th order risk preferences and we examine risk attitudes at even higher levels. The consistency of these results with expected utility theory and with a few non-expected utility theories is also examined.

JEL-Code: C900, D800.

Keywords: risk apportionment, mixed risk aversion, mixed risk loving, prudence, temperance, edginess, laboratory experiments, moment preference, prospect theory.

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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 the notion of one's being risk averse is fairly consistent across the various models. 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 2nd order risk aversion alone. 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 have generally been ignored, although there have been attempts to explain this type of "misbehavior." 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 mostly ignored.

Our motivation in this paper is to examine a consistent framework for viewing such 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 combing relatively good outcomes with relatively bad outcomes; as opposed to the alternative of combing "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 (2012) 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. (2012) 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. (2012) apply the analysis to 3^{rd} and 4^{th} order risk attitudes to show that risk averters also *can be* both prudent and intemperate. However, a comment by Ebert (2012) explains how neither prudence nor intemperance *needs* to follow from risk-loving behavior.

Whether or not risk lovers actually do tend to exhibit this preference to combine "good with good" would seem to be an empirical question. In this paper, we examine both risk-loving and risk-averse behavior in the laboratory and we examine how such behavior relates to higher-order risk preference. Whereas risk averters seem to generally exhibit a preference for combining "good with bad," risk lovers do indeed seem to prefer combining "good with good."

Although Crainich et al. (2012) 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 4^{th} 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. (2012) and tests the results in the laboratory. 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 1-6. In this manner we were able to see evidence to support a hypothesis that can be easily derived from Eeckhoudt et al. (2009) and Crainich et al. (2012). Namely, that this lottery preference for either combing "good with bad" or for combining "good with good" more basically describes risk-averse behavior or risk-loving behavior respectively.

This type of dichotomous behavior leads to two distinct patterns:

-- Risk averters dislike an increase in risk for every degree n

-- Risk lovers 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 3^{rd} order prudence. But risk averters and risk lovers disagree on their risk attitudes of even orders. For example, at the 4^{th} 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, Crainich et al. (2012) use the terminology "mixed risk loving" to characterize the second pattern of behavior.

Our evidence provides a fair amount of support for this hypothesis. Since risk lovers seem to follow this consistent pattern, it seems hard to simply ignore their behavior, or to dismiss their behavior as somehow erratic. Specifically, our evidence shows that 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 et al. (2012) 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, this paper is also the first to make any experimental attempt at determining risk attitudes for orders higher than 4. Our results for 5th order attitudes also support the above-mentioned patterns, although the support is rather weak. Likewise, 6th order attitudes are weakly consistent, but behavior at this order is not statistically different from making 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 higher degrees of risk increases.

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, we show how our results are consistent with expected utility models: both for risk averters and for the less examined case of risk lovers.[2] We also show how the evidence can be used to support (or not support) other preference models as well, such as moment preference and cumulative prospect theory (Tversky and Kahneman (1992)).

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 5th and 6th 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 patters. 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.

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 overview 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.

[2] 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.

Risk aversion (2nd order risk apportionment)

Consider an individual with an initial wealth $W > 0$.[3] Let $k_1 > 0$ and $k_2 > 0$. Consider the two lotteries A_2 and B_2 expressed via probability trees, as shown in Figure 1. We assume that all branches have a probability of occurrence of one-half, and 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 $(u'' < 0)$. Eeckhoudt and Schlesinger (2006) describe the preference for B_2 over A_2 as a preference for "disaggregating the harms." Since they extend this idea to higher-order preferences, they generically label this second-order risk attitude as "risk apportionment of order 2." The "harms" are the losses of k_1 and k_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.

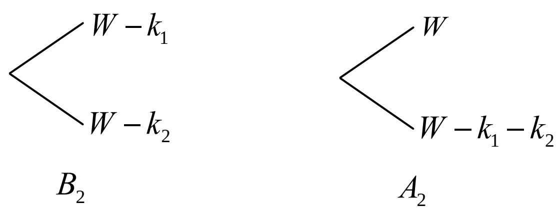

Figure 1: Lottery preference as risk aversion

Another way to interpret this preference is given by Eeckhoudt, et al. (2009). Consider the two potential changes to wealth in the set $S_1 \equiv \{0, -k_1\}$. Obviously, receiving zero is the "good" outcome, whereas receiving the "harm" $-k_1$ is the "bad" outcome. Now consider another two specific additions to wealth $S_2 \equiv \{0, -k_2\}$. We can once again label zero as relatively "good" as compared to $-k_2$, which we can label as relatively "bad." Suppose that we have an initial wealth W and that we must add one element of S_1 plus one element from S_2 to one branch of a 50-50 lottery. We also must then add the non-used elements of S_1 and S_2 to the other branch of the 50-50 lottery. Lottery B_2 in Figure 1 thus combines one good outcome and one bad outcome in the up-state $(0 - k_1)$, and it adds the other good outcome to the other bad outcome in the down state $(0 - k_2)$. Lottery A_2, on the other hand, combines both good outcomes in the up-state $(0 + 0)$ and combines both bad outcomes in the down-state $(-k_1 - k_2)$. Eeckhoudt et al. (2009) describe this as "a preference for combining good with bad" vs. "a preference for combining good with good."

[3] 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.

Of course a risk lover would have exactly the opposite preference. She would prefer the adding of either both good outcomes or both bad outcomes as opposed to adding one good with one bad. This is illustrated by a preference for lottery A_2 in Figure 1. We will call this "a preference for combining good with good."

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 $\tilde{\varepsilon}$ be any zero-mean random variable.[4] Eeckhoudt and Schlesinger (2006) then define prudence as a preference for lottery B_3 over lottery A_3 in Figure 2, for every arbitrary W, $k > 0$ and $\tilde{\varepsilon}$. They also show how this lottery preference is equivalent to a convex marginal utility in expected-utility models, $u''' > 0$. In addition, they show how 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*.

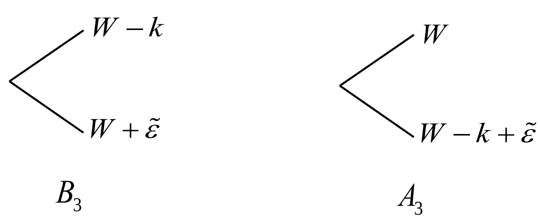

Figure 2: Lottery preference as prudence

Eeckhoudt and Schlesinger assume risk aversion, and thus they describe prudence as a preference for once again "disaggregating the harms." However, the zero-mean random wealth variable $\tilde{\varepsilon}$ is only a "harm" to a risk averter. To a risk lover, $\tilde{\varepsilon}$ is desirable.

To view prudence in the framework of Eeckhoudt et al. (2009), consider the pair {-*k*, 0} and the pair $\{\tilde{\varepsilon}, 0\}$. For the first pair, -*k* is relatively bad and zero is relatively good. For the risk averter, in the second pair $\tilde{\varepsilon}$ is relatively bad and again zero is relatively good. Thus, the risk averter, who is also prudent, prefers combining bad with good ($\tilde{\varepsilon}$ with 0, and -*k* with 0), as opposed to mixing bad with bad (-*k* with $\tilde{\varepsilon}$) and good with good (0 with 0).

As for someone who is a risk lover, since $\tilde{\varepsilon}$ is desirable, a preference for B_3 over A_3 would be a preference for mixing good with good, and mixing bad with bad. But recall that this was also the type of second-order lottery preference exhibited by risk lovers. Thus, to the extent that

[4] To avoid definitional problems and bankruptcy issues, we assume always that variables only take on values that leave total final wealth positive. The terminology "prudence" is due to Kimball (1990), who examined precautionary effects within an expected-utility framework.

combining good with good is an inherent trait, a risk lover would also tend to be prudent. Describing risk lovers as those who like “combining good with good,” Crainich et al. (2012) explain how risk lovers should also be prudent; or at least that is their conjecture. Although these authors only stay within the realm of expected utility, there is no compelling reason to limit their conjecture to this setting.

Temperance (4th order risk apportionment)

To define the fourth-order risk attitude of *temperance*, Eeckhoudt and Schlesinger (2006) now replace the sure loss of $-k_1$ with a second zero-mean risk $\tilde{\delta}$, where the distribution of $\tilde{\delta}$ is assumed to be statistically independent to that of $\tilde{\varepsilon}$.[5] Someone who is temperate will prefer lottery B_4 to lottery A_4 in Figure 3 for all values of W and for all zero-mean random variables $\tilde{\varepsilon}$ and $\tilde{\delta}$. For a risk averter, adding zero to W is preferred to adding either $\tilde{\varepsilon}$ or $\tilde{\delta}$. Thus, Eeckhoudt and Schlesinger (2006) describe temperate behavior as a preference for “disaggregating the harms.”

We also can interpret temperance as a preference for combining good with bad, as in Eeckhoudt et al (2009): the addition of the 50-50 lottery $[\tilde{\varepsilon}+0, \tilde{\delta}+0]$ to W is preferred to the addition of the 50-50 lottery $[\tilde{\varepsilon}+\tilde{\delta}, 0+0]$. On the other hand, an individual who prefers combining good with good and prefers combining bad with bad, such as a risk lover, will always prefer A_4 to B_4. Such an individual is referred to as being *intemperate*.

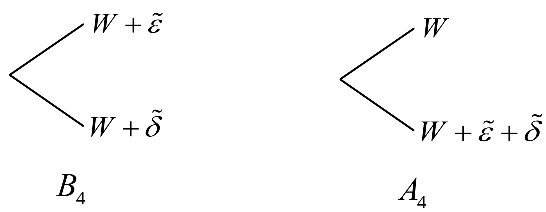

Figure 3: Lottery preference as temperance

An alternative, and equivalent, characterization of temperance follows from Eeckhoudt et al. (2009), and was characterized explicitly in this manner by Crainich et al. (2012). To this end let $\tilde{\theta}_1$ and $\tilde{\theta}_2$ be two statistically-independent random variables that possess the same mean and the same variance as each other. We assume that $\tilde{\theta}_1$ has more 3rd degree risk than $\tilde{\theta}_2$, i.e. more downside risk as defined by Menezes et al. (1980).[6] Thus, someone who is prudent would prefer

[5] 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).
[6] Downside risk is equivalent to third-degree risk as defined by Ekern (1980). One characterization is that for two random variables with the same mean and variance, the random variable $\tilde{\theta}_1$ has more downside risk than the random

$\tilde{\theta}_2$. Up to this point, we have let zero be the "good" alternative. But, for a prudent individual, we can let $\tilde{\theta}_2$ denote the relatively good alternative, while $\tilde{\theta}_1$ is relatively bad.[7] An alternative characterization of temperance is a preference for the lottery $\hat{B}_4$ over the lottery $\hat{A}_4$ in Figure 4.

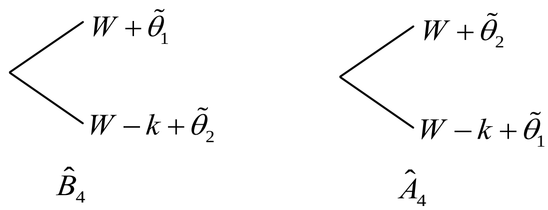

Figure 4: **An alternative lottery preference as temperance**

For the pair $\{-k, 0\}$, the first element in the set is "bad," while zero is "good." But for the second pair, $\{\tilde{\theta}_1, \tilde{\theta}_2\}$, the first element $\tilde{\theta}_1$ is relatively bad, while $\tilde{\theta}_2$ is relatively good, so long as the individual is prudent. Thus, an individual who always prefers combining bad with good will prefer lottery $\hat{B}_4$ over lottery $\hat{A}_4$ and is temperate. On the other hand, and individual who prefers combining good with good, such as a risk lover, is also prudent and thus agrees with the good vs. bad ranking in the set $\{\tilde{\theta}_1, \tilde{\theta}_2\}$. However, her preference for mixing good with good implies that she will always prefer lottery $\hat{A}_4$ to lottery $\hat{B}_4$ in Figure 4. Thus, this individual will be intemperate.

HIGHER-ORDER RISK ATTITUDES

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

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variable $\tilde{\theta}_2$ if and only if $\tilde{\theta}_2$ dominates $\tilde{\theta}_1$ via third-order stochastic dominance. We also note here that a necessary condition for more downside risk is that $\tilde{\theta}_1$ has a lower skewness (i.e. is more left skewed) than $\tilde{\theta}_2$.

[7] Note that "good" and "bad" are always expressed only in terms relative to each other. For example, if both $\tilde{\theta}_1$ and $\tilde{\theta}_2$ have zero means, then both are bad to a risk averter, in an absolute sense, but the risk averter prefers $\tilde{\theta}_2$.

[8] Note that by Ekern's (1980) definition, these random variables have the same level of risk for every degree less than *n*.

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* $\{\tilde{X}_n, \tilde{Y}_n\}$ *and* $\{\tilde{X}_m, \tilde{Y}_m\}$ *as described above, the 50-50 lottery* $[\tilde{X}_n + \tilde{X}_m, \tilde{Y}_n + \tilde{Y}_m]$ *has more* $(m+n)^{th}$ *degree risk than the lottery* $[\tilde{X}_n + \tilde{Y}_m, \tilde{Y}_n + \tilde{X}_m]$.

For someone who is risk apportionate of every order, all of the $\tilde{X}_i$ random variables are "good" and all of the $\tilde{Y}_i$ random variables are bad. Hence this individual, who prefers less n^{th} degree risk for every degree *n*, is someone who prefers combing good with good.

As an example, for n=1, we can set $\tilde{X}_1 = 0$ and $\tilde{Y}_1 = -k$.[9] At the same time, if m=2, we can set $\tilde{X}_2 = 0$ and $\tilde{Y}_2 = \tilde{\varepsilon}$, where $\tilde{\varepsilon}$ is a zero-mean non-degenerate random variable. It then follows from the Theorem that the lottery $[-k + \tilde{\varepsilon}, 0 + 0]$ has more 3rd degree risk than the lottery $[-k + 0, 0 + \tilde{\varepsilon}]$. Consider a risk averse individual. For this individual both of the $\tilde{X}_i$ random variables are relatively "good", whereas both of the $\tilde{Y}_i$ random variables are relatively "bad." But now note that adding the first lottery to initial wealth W is precisely the lottery A_3 from the previous section (Figure 2); and adding the second lottery to W is precisely lottery B_3. Ergo the lottery B_3 has less 3rd degree risk than he lottery A_3. Someone who is prudent is someone who prefers less 3rd degree risk and, hence, prefers lottery B_3.

As another example, keep $\tilde{X}_1 = 0$ and $\tilde{Y}_1 = -k$, but now define $\tilde{X}_3 = \tilde{\theta}_2$ and $\tilde{Y}_3 = \tilde{\theta}_1$, where $\tilde{\theta}_1$ has more 3rd degree risk than $\tilde{\theta}_2$, as in Figure 4. The Theorem implies that the 50-50 lottery $[0 + \tilde{\theta}_1, -k + \tilde{\theta}_2]$ has less 4th degree risk than the lottery $[-k + \tilde{\theta}_1, 0 + \tilde{\theta}_2]$. Now, for someone who is prudent, $\tilde{\theta}_2$ is relatively good compared to $\tilde{\theta}_1$. Someone who is temperate prefers the lottery with less 4th degree risk. This is equivalent to a preference for lottery $\hat{B}_4$ in Figure 4. Thus, she likes to combine good with bad. On the other hand, the prudent individual who is intemperate prefers the lottery with more 4th degree risk. This individual prefers to combine good with good. This is equivalent to a preference for lottery $\hat{A}_4$ in Figure 4.

By adding initial wealth W to the lotteries in the Theorem we obtain the two lotteries on wealth shown in Figure 5:

[9] 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.

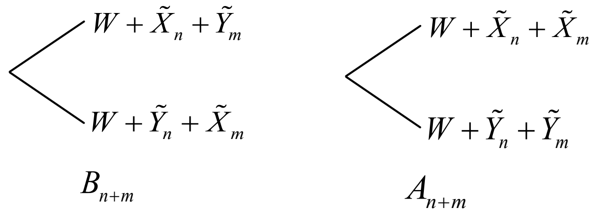

Figure 5: Higher order risk apportionment

Edginess (5th order risk apportionment)

The fifth-order attitude of *edginess* can be defined by setting $\tilde{Y}_3=\tilde{\theta}_1$ and $\tilde{X}_3=\tilde{\theta}_2$ as previously defined (where $\tilde{\theta}_1$ has more downside risk).[10] We introduce two additional random variables $\tilde{\varepsilon}_1$ and $\tilde{\varepsilon}_2$, which we assume have the same mean, but with $\tilde{\varepsilon}_1$ having more second-degree risk than $\tilde{\varepsilon}_2$.[11] We can now set $\tilde{Y}_2=\tilde{\varepsilon}_1$ and $\tilde{X}_2=\tilde{\varepsilon}_2$, so that $\tilde{Y}_2$ has more 2nd degree risk than $\tilde{X}_2$. We thus know from the Theorem that the lottery $[\tilde{\theta}_2+\tilde{\varepsilon}_2,\tilde{\theta}_1+\tilde{\varepsilon}_1]$ has more 5th degree risk than $[\tilde{\theta}_2+\tilde{\varepsilon}_1,\tilde{\theta}_1+\tilde{\varepsilon}_2]$. An individual who always prefers lottery B_{3+2} to lottery A_{3+2} in Figure 5 is called *edgy*. Following Eeckhoudt and Schlesinger (2006), we also say that preferences satisfy *risk apportionment of order 5*. Although we have not seen a terminology for someone with the opposite lottery preference (a preference for A_{3+2} over B_{3+2}), we will call such an individual *non-edgy* and say that preferences satisfy *anti-risk apportionment of order 5*.

From the Theorem, it also follows that we can describe risk apportionment of order 5 by letting n=1 and m=4. For example, we can let $\tilde{X}_1=0$ and $\tilde{Y}_1=-k$; and we can let $\tilde{X}_4$ equal the 50-50 lottery $[0+\tilde{\varepsilon},0+\tilde{\delta}]$ and $\tilde{Y}_4$ be the 50-50 lottery $[0+0,\tilde{\varepsilon}+\tilde{\delta}]$, where $\tilde{\varepsilon}$ and $\tilde{\delta}$ are independent zero-mean risks, identical to those in Figure 3.[12] Using these random variables in Figure 5, we can define risk apportionment of order 5 as a preference for lottery B_{1+4} over lottery A_{1+4}. The lottery B_{1+4} has less 5th degree risk. The equivalence of the two descriptions of 5th order risk attitudes is proven in Eeckhoudt et al. (2009).

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[10] 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. Fifth-order and higher attitudes are analyzed in Eeckhoudt and Schlesinger (2006) by nesting some of the previous lotteries into compound lotteries.

[11] Again, our terminology derives from Ekern (1980). An increase in second-degree risk also was analyzed much earlier by Rothschild and Stiglitz (1970), who referred to it as a "mean-preserving increase in risk." We also note here that $\tilde{\varepsilon}_1$ having a higher variance than $\tilde{\varepsilon}_2$ is a necessary (but not sufficient) condition for $\tilde{\varepsilon}_1$ to have more second-degree risk.

[12] This example is how Eeckhoudt and Schlesinger (2006) define risk apportionment of order 5, by "nesting" their lower order lotteries.

6^{th} order risk apportionment

To obtain *risk apportionment of order 6*, we can once again apply the Theorem in Figure 5 and choose any positive integers n and m with $n+m$=6. This gives us three different ways to construct lotteries with risk apportionment of order 6 (with $n+m$ equaling either 1+5, 2+4 or 3+3). In our experiment, we limit our analysis to the two cases where $n=m=3$, and where $n=2$ with $m=4$. Risk apportionment of order 6 follows from a preference for B_{3+3} over A_{3+3} or from a preference for B_{2+4} over A_{2+4}. The opposite preference 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.

(Mixed) risk lovers versus (mixed) risk averters

Recall that mixed risk aversion could be described as preference for combining good with bad. On the other hand, mixed risk loving behavior shows a preference for combining good with good. 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.

One question addressed via our experiment is whether or not a risk lover is also a *mixed* risk lover: someone who likes to combine good with good and to combine bad with bad? We have already seen how this trait implies that a mixed risk lover is prudent, but also intemperate. Using the Theorem, it is simple by using induction to see that someone who is mixed risk averse -- 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).

RELATION TO EXPECTED UTILITY AND THE UTILTY PREMIUM

Although neither Eeckhoudt and Schlesinger (2006) nor Eeckhoudt et al. (2009) assume EUT, they do define preferences over compound lotteries, as in our figures above. To the extent that individual preferences do not satisfy the axiom of the reduction of compound lotteries (ROCL), their descriptions might not hold for lotteries appearing in a reduced form. Likewise, the equivalence of preferences for lottery $B_{\mathrm{n+m}}$ over lottery $A_{\mathrm{n+m}}$ for every $n+m$ with the same sum, as in Eeckhoudt et al. (2009) will not automatically hold. We will address this point later, when discussing our experiment.

All of the definitions above do not explicitly assume that preferences are formed via expected utility theory (EUT). However, 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 $u^{(n)}$ denotes the n^{th} derivative of the utility function u.[13] If the above condition holds for all n, marginal utility is said to be completely monotone.[14] 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. As one example of a fairly common utility function without this property, consider the quadratic utility function $u(t) = t - \beta t^2$, where we assume 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 to lotteries B_{n+m} and A_{n+m}.

An interesting way to interpret risk attitudes in an EUT setting follows from Eeckhoudt and Schlesinger (2009), who resurrect the utility premium as introduced by Friedman and Savage (1948). We assume throughout that utility is differentiable to the degree needed. Although Eeckhoudt and Schlesinger (2009) only discuss the case of risk aversion, we can easily extend their analysis to risk lovers. To this end, we define the *utility premium* for a risk $\tilde{X}$ added to wealth W as follows:

(1) $$\Psi(W;\tilde{X}) \equiv Eu(W+\tilde{X}) - u(W+E\tilde{X}) .$$

<u>(*Mixed*) *risk averters*</u>

For a risk averter, the utility premium Ψ will be negative. We can view the utility premium as the utility gained from the risk inherent in $\tilde{X}$, which of course is negative for a risk averter. Eeckhoudt and Schlesinger (2009) refer to the utility premium as a measure of "pain" for this individual stemming from the risk in $\tilde{X}$.

Using Jensen's inequality, it is easy to see that $\frac{\partial \Psi}{\partial W} > 0$ for all W if and only if marginal utility u' is a convex function, i.e. iff $u'''(t) > 0$. Thus, for the prudent individual, the amount of pain is decreasing (less negative) as wealth increases.[15] If $\tilde{X}$ is a zero-mean random variable, then it would be better to add $\tilde{X}$ at a higher wealth level, as opposed to a lower wealth level. Of course this is precisely the driving force for the lottery preference describing prudence in Figure 2. It is interesting here to note the often overlooked difference between prudence and decreasing absolute risk aversion (DARA). For example, consider a utility function exhibiting CARA. It also has $u'''(t) > 0$, so that the level of pain is decreasing from the risk $\tilde{X}$ as wealth increases. The reason why the risk premium (the willingness to pay to eliminate the risk in $\tilde{X}$) remains

[13] Of course, since we assume that more wealth is desirable, we also have $u' > 0$

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

[15] Although concepts such as "prudence" had not yet appeared in the literature, Hanson and Menezes (1971) noticed long ago that the utility premium was decreasing as wealth increase if and only if $u''' > 0$.

constant (as opposed to also decreasing) is that marginal utility of wealth is declining as wealth increases, so that money becomes less dear (in terms of utility) as wealth increases.[16]

We can differentiate once again and apply Jensen's inequality to see that $\frac{\partial^2 \Psi}{\partial W^2} > 0$ if an only if u'' is concave, i.e. if and only if $u^{(4)}(t) < 0$. An important aspect of this property is shown by examining the so-called derived utility premium for adding a second risk $\tilde{Y}$ that is assumed to be statistically independent from $\tilde{X}$, as defined in Eeckhoudt and Schlesinger (2006):

(2) $$\Upsilon(W;\tilde{Y}) \equiv E\Psi(W+\tilde{Y};\tilde{X}) - \Psi(W+E\tilde{Y};\tilde{X}).$$

The term $E\Psi(W+\tilde{Y};\tilde{X})$ represents how much expected utility is gained from the inherent risk in $\tilde{X}$, given the presence of the random variable $\tilde{Y}$. The second term $\Psi(W+E\tilde{Y};\tilde{X})$ is the expected utility gained from the inherent risk in $\tilde{X}$, if we first eliminate the risk in $\tilde{Y}$. Note here that both of these "gains" will be negative for a risk-averse individual. Thus, the derived utility premium $\Upsilon(W;\tilde{Y})$ represents how much extra utility is gained from the risk $\tilde{X}$, when the risk in $\tilde{Y}$ is present.

From Jensen's inequality, it follows that the derived utility premium $\Upsilon(W;\tilde{Y})$ will be negative if and only if the utility premium itself, $\Psi(W;\tilde{X})$, is a concave function in *W*. But this last property is equivalent to $u^{(4)}(t) < 0$, as we have already seen. Thus temperance, $u^{(4)}(t) < 0$, implies that the amount of pain (the negative gain) is higher (more negative) from adding $\tilde{X}$ to wealth when $\tilde{Y}$ is risky, as opposed to when $\tilde{Y}$ is not risky (replaced with $E\tilde{Y}$).[17]

By differentiating (2) with respect to *W*, Eeckhoudt and Schlesinger (2006) show that this extra pain from $\tilde{X}$ in the presence of a risky $\tilde{Y}$ is decreasing as wealth increases, if and only if $u^{(5)}(t) > 0$, i.e. for an edgy individual. Eeckhoudt and Schlesinger (2006) extend these results for 6^{th} and higher orders of risk apportionment, but this requires more complicated "nesting" than in equation (2) and we do not present any analysis here. For the individual who is risk apportionate of order 6, we will simply note that $u^{(6)}(t) < 0$.

Risk lovers

For the risk lover, who likes mixing good with good, at least for 2^{nd} degree risk, her utility premium in (1) will be positive. The risk lover gains expected utility due to the inherent risk in

[16] More details as well as other examples can be found in Eeckhoudt and Schlesinger (2009).
[17] Kimball (1993) refers to the two risks, in this case, as being "mutually aggravating." The relation between 4^{th} degree risk and the fourth derivative of utility was derived in a completely different manner by Menezes and Wang (2002), who refer to the riskier option has having more "outer risk."

$\tilde{X}$. As opposed to measuring the "pain" for a risk averter, we can say the utility premium measures the "joy" of the risk lover.

If this risk loving individual also prefers combining good with good for higher orders, she will prefer to have the risk $\tilde{X}$ being added to a higher initial wealth level, as opposed to a lower wealth level. In other words, we would expect $\frac{\partial \Psi}{\partial W} > 0$: the joy from adding $\tilde{X}$ increases as W increase. As previously, this derivative will always be positive if and only if the individual is prudent, $u'''(t) > 0$.

To understand the 4th order risk attitude of intemperance, differentiate the utility premium a second time and apply Jensen's inequality to see that $\Psi(W;\tilde{X})$ is convex in W, $\frac{\partial^2 \Psi}{\partial W^2} < 0$, if and only if u'' is convex, $u^{(4)}(t) > 0$. Also, note from equation (2) that $\Psi(W;\tilde{X})$ convex implies that the derived utility premium $\Upsilon(W;\tilde{Y})$ is positive. Hence, for the imprudent individual, the extra joy derived from adding the risk inherent in $\tilde{X}$ is higher, if the individual also has a risky $\tilde{Y}$. Put differently, eliminating the risk inherent in $\tilde{Y}$ would reduce the joy of carrying the risk $\tilde{X}$. As opposed to Kimball's (1993) description of the two risks being mutually aggravating, we can say that the two risks are *mutually enhancing*.[18]

The enhancement $\Upsilon(W;\tilde{Y})$ will be increasing in wealth for all W if and only if $u^{(5)}(t) > 0$. That is, the extra joy from having both risks together increases as the individual adds wealth. Thus, the mixed risk loving individual, who prefers to combine good with good, is also edgy. Again, we do not show 6th order risk attitudes here, but it follows in a straightforward manner from Eeckhoudt and Schlesinger (2006) that the individual who prefers combining good with good, i.e. who is anti-risk apportionate of order 6, will have $u^{(6)}(t) > 0$.

The theoretical results on the higher order risk orders discussed here are summarized in Table 1. Recall that we assume that everyone prefers more wealth to less.

Table 1: Projected higher order risk attitudes

Prefer combining good with bad	**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* $(u^{(6)} > 0)$

[18] Many examples of how the signs of the first four derivatives can be applied within decision models in economics and finance can be found in Gollier (2001).

EXPERIMENTAL DESIGN

A total of 57 undergraduates at the University of Arkansas participated in the study. The participants were recruited from the Behavioral Business Research Laboratory's database of volunteers.[19] Subjects were recruited for a 45 minute session and received a $5 participation payment in addition to their salient earnings, which averaged $20.32 (minimum was $1 and maximum was $76).

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

The 38 choice tasks that the participants encountered are shown in Table 2. Each task involved a binary comparison of fixed amounts of money or 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 6 below. This technique is intended to facilitate participant understanding. 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. In this respect, the presentation follows the intuitive approach of Eeckhoudt and Schlesinger (2006) and Eeckhoudt et al. (2009) who look at "combining good with bad," rather presenting the lotteries in a reduced form, which obfuscates this interpretation.[20]

<u>Table 2</u>: Choice Tasks

Task	Order	Construction	Option A	Option B
1	1	n.a.	$20	$20+$10
2	1	n.a.	$2	$2+$5
3	1	n.a.	[$2+ ($10|$20)] | $20	$25 | [$27+ ($-1|$1)]
4	2	n.a.	$5 | ($10 + $5)	($5 + $5) | $10
5	2	n.a.	$2 | ($4 + $8)	($2 + $8) | $4
6	2	n.a.	$10 | ($15 + $5)	($10 + $5) | $15
7	2	n.a.	$2 | ($4 + $3)	($2 + $3) | $4

[19] 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.

[20] The paper by Maier and Rüger (2012) does just the opposite and present lotteries for risk attitudes of orders 2-4 in a reduced form. Their basic results do not differ at all from other experiments to date, each of which presents the choices as compound lotteries. Indeed, only the "intemperance" result of Deck and Schlesinger (2010) appears to be an outlier.

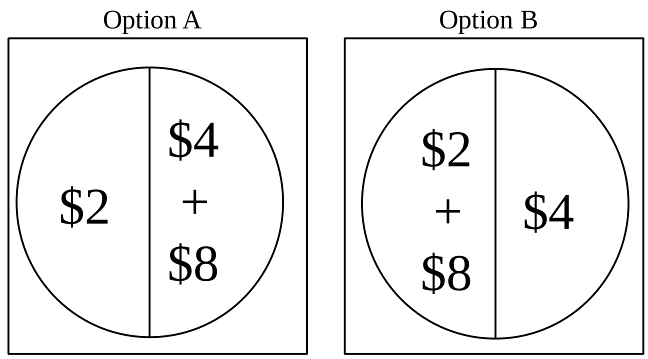
8	2	n.a.	$20 | ($40 + $30)	($20 + $30) | $40
9	2	n.a.	$4 | $10	$7
10	2	n.a.	$1 | $19	$10
11	3	n.a.	[$5 + ($-2|$2)] | $10	$5 | [$10 + ($-2|$2)]
12	3	n.a.	[$10 + ($-4|$4)] | $20	$10 | [$20 + ($-4|$4)]
13	3	n.a.	[$5 + ($-4|$4)] | $10	$5 | [$10 + ($-4|$4)]
14	3	n.a.	[$2 + ($1\|$-1)] | $4	$2 | [$4 + ($1\|$-1)]
15	3	n.a.	[$20 + ($10\|$-10)] | $40	$20 | [$40 + ($10\|$-10)]
16	3	n.a.	[$8 + ($2\|$-2)] | $10	$8 | [$10 + ($2\|$-2)]
17	3	n.a.	[$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)]
19	4	2+2	[($7|$10)+($7|$10)] | [($5|$12)+($5|$12)]	[($5|$12)+($7|$10)] | [($7|$10)+($5|$12)]
20	4	2+2	(Task 8 Option B + Task 7 Option B) | (Task 8 Option A + Task 7 Option A)	(Task 8 Option A + Task 7 Option B) | (Task 8 Option B + Task 7 Option A)
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+ Task 12 Option A) | ($24+Task 12 Option B)	($14+ Task 12 Option B) | ($24+Task 12 Option A)
23	4	1+3	($7+ Task 11 Option A) | ($12+Task 11 Option B)	($7+ Task 11 Option B) | ($12+Task 11 Option A)
24	4	1+3	($1+ Task 11 Option A) | ($18+Task 11 Option B)	($1+ Task 11 Option B) | ($18+Task 11 Option A)
25	5	2+3	($7|$10 + Task 11 Option B) | ($5|$12 + Task 11 Option A)	($7|$10 + Task 11 Option A) | ($5|$12 + Task 11 Option B)
26	5	2+3	($10|$4 + Task 12 Option B) | ($2|$12 + Task 12 Option A)	($10|$4 + Task 12 Option A) | ($2|$12 + Task 12 Option B)
27	5	2+3	($50|$40 + Task 11 Option B) | ($20|$70 + Task 11 Option A)	($50|$40 + Task 11 Option A) | ($20|$70 + Task 11 Option B)
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 + Task 19 Option A) | ($7 + Task 19 Option B)	($5 + Task 19 Option B) | ($7 + Task 19 Option A)
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 + Task 20 Option A) |	($1 + Task 20 Option B) |

			($20 + Task 20 Option B)	($20 + Task 20 Option A)
32	6	3+3	(Task 11 Option A + Task 11 Option A) | (Task 11 Option B + Task 11 Option B)	(Task 11 Option A + Task 11 Option B) | (Task 11 Option B + Task 11 Option A)
33	6	3+3	(Task 11 Option A + Task 12 Option A) | (Task 11 Option B + Task 12 Option B)	(Task 11 Option B + Task 12 Option A) | (Task 11 Option A + Task 12 Option B)
34	6	3+3	(Task 12 Option A + Task 14 Option A) | (Task 12 Option B + Task 14 Option B)	(Task 12 Option A + Task 14 Option B) | (Task 12 Option B + Task 14 Option A)
35	6	3+3	(Task 16 Option A + Task 16 Option A) | (Task 16 Option B + Task 16 Option B)	(Task 16 Option A + Task 16 Option B) | (Task 16 Option B + Task 16 Option A)
36	6	2+4	[$8|$12 + Task 19 Option B] | [$5|$15 + Task 19 Option A]	[$5|$15 + Task 19 Option B] | [$8|$12 + Task 19 Option A]
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 + Task 20 Option B] | [$5|$1 + Task 20 Option A]	[$5|$1 + Task 20 Option B] | [$2|$4 + Task 20 Option A]

In this table X|Y denotes a lottery where there is a 50% chance of receiving X and a 50% chance of receiving Y. Construction refers to the *m* and *n* chosen for $(m+n)^{th}$ order risk, as in our Theorem.

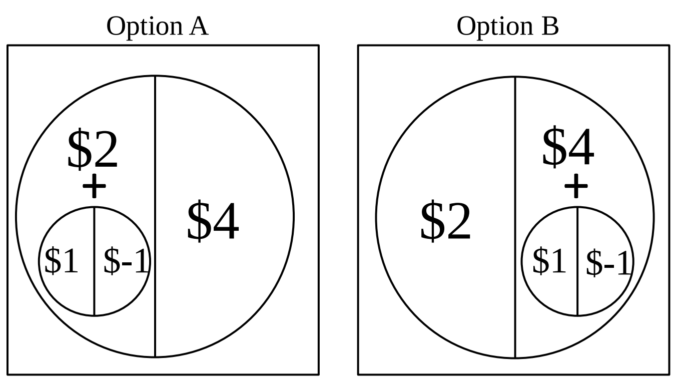
The first 3 tasks are designed to verify that participants understand the task under our assumption that they prefer more money to less. For example, in Task 1 participants are asked if they prefer $20 or $20+$10 = $30. In Task 3, Option A was a 50-50 lottery where one would receive either $20 or $2 plus a 50-50 lottery for either $10 or $20. 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 form Option B, monotonicity alone is sufficient for one to prefer Option B to Option A.

Second order tasks (Tasks 4-10) identify which participants are risk averse (loving) as those individuals would prefer to add a positive amount of money to the less (more) preferred outcome of a 50-50 lottery. For example, Task 5 presents the subjects with Option A which reduces to a 50-50 lottery for either $2 or $12 whereas Option B yields a 50-50 lottery for either $4 or $10. Since the expected value is the same, a risk averse (loving) person would prefer option A (B) with the higher variance. Figure 6 shows this choice task as it was presented to the subjects. Notice that in keeping with Eeckhoudt et al. (2009) the task is presented as adding $8 to one outcome in a 50-50 lottery between $2 or $4. A risk averse (loving) person would prefer to combine the good $8 with the bad $2 (good $4) outcome. In general, a risk averse (loving) person prefers Option B (A) for Tasks 4-10.



<u>Figure 6</u>: Task 5, a Second Order Task, as Presented to Participants

Third order preferences are measured by tasks 11-17 and are similar to those used to measure second order preferences except that it is a zero-mean 50-50 lottery that can be added to the good or bad outcome of the main 50-50 lottery.[21] Notice that this process holds the mean and the variance constant across options and only changes the skewness. Figure 7 shows a third order task as presented to the participants. A prudent (imprudent) person would prefer option B (A). Recall that the 50-50 lottery to win or lose $1 is "bad" only to a risk averter and is "good" to a risk lover.



<u>Figure 7</u>: Task 14, a Third Order Task, as Presented to Participants

Higher order preferences are measured by replacing the simple items in the lotteries for second and third order tasks with more complicated items. Notice that the difference between the second and third order tasks is whether or not a fixed amount (a first order item) or a 50-50 lottery (a second order item) is being placed with the good or bad outcome of the main lottery. This process can be iterated to generate higher order tasks. For example, a fourth order task can be created by replacing the zero mean lottery in Figure 7 with a third order item as was done to

[21] 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.

construct Tasks 22-24. Alternatively, the first order fixed outcomes of the main lottery could be replaced with second order items as done in Tasks 18-21. For convenience, the former approach to constructing a 4^{th} order task is referred to as a 1+3 task while the latter is a 2+2 as it is a combination of second order items. Regardless of construction, a temperate (intemperate) person would prefer Option B (A) for Tasks 18-23. The 4^{th} order tasks are such that the mean, variance, and skewness are held constant while only the kurtosis differs between options. Tasks 24-30 measure 5^{th} order preferences while holding the first four moments fixed. The first four 5^{th} order tasks are constructed as 2+3 tasks and the others are constructed as 1+4 tasks. The last seven tasks measure 6^{th} order preferences; the first four with 3+3 tasks and the last three with 2+4 tasks.

While all the subjects observed the same tasks in a within subjects design, the order of the tasks was randomized for each person. 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 this paper, all references to Option A or Option B are in terms of the option labels shown in Table 2 and consistent with the terminology of Eeckhoudt and Schlesinger (2006).

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.[22] 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 a line through the middle, similar to the image shown in Figures 1 and 2. Participants were allowed to make the spin subject to the requirement that the arrow "go 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.

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.

[22] We realize that this method of payment itself, although generally accepted, is still often debated. See for example Starmer and Sugden (1991), Laury (2005), Harrison and Swarthout (2012) and Harrison, Martinez-Correa and Swarthout (2012).

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. Figures 3 – 8 show the distribution of the number of Option A choices participants made for 1st – 6th order tasks respectively. The solid line indicates the frequency with which a given number of A choices one would expect to observe if each participant made a random choice on each task.

Based on Figure 8, we conclude that participants understand the experiment interface and prefer more money to less, with over 91% never selecting the lower payoff Option A. The observed distribution is statistically different from what would be observed by chance based on a chi-square (p-value < 0.001). Of those few that did select a lower payoff, none did so more than once and all did so only in the more complicated version in Task 3. All of our results in this experiment are qualitatively unchanged, if these participants are excluded.

Consistent with the large volume of previous lab experiments, the participants are overwhelmingly risk averse in aggregate as most people made 3 or fewer (out of 7) Option A choices on 2nd order tasks (see Figure 9).[23] In fact, a large fraction of the subjects exhibit fairly strong risk aversion making one or zero Option A choices. The amount of risk aversion is greater than would be expected by chance (chi-square test p-value < 0.001).

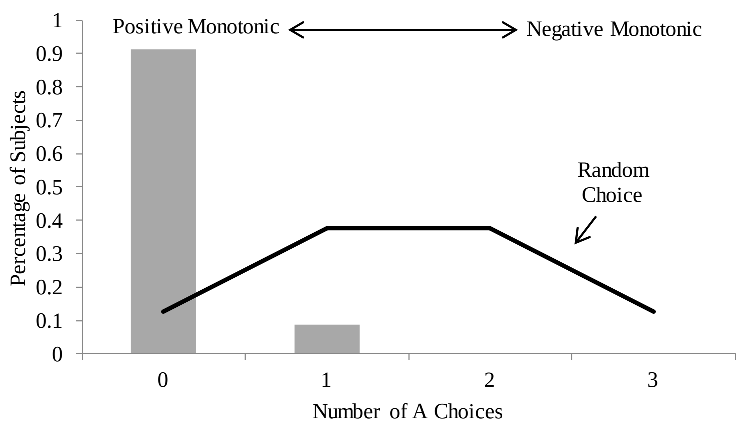
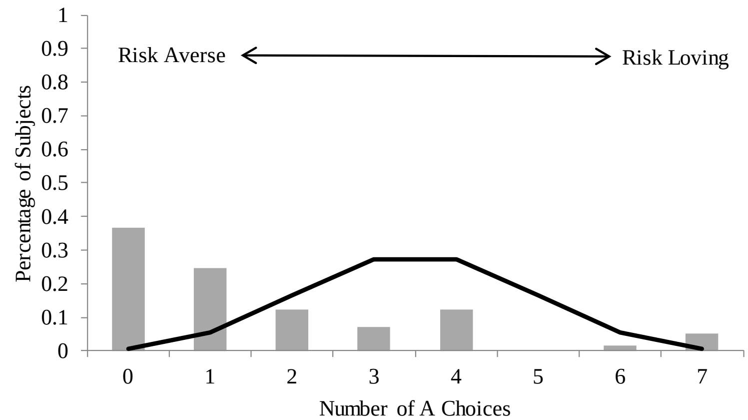
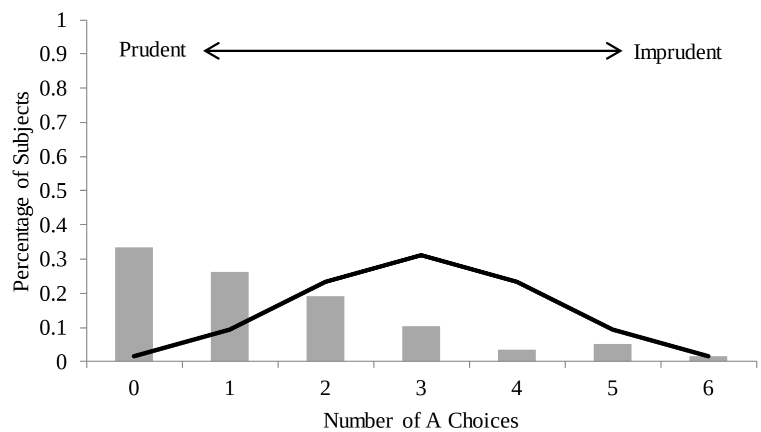


Figure 8: Distribution of Participant Behavior on 1st Order Tasks

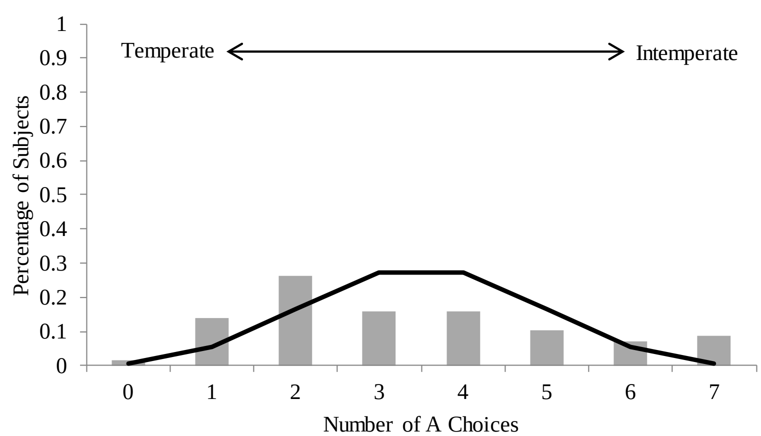
[23] Of course, making even one risk-loving decision might disqualify an individual from being labeled as "risk averse." Although we do not wish to get sidetracked on stochastic preferences in choice models, we will adopt a stochastic type of labeling and refer to someone whose majority of choices is for Option B as being "risk averse." See Wilcox (2008) for a good review of these concepts.



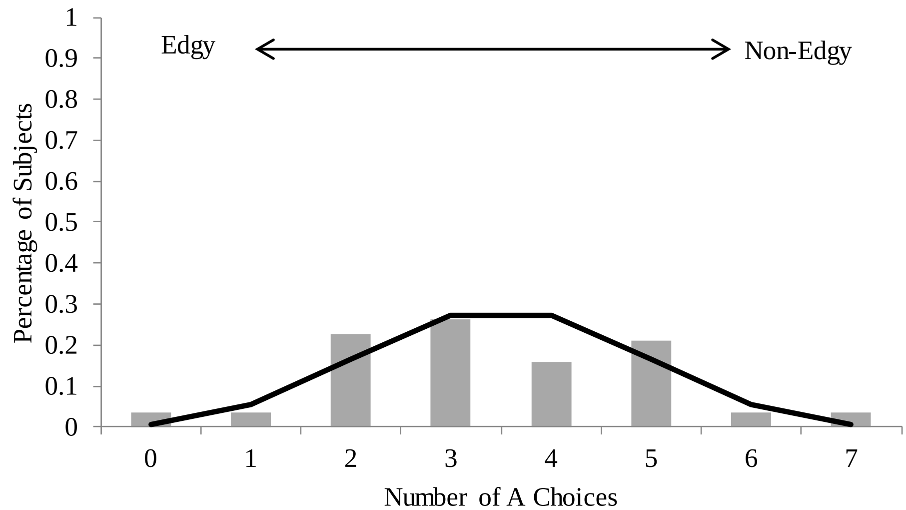
<u>Figure 9</u>: Distribution of Participant Behavior on 2nd Order Tasks



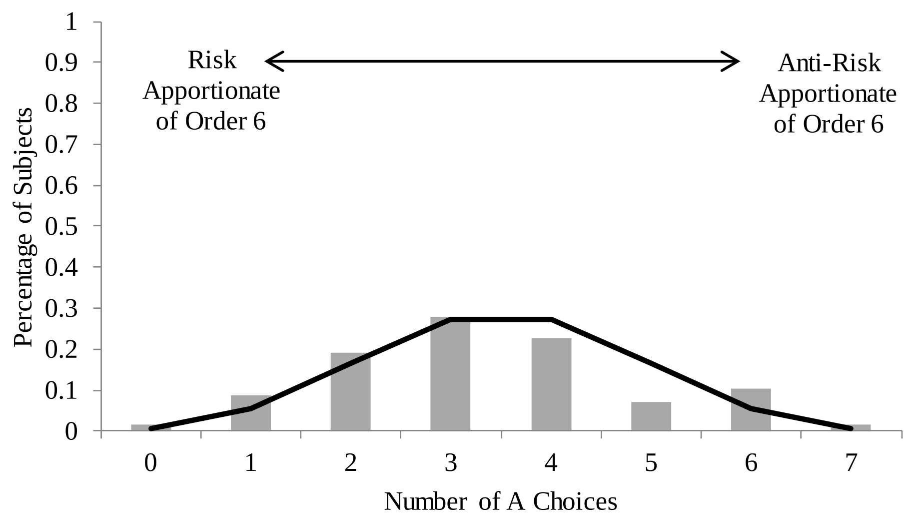
<u>Figure 10</u>: Distribution of Participant Behavior on 3rd Order Tasks



<u>Figure 11</u>: Distribution of Participant Behavior on 4th Order Tasks



<u>Figure 12</u>: Distribution of Participant Behavior on 5th Order Tasks



<u>Figure 13</u>: Distribution of Participant Behavior on 6th Order Tasks

The aggregate behavior shown in Figure 10 indicates that the participants were generally prudent, consistent with all of the other previous lab studies to date. The number of prudent choices was more than would occur by chance (chi-square p-value < 0.001). Indeed the strength of prudence as measured by the number of prudent choices seems rather strong here. To the extent that both risk lovers and risk averters would both be prudent, as suggested by Crainich et al. (2012), this result would be expected.

As discussed in the introduction, most previous research has found respondents to be moderately temperate.[24] Our participants in this study also exhibit temperance, although based on Figure 11, they do not appear to be strongly temperate. The average number of A choices on 4th order tasks was 3.33 out of 7, indicating at most mild temperance. While a chi square test rejects that 4th order behavior was random (p-value < 0.001), it appears to be the case that too much weight is placed on both tails and too 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 according to Crainich et al (1012), we would expect that temperance is exhibited less frequent than prudence. Our result here -- that temperance is less prevalent than prudence -- is consistent with this hypothesis. Noussair, et al. (2012) and Ebert and Wiesen (2012) also show that prudence is exhibited more frequently than temperance.

Moving to the 5th order tasks, this pattern of some participants exhibiting clear preferences with others perhaps choosing randomly continues (see Figure 12). A chi-square test rejects random behavior (p-value = 0.011); but there seems to be no clear preference in the group, only a very slight tendency towards edginess (i.e., towards 5th order risk apportionment.) If risk lovers agree with risk averters about 5th order attitudes, as in Crainich et al. (2012), 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 shown in Figure 13, behavior is essentially random (chi-square p-value = 0.171), although overall a bit more A choices are made. 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. (2012).

In the laboratory, we also recorded the amount of time that subjects took to make each decision. On average, people spent less than 7 seconds on first order tasks. While this may not sound like a lot of time it was clearly sufficient to identify the option with the larger payoff as evidenced by Figure 8. Time spent increased slightly for second order tasks and continued to increase with successively higher orders. Participants spent the most time on the 6th order tasks, just over 20 seconds per task on average. Again this may not sound like a long time, but it might seem longer if you stop to think about it for, say, a full 20 seconds.

[24] 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 $\tilde{\varepsilon}$ in our Figure 2 would lead to more lottery B choices; but this is precisely the "good with bad" type of temperance preference that we describe in Figure 4. Thus, their results also indicate temperate behavior in the aggregate.

That people spent more time on more complicated tasks and behavior still becomes random suggests to us that the limit of how deeply people think about uncertainty is limited and that the fifth or sixth order is pushing the upper bound. In fact, Figures 3-8 show a gradual evolution from virtual complete agreement to a random distribution. 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 the variances, none were 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.

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, although men appear to be nominally more risk taking than women.[25] Chi-square tests fail to reject that the male and female distributions are the same at the 95% confidence level for each of the six orders. Further, the average percentage of A choices does not differ statistically for males and females on any order at traditional significance levels.

Individual Behavior

As described previously, an individual who is risk averse should be temperate and pick Option B on 6^{th} order tasks. An individual who is risk loving should be intemperate and pick Option A on 6^{th} order tasks. However, both types of individuals should have monotonic preferences, be prudent, and select Option B on 5^{th} order tasks. More generally, according to Crainich et al. (2012), these two groups should behave similarly on odd numbered tasks and behave differently on even numbered tasks.

To further explore this hypothesis, we examine risk averters and risk lovers separately.[26] Figure 14 replicates Figures 3 – 8, separating risk-averse participants (shown as white bars) from risk loving participants (shown as black bars). The pattern revealed in Figure 14 follows the pattern predicted by Crainich et al (2012) through order 5. For order 6, behavior is essentially random. Although we do not test behavior for even higher orders, it seems pretty clear that it would likely also be essentially random.

Table 3 reports the p-values associated with the chi-square tests that the two groups follow the same distribution for each task order. The results indicate that an alternating pattern is observed.

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[25] Males chose the risk-loving Option A 26% of the time on average for the second order tasks whereas women did so only 21% of the time. This difference is not significant based upon a two sided t-test (p-value = 0.445).
[26] Recall that a participant is classified as being risk averse [risk loving] if he or she chose Option B [Option A] on a majority of second order tasks.

through the 5th order. Risk averters and risk lovers are not behaving in the same way on 4th order tasks, but are behaving in the same way on odd order (3rd order and 5th order) tasks.

Table 3: p-values for Chi-Square Test that Risk Attitudes Agree on Alternate Orders

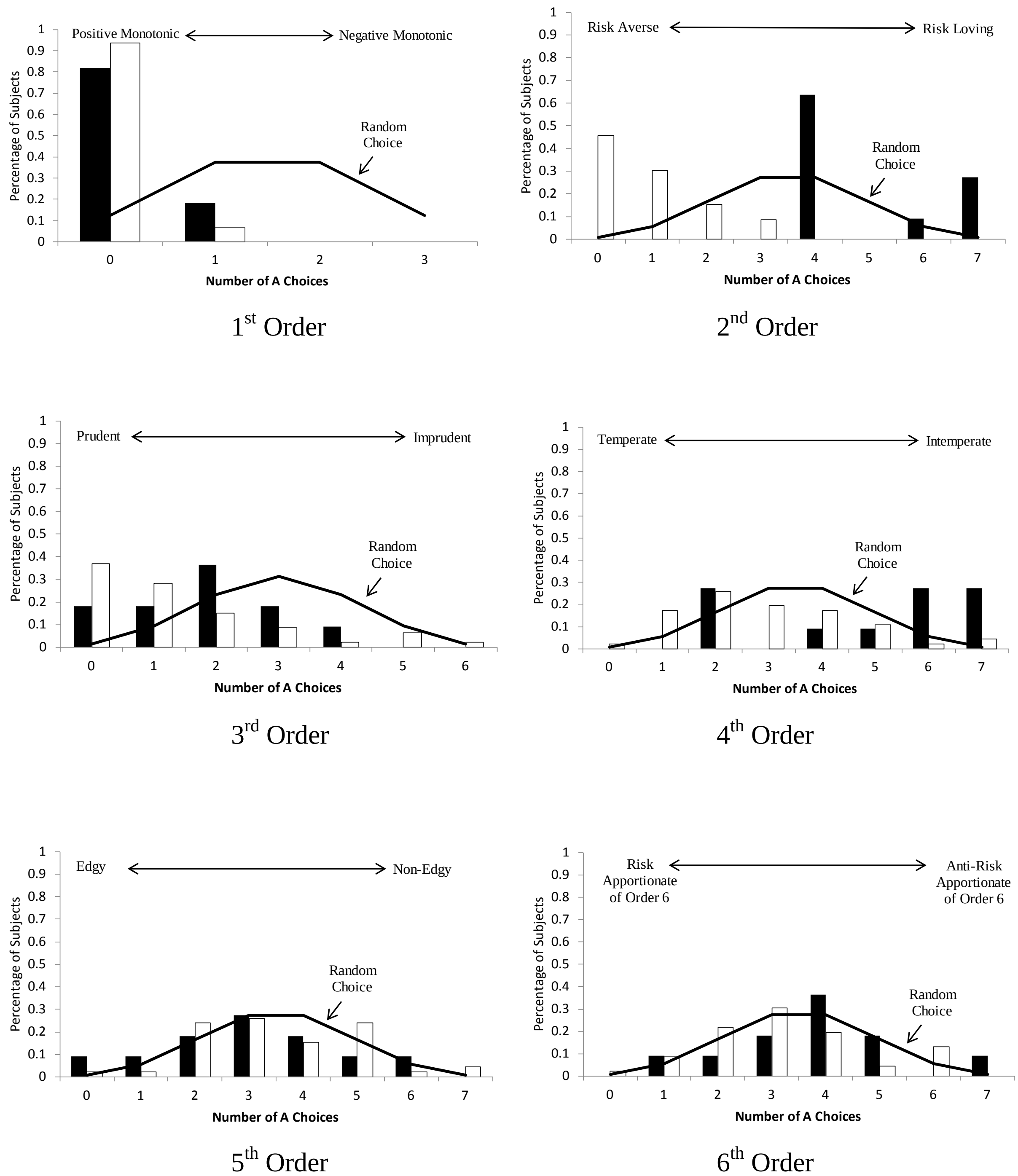
Order	1st	2nd	3rd	4th	5th	6th
Prediction	Same	n.a.	Same	Different	Same	Different
p-value	0.219	n.a.	0.394	0.012	0.633	0.158

Further evidence for this relationship is found in Table 4, which reports the correlation in individual behavior between tasks of different orders. Specifically, Table 4 gives the correlation between the percentages of times a participant chose Option A on two different orders. 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 not between even and odd orders. This is in fact the general pattern that is observed. The one exception is that 2nd and 6th order behavior is not significantly positively correlated; however, this is consistent with people fewer and fewer people being able to discern differences in higher and higher order tasks as discussed previously.

Table 4: Correlation of Individual Behavior Between Tasks of Different Orders

	% A Choices for 3rd Order	% A Choices for 4th Order	% A Choices for 5th Order	% A Choices for 6th Order
% A Choices for 2nd Order	-0.006	**0.471****	-0.228	0.120
% A Choices for 3rd Order	-	0.0556	**0.273***	0.136
% A Choices for 4th Order	-	-	0.037	**0.398****
% A Choices for 5th Order	-	-	-	0.007

* and ** indicate significance at the 5% and 1% significance levels, respectively.
1st order choices are omitted due to the limited variability in behavior.



<u>Figure 14</u>: Distributions of Participant Behavior for Each Order by Participant Type [Risk Averse (white) and Risk Loving (black)]

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 2nd order tasks and a combination of a 1st and 3rd order tasks. Behavior was largely consistent between these two constructions (correlation = 0.390, p-value = 0.001). To the extent that such behavior would be inconsistent, it would bring into question the reduction of compound lotteries. Although we do not have a completely reduced form lottery, we do examine two different ways of compounding. At least for the fourth order tasks, we do not see any strong evidence against reduction of compound lotteries. Behavior was still at least marginally consistent between constructions for the more complicated 5th order tasks, which were constructed as a combination of either 1st and 4th orders or of 2nd and 3rd orders (correlation = 0.193 and p-value = 0.075). For 6th order tasks, we also have some weak consistency (correlation = 0.181 and p-value = 0.089). These results also suggest that up to a point, people are deliberate in their actions, but do not evaluate uncertainty beyond some order, which seems to be around order 5.

CONSISTENCY WITH EXPECTED- AND NON-EXPECTED UTILITY BEHAVIORS

Mixing "good with bad" or "good with good" under EUT

Most commonly used utility functions, such as those exhibiting either constant absolute risk aversion or constant relative risk aversion, 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.).[27] Deck and Schlesinger (2010) point out that we do not often see utility with risk aversion and intemperance (their experimental result). But if we think that Crainich et al. (2012) are correct and that the fundamental behavior of risk lovers is driven by this preference for "combining good with good" -- so that they are also prudent, intemperate, edgy, etc. -- it is relatively easy to find utility functions that have all their derivatives positive. Our experimental evidence seems to support their hypothesis of combing "good with bad" or "good with good."

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. (2012) 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 also fit quite well with

[27] 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.

the Crainich el. (2012) 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. (2012) claim a statistically significant positive correlation between risk aversion and prudence, a careful look at their evidence shows that this result is 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 combing either "good with good" or "bad with bad." In particular, they regress their percent of *Y* choices on their percent of *X* choices, where *X* and *Y* are particular n^{th} order task choices, n = 2,3,4. 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.[28]

Moment preference

For some reason, the paper by Crainich et al. (2012) 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. 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. For example, in tasks 4 – 10 for risk aversion, both Option A and Option B have equal means, but option A has a higher variance. Although we know, for example from Rothschild and Stiglitz (1970) that risk aversion is not "variance aversion," a higher variance is a necessary condition for higher 2^{nd} degree risk. As another illustration, all of our 4^{th} order tasks, tasks number 18-24, have the same first three moments, but option A has a higher kurtosis (more leptokurtic) than option B. Unfortunately, in our experimental tasks, we cannot distinguish between a preference against (or for) n^{th} degree risk and preference against (or for) higher moments.

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 always prefer higher odd order moments and smaller 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.

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[28] For *Y* risk aversion and *X* prudence, their slope is 0.5144 (R^2 = 0.193) and for *Y* prudence and *X* temperance, their slope is 0.5978 (R^2 = 0.3216).

Our experimental results support these types of moment preferences, at least for smaller orders. Once we get to order 5, this preference is very weak, and it seems to disappear completely by the time we get to order 6. Perhaps it is not a coincidence that most economists, at least anecdotally, are familiar with the names for the first four moments of a probability distribution, but not the fifth or sixth.

Cumulative Prospect Theory?

The paper by Ebert and Wiesen (2012) purports to use their experimental data to show that cumulative prospect theory (Tversky and Kahneman (1992)) has the best "fit" for explaining their prudence and their temperance. In particular, they use a type of compensating variation (how much cash can be added to Option A before one prefers it to Option B) to measure the intensities of both of these risk attitudes.[29]

Cumulative prospect theory (CPT) generally consists of first defining a so-called reference point, from which we can frame "gains" and "losses," and then defining both a value function of wealth and a weighting of the cumulative distribution function. As proposed by Tversky and Kahneman (1992), the value function is concave over the domain of gains but convex over the domain of losses. At the same time, the probability distortion puts more weight into both tails than the objective probability distribution. If we use the expected final payoff as our reference point for 3rd and 4th order risk preferences, the value function and the probability weighting work in opposite directions, as first pointed out by Deck and Schlesinger (2010).[30]

Consider first prudence. The structure of the value function makes it clear that a zero-mean risk would be preferred in the domain of loses, since the value function is convex (risk loving) there. In this regard, CPT would seem to indicate that individuals are intemperate. In Figure 2, using $W-\frac{1}{2}k$ as the reference point, Option A would be preferred. But now consider the probability weighting function. The additional weight in the upper tail means that an objectively zero-mean gamble within the domain of gains would be "re-weighted" to seem like a favorable gamble. Likewise, the thicker lower tail would imply that this same objectively zero-mean gamble in the domain of losses would be "re-weighted" to seem like an unfavorable gamble. Ignoring the value function, for the moment, these two tendencies would imply that an individual should be prudent: the gamble is preferred at the higher wealth (in the domain of gains). Thus, to the extent that we have prudence, the probability weighting effect would be stronger.[31]

[29] Their approach is similar to the one taken by Holt and Laury (2002) in testing for risk aversion.

[30] Deck and Schlesinger (2010) use Tversky and Kahneman (1992) to calibrate their CPT model. To the best of our knowledge, other set-ups, as described in Stott (2006), have not been examined with regards to higher order risk preferences.

[31] Of course, this analysis is sensitive to the choice of a reference point. For example, Maier and Rüger (2011) consider a model with a stochastic "reference point."

Likewise for temperance: the value function would imply that fat tails do not matter much, while the probability distortion would make the tails seem even "fatter." Thus, to the extent that an individual exhibits temperance, it would say that the probability weighting effect was stronger.

But what about those individuals who prefer to combine good with good? To the best of our knowledge, CPT has not really examined risk lovers. Indeed, "loss aversion" is typically built into the value function, so that bets that yield the reference point as the mean are always disliked. We can easily alter this process for someone who likes these bets, mimicking a risk lover. But what about higher orders – at least for orders 3 and 4? If combining good with good is a common trait for some individuals, can we model such behavior using CPT? This remains an aspect of CPT that is hitherto unexplored.

House money effects?

Finally, we consider how our experiments may be viewed by many subjects as simply a game show, whose objective is to take the opportunity to win. This "house money" effect is examined in more detail by Thaler and Johnson (1990). But it is well known that many contestants in games of chance are willing to take on more risk if they are "playing" with someone else's money.[32] As a result, observed risk-loving behavior in experiments is often attributed to this house money effect. But is there also a house-money effect for higher orders?

If we look at the tasks of all orders greater than two, it is easy to notice that the choice that combines good with good (Option A for even order tasks and Option B for odd order tasks) is always the choice with highest maximum payoff. For risk aversion: more risk in our Option A binary lotteries implies a higher maximum payoff. For prudence, the higher right skew in our Option B lotteries implies a higher maximum payoff. For temperance, the fatter tails in our Option A lotteries implies a maximum payoff. And this pattern continues for the 5th and 6th orders as well. Thus, a house money effect might really be seeking the maximum payoff, as opposed to simple risk loving.

Maier and Rüger (2012) use stronger criteria for their classifications. To be classified as risk averse [or prudent or temperate], a subject must choose at least 18 out of 28 tasks that coincide with such behavior. For risk loving [or imprudent or intemperate] classification, no more than 10 out of 28 tasks may be made that coincide with this behavior. As such, the correlations between behaviors that they present (all positive correlations) are hard to interpret. But as we mentioned previously, they run linear regressions between pairs of behaviors, based on the percentage of times each subject behaviors in accordance with a particular order risk preference. Their regressions show quite clearly that the strongest positive relationship is between risk aversion and prudence, which supports Crainich et al. (2012).

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[32] See, for example, Post et al. (2008) and the references contained therein.

Maier and Rüger (2012) also use an interesting two-date experiment, where the subjects all earned some money on date 1. Three weeks later, these same subjects were presented with choices where they could lose money for the day. Although the net over the two dates was always positive, the idea was that the two dates were separated enough in time, so that subjects viewed "real losses" as being entirely possible at date 2. Their stated purpose was to consider "the domain of losses" from prospect theory.[33] However, this two-date methodology would seem to promote behavior on date 2 that is not derived from playing with house money.

Unfortunately, Maier and Rüger (2012) do not record any higher order risk attitudes at date 1. Thus, we cannot see if this "combine good with good" type of behavior is less common at date 2 than it was a date 1. Still, it seems that "combining good with good" is not just some type of house money effect, as it does persist in their two-date setting.

CONCLUDING REMARKS

In this paper we generalized Eeckhoudt et al (2009) and Crainich et al. (2012) 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 basically prefer to combine "good with bad" and thus dislike an increase in risk for every degree *n*
> -- Risk lovers basically prefer to combine "good with good" and thus like risk increases of even degrees, but dislike risk 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 previously examined.

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 most studies to date, both experimental and otherwise, do not pay much attention to risk-loving behavior, other than perhaps to simply note it. Risk-loving behavior has not been extensively studied, except perhaps to determine whether or not particular settings or contexts lead to such behavior. Fairly often, risk lovers are simply viewed as outliers, who can be safely ignored. For instance, prior experiments test for higher order attitudes independent of risk aversion, except perhaps to note any correlations.

[33] Of course, whether the subjects who start with zero on date 2 view "zero" as their reference point is not tested. Perhaps the reference point is the expected payoff. But in any case, it would seem that the house-money effect should be negated on date 2.

Our evidence in this paper 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 this type of dichotomous behavior, and indeed we can. So perhaps just ignoring this type of risk-loving behavior as somehow being erratic is not warranted.

Both expected utility theory and non-expected utility theory have been modeled around the prototypical risk-averse decision maker; with perhaps some attention given to 3rd and 4th order attitudes (prudence and temperance). In addition to theories mentioned in the previous section of this paper, extensions to other types of 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. And a recent paper by Baillon (2012) shows how one can extend the concept of risk apportionment to models of ambiguity.

Of course risk loving behavior can be described in all of the various theories, but none seems to go beyond the superficial in terms of a deeper understanding of such preferences. What is a counterpart to, say, decreasing absolute risk aversion for risk lovers? Or, what can be said about individuals who favor ambiguity, as opposed to being ambiguity averse? To what extent might higher-order behavior be consistent with basic 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 attitudes[34], 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.

Of course, all of the above arguments are based on a stochastic type of categorization of individuals as being "risk averse" or being "risk loving." And, if individuals are always risk loving (or even risk neutral) for every conceivable task, regardless of the context, we can run into anomalies like the famous St. Petersburg paradox. Still, the analysis of choice decisions under risk typically limits the context for the decision being studied. Although Ebert (2012) is correct in stating that risk lovers need not be mixed risk lovers, our experimental evidence shows that they typically are indeed mixed risk lovers. In this regard, confining most economic analyses to a universe of (mixed) risk averters might be obstructing our view of the forest.

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

References

Arrow, K.J., 1965. Yrjo Jahnsson Lecture Notes, Helsinki: Yrjo Jahnsson Foundation. Reprinted in: Arrow, K.J., (1971), *Essays in the Theory of Risk Bearing*, Chicago: Markum Publishing Company.

Baillon, A., 2012. "Prudence (and More) with Respect to Uncertainty and Ambiguity." Erasmus University Working Paper.

Bostian, A.J. and C. Heinzel, 2012. "Prudential Saving: Evidence from a Laboratory Experiment." University of Virgina Working Paper. http://aj.bostian.us.com/pdf/bostian_heinzel_2011.pdf

Caballé , J. and A. Pomansky, 1995. "Mixed risk aversion." *Journal of Economic Theory* 71, 485–513.

Crainich, D., L. Eeckhoudt and A. Trannoy, 2012. "Even (Mixed) Risk Lovers are Prudent." *American Economic Review*, forthcoming.

Deck, C., J. Lee, J. Reyes, J., and C. Rosen, 2012. "Measuring Risk Aversion on Multiple Tasks: Can Domain Specific Risk Attitudes Explain Apparently Inconsistent Behavior." University of Arkansas Working Paper.

Deck, C. and H. Schlesinger, 2010. "Exploring Higher-Order Risk Effects" *Review of Economic Studies* 77, 1403-1420.

Dréze, J. and F. Modigliani, 1972. "Consumption Decisions under Uncertainty." *Journal of Economic Theory* 5, 308-335.

Ebert, S., 2012. "Even (Mixed) Risk Lovers are Prudent: Comment." University of Bonn Working Paper.

Ebert, S., and D. Wiesen, 2011. "Testing for Prudence and Skewness Seeking." *Management Science* 57, 1334-1349.

Ebert, S., and D. Wiesen 2012. "Joint Measurement of Risk Aversion, Prudence, and Temperance: A Case for Prospect Theory." University of Bonn Working Paper. http://ssrn.com/abstract=1975245

Eeckhoudt, L., C. Gollier and H. Schlesinger, 1996. "Changes in Background Risk and Risk-Taking Behavior." *Econometrica* 64, 683-90.

Eeckhoudt, L. and H. Schlesinger, 2006. "Putting Risk in its Proper Place." *American Economic Review* 96, 280-89

Eeckhoudt, L. and H. Schlesinger, 2008. "Changes in Risk and the Demand for Saving." *Journal of Monetary Economics* 55, 1329-336.

Eeckhoudt, L. and H. Schlesinger, 2009. "On the Utility Premium of Friedman and Savage." *Economics Letters* 105, 46-48.

Eeckhoudt, L., H. Schlesinger and I. Tsetlin, 2009. "Apportioning of Risks via Stochastic Dominance." *Journal of Economic Theory* 144, 994-1003.

Ekern, S., 1980. "Increasing N^{th} Degree Risk." *Economics Letters* 6, 1980, 329-33.

Friedman, M. and L. Savage, 1948. "The Utility Analysis of Choices Involving Risk." *Journal of Political Economy* 56, 279-304.

Gollier, C. and J. Pratt, 1996. "Risk Vulnerability and the Tempering Effect of Background Risk." *Econometrica* 64, 1109-1124.

Gollier, C., 2001. *The Economics of Risk and Time*. Cambridge: MIT Press.

Hanson, D.L. and C.F. Menezes, 1971. "On a Neglected Aspect of the Theory of Risk Aversion." *Western Economic Journal* 9, 211-217.

Harrison, G.W. and J.T. Swarthout, 2012. "The Independence Axiom and the Bipolar Behavioralist." Georgia State University Working Paper http://excen.gsu.edu/workingpapers/GSU_EXCEN_WP_2012-01.pdf

Harrison, G.W., J. Martínez-Correa and J.T. Swarthout, 2012. "Reduction of Compound Lotteries with Objective Probabilities: Theory and Evidence." Georgia State University Working Paper http://excen.gsu.edu/workingpapers/GSU_EXCEN_WP_2012-04.pdf

Holt, C. and S. Laury, 2002. "Risk Aversion and Incentive Effects." *American Economic Review* 92, 1644-655

Kimball, M.S.¸ 1990. "Precautionary Savings in the Small and in the Large." *Econometrica* 58, 53-73.

Kimball, M.S., 1992. "Precautionary Motives for Holding Assets." in *The New Palgrave Dictionary of Money and Finance*. P. Newman, M. Milgate, and J. Falwell, eds. London: MacMillan.

Kimball, M.S., 1993. "Standard Risk Aversion," *Econometrica*, 61, 589-611.

Kimball, M.S. and P. Weil, 2009. "Precautionary Saving and Consumption Smoothing across Time and Possibilities." *Journal of Money, Credit and Banking* 41, 245–284.

Kreps, D.M. and E. Porteus, 1978. "Temporal Resolution of Uncertainty and Dynamic Choice Theory." *Econometrica* 46, 185–200.

Laury, S., 2005 "One or Pay All: Random Selection of One Choice for Payment" Georgia State University Working Paper http://ssrn.com/abstract=894271

Lajeri-Chaherli, F., 2004. "Proper Prudence, Standard Prudence and Precautionary Vulnerability." *Economics Letters* 82, 29-34.

Leland, H.E., 1968. "Saving and Uncertainty: The Precautionary Demand for Saving." *Quarterly Journal of Economics* 82, 465-73.

Maier, J. and M. Rüger, 2011 . "Reference-Dependent Risk Preferences of Higher Orders" University of Munich Working Paper.

Maier, J. and M. Rüger, 2012 "Experimental Evidence on Higher-Order Risk Preferences with Real Monetary Losses." University of Munich Working Paper.

Menezes, C.F., C. Geiss and J. Tressler, 1980. "Increasing Downside Risk." *American Economic Review* 70, 921-32.

Menezes, C.F. and X.H. Wang, 2005. "Increasing Outer Risk." *Journal of Mathematical Economics* 41, 875-866.

Noussair, C.N., S.T. Trautmann, G. vd Kuilen, 2012. "Higher Order Risk Attitudes, Demographics, and Saving." CentER at Tilburg University Working Paper. http://ssrn.com/abstract=2023584

Post, T., M.J. vd Assem, G. Baltussen and R.H. Thaler, 2008. "Deal or No Deal? Decision Making under Risk in a Large-Payoff Game Show." *American Economic Review* 98, 38-71.

Pratt, J.W., 1964. "Risk Aversion in the Small and in the Large," *Econometrica* 32, 122-136.

Pratt, J.W. and Zeckhauser, R., 1987. "Proper Risk Aversion." *Econometrica*, 55, 1987, 143-154.

Rothschild, M. and J.E. Stiglitz, 1970. "Increasing Risk: I. A Definition." *Journal of Economic Theory* 2, 225-43.

Sandmo, A., 1970. "The Effect of Uncertainty on Saving Decisions." *Review of Economic Studies* 37, 353-60.

Starmer, C. and R. Sugden, 1991. "Does the Random-Lottery Incentive System Elicit True Preferences? An Experimental Investigation," *American Economic Review* 81, 971-978.

Stott, H.P., 2006. "Cumulative Prospect Theory's Functional Menagerie." *Journal of Risk and Uncertainty* 32: 101-30.

Tarazona-Gomez, M., 2004, "Are Individuals Prudent? An Experimental Approach using Lotteries," University of Toulouse Working Paper http://www2.toulouse.inra.fr/lerna/cahiers2005/05.13.177.pdf

Thaler, R.H. and E.J Johnson, 1990. "Gambling with the House Money and Trying to Break Even: The Effects of Prior Outcomes on Risky Choices," *Management Science* 36, 643-60

Tversky, A. and D. Kahneman, 1992. "Advances in Prospect Theory: Cumulative Representation of Uncertainty," *Journal of Risk and Uncertainty* 5, 297-324.

Wilcox, N.T., 2008. "Stochastic Models for Binary Discrete Choice Under Risk: A Critical Stochastic Modeling Primer and Econometric Comparison", in J.C. Cox, and G.W. Harrison, eds., *Risk Aversion in Experiments*: *Research in Experimental Economics Volume. 12*, Bingley (UK): Emerald, 197-292.

APPENDIX: 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.

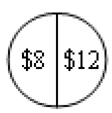
Page 1 of the Directions:

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, <u>one</u> of the thirty-eight tasks will be randomly selected to determine your payoff.

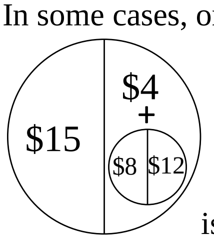
Page 3 of the Directions:

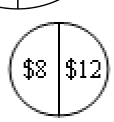
Each option will involve amounts of money and possibly one or more 50-50 lotteries represented as a circle with a line through the middle. A 50-50 lottery means there is a 50% chance of receiving the item to left of the line and a 50% chance of receiving the item to the right of the line. For example, 

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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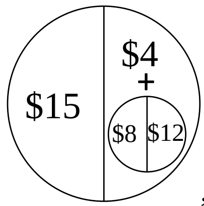
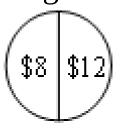
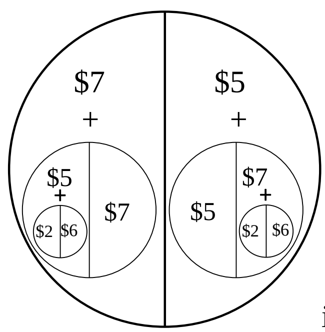
Page 5 of the Directions:

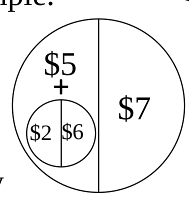
Continuing with the example, 

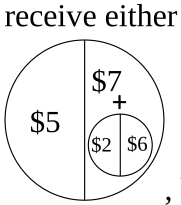
, there is a 50% chance that you would receive $15 in the big 50-50 lottery and that would be it. There is also a 50% chance that you would receive $4 + 

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:

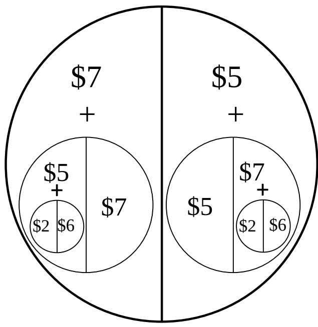
Let's look at a more complicated example. 

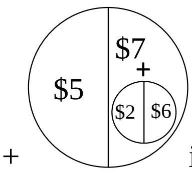
is 50-50 lottery where you receive either $7 plus the 50-50 lottery 

or you receive $5 plus the 50-50 lottery 

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

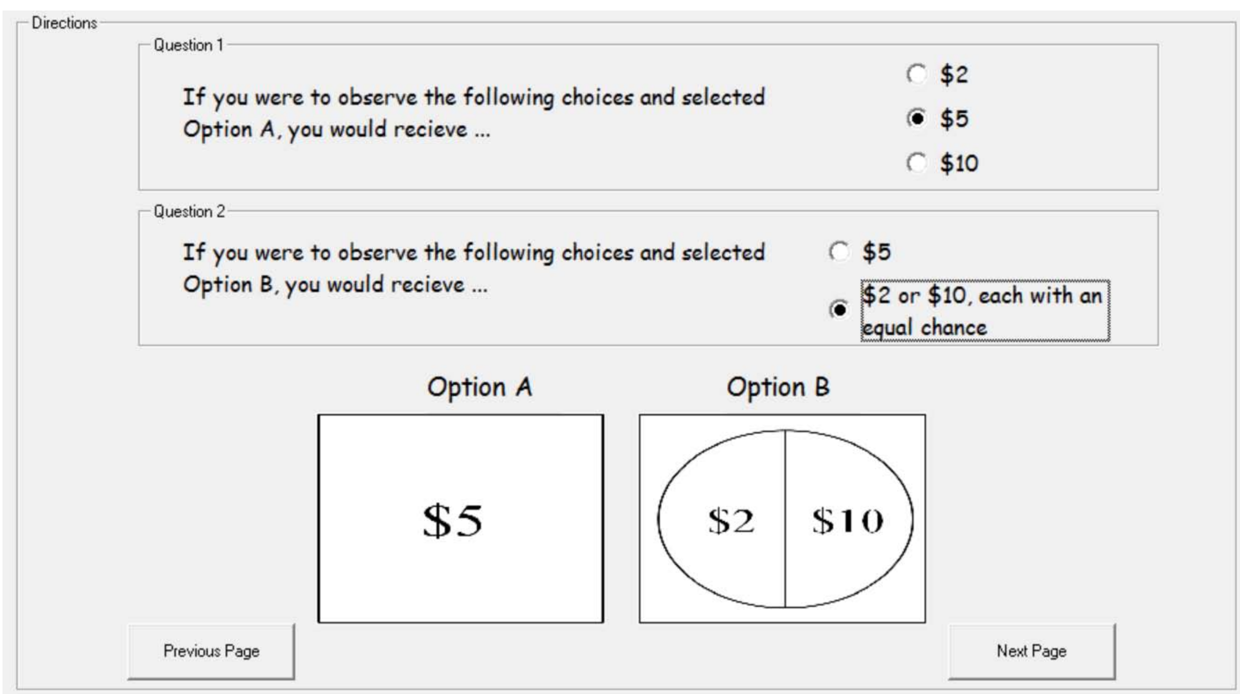
Page 7 of the Directions:

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):