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# Further Reflections on Prospect Theory

Susan K. Laury and Charles A. Holt\*

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## Abstract

This paper reports a new experimental test of prospect theory's reflection effect. We conduct a sequence of experiments that allow us to directly compare choices under reflected gains and losses where real and hypothetical payoffs range from several dollars to over \$100. Lotteries with positive payoffs are transformed into lotteries over losses by reflecting all payoffs around zero. When we use hypothetical payments, more than half of the subjects who are risk averse for gains turn out to be risk seeking for losses. This "reflection effect" is diminished considerably with cash payoffs, where the modal choice pattern is to exhibit risk aversion for both gains and losses. However, we do observe a significant difference in risk attitudes between losses (where most subjects are approximately risk neutral) and gains (where most subjects are risk averse). Reflection rates are further reduced when payoffs are scaled up by a factor of 15 (for both real and hypothetical payoffs).

Keywords: lottery choice, reflection effect, prospect theory, risk aversion, incentive effects, hypothetical payoffs.

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## 1. Introduction

One of the most widely cited articles in economics is Kahneman and Tversky's (1979) paper on prospect theory, which is designed to explain a range of lottery-choice anomalies. This theory is motivated by the authors' laboratory experiments and by subsequent field observations (e.g., Camerer, 2001). A key observation is that decision making begins by identifying a reference point, often the current wealth position, from which people tend to be risk averse for gains and risk loving for losses. A striking prediction of the theory is the "reflection effect": a replacement of all positive payoffs by their negatives (reflection around zero) reverses the choice pattern. For example, a choice between a sure payoff of 3,000 and an 80 percent chance of getting 4,000 would be replaced by a choice between a certain *loss* of 3,000 and an 80 percent chance of losing 4,000. The typical reflection effect would imply a risk-averse preference for the sure safe 3,000 gain, but a reversed preference for the risky lottery in the loss domain. Reflected choice patterns reported by Kahneman and Tversky (1979) were quite high; for example, 80 percent of subjects chose the sure gain of 3,000, but only 8 percent chose the sure outcome when all payoffs were transformed into losses. The intuition is that "... certainty increases the aversiveness of losses as well as the desirability of gains." (Kahneman and Tversky, 1979, p. 269). The mathematical value functions used in prospect theory (concave for gains, convex for losses) can explain such a reflection effect, even when the safer prospect is not certain. This paper reports new experimental tests of these predictions by comparing choices under reflected gains and losses, using lotteries with real payoffs that range from several dollars to over \$100.

Despite the widespread references to prospect theory in theoretical and experimental work, the direct tests reported in Kahneman and Tversky (1979) and Tversky and Kahneman (1992) are based on hypothetical payoffs, set to be about equal to median monthly income in Israeli pounds at the time. They acknowledged that using real payoffs might change some behavioral patterns. However, their interest was in economic phenomena with larger stakes than those typically used in the lab; therefore they believed using high hypothetical payoffs was the preferred method of eliciting choices. In doing so, they relied on the "assumption that people

often know how they would behave in actual situations of choice, and on the further assumption that subjects have no special reason to disguise their true preferences” (Kahneman and Tversky, 1979). In Tversky and Kahneman (1992) they state that they found little difference in behavior between subjects who faced real and hypothetical payoffs.

While the use of hypothetical payoffs may not affect behavior much when low amounts of money are involved, this may not be the case with very high payoffs of the type used by Kahneman and Tversky to document the reflection effect. For example, Holt and Laury (2002) report that switching from hypothetical to real money payoffs has no significant effect in a series of lottery choices when the scale of payoffs is in the range of several dollars per decision problem, as is typical in economics experiments. In addition, there is no significant effect on choices when *hypothetical* payoffs are scaled up by factors of 20, 50, and 90, yielding (hypothetical) payoffs of several hundred dollars in the highest payoff conditions. This might lead researchers to conclude that increasing the scale of payoffs, or using hypothetical incentives, does not affect behavioral patterns. However, risk aversion increases sharply when *real* payoffs in these lotteries are increased in an identical manner. A similar increase in risk aversion as real payments are scaled up was reported by Binswanger (1980). These results are not surprising to the extent that risk aversion may be influenced by emotional considerations that psychologists call “affect” (Arkes, Herren, and Isen, 1988; Slovic, 2001), since emotional responses are likely to be stronger when gains and losses must be faced in reality. In addition, the idea that one might respond to losses and gains differently is supported by Gehring and Willoughby (2002) who measure brain activity (event-related brain potentials) milliseconds after a subject makes a choice that results in a gain or loss. They find that this brain activity is greater in amplitude after a (real) loss is experienced than when a gain is experienced. In view of economists’ skepticism about hypothetical incentives and of psychologists’ notions of affect, we decided to reevaluate the reflection effect using actual monetary gains and losses.<sup>1</sup>

Risk seeking over losses has been observed in experiments with financial incentives that implement insurance markets. For example, Myagkov and Plott (1997) use market price and quantity data to infer that a majority of subjects are risk-seeking in the loss domain in early

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<sup>1</sup> For a survey of the effects of using money payoffs in economics experiments, see Smith and Walker (1993), Hertwig and Ortmann (2000), Laury and Holt (2002), and Camerer and Hogarth (1999).

periods of trading, but this tendency tends to diminish with experience. In contrast, Bosch-Domenech and Silvestre (1999) report a very strong tendency for subjects to purchase actuarially fair insurance over relatively large losses. This observation may indicate risk aversion in the loss domain; alternatively, it may be attributed to over-weighting the low (0.2) probability of a loss (as suggested by the probability weighting function typically assumed in prospect theory). Laury and McInnes (2003) also find that almost all subjects choose to purchase fair insurance against low probability losses. The percentage insuring decreases as the probability of incurring a loss increases, but about two-thirds purchase insurance when the probability of a loss is close to one-half and systematic probability misperceptions cannot be a factor.

None of these studies were primarily focused on the reflection effect, and therefore, none of them had parallel gain/loss treatments. Taken together, these market experiments provide no strong evidence either for or against such an effect, although there is some evidence in each direction. Some lottery choice experiments have directly tested the reflection effect. Hershey and Schoemaker (1980) find evidence of reflection using hypothetical choices; in their study the highest rates of reflection were observed when probabilities were extreme. Both Battalio et al. (1990) and Camerer (1989) report lottery choice experiments in which reflection patterns are present with real payoffs. These both involve choices where one gamble is a mean-preserving spread of the other, which is typically a certain amount of money. However, the amount of reflection (about 50 percent) is less than that reported by Kahneman and Tversky for most of their gambles. Harbaugh, Krause, and Vesterlund (2002) find that support for reflection depends on how the choice problem is presented. Specifically, they report that risk attitudes are consistent with prospect theory when subjects are asked to price gambles, but not when they choose between the gamble and its expected value.

Market and insurance purchase experiments are useful in that they provide a rich, economically relevant context. Our approach is complementary; we use a simple tool to measure risk preferences directly, based on a series of lottery choices with significant money payoffs in parallel gain and loss treatments. This menu of choices allows us to obtain a well calibrated measure of risk attitudes, which is not possible given the single pair-wise choices used in earlier

studies. Our design, procedures, results (for low then high payoff conditions), and conclusions are presented in sections 2 through 6, respectively.

## 2. Lottery Choice Design and Prospect Theory’s Predictions

The lottery choice task for the loss domain is shown in Table 1, as a menu of ten decisions between lotteries that we will denote by  $S$  and  $R$ . These will be referred to as Decisions 1 through 10 (from top to bottom). In Decision 1 at the top of the table, the choice is between a loss of \$3.20 for  $S$  and a loss of 20 cents for  $R$ , so subjects should start out choosing  $R$  at the top of the table, and then switch to  $S$  as the probability of the worse outcome (-\$4.00 for  $S$  or -\$7.70 for  $R$ ) gets high enough. The optimal choice for a risk-neutral person is to choose  $R$  for the first five decisions, then switch to  $S$ , as indicated by the sign change in the expected payoff differences shown in the right column of the table. In fact, the payoff numbers were selected so that the risk neutral choice pattern (five risky followed by five safe choices) was optimal for constant absolute risk aversion in the range (-0.05, 0.05), which is symmetric around zero.

**Table 1. Lottery Choices in the Loss Domain**

Lottery $S$	Lottery $R$	Expected Payoff of $S$ – Expected Payoff of $R$
0/10 of -\$4.00, 10/10 of -\$3.20	0/10 of -\$7.70, 10/10 of -\$0.20	-\$3.00
1/10 of -\$4.00, 9/10 of -\$3.20	1/10 of -\$7.70, 9/10 of -\$0.20	-\$2.33
2/10 of -\$4.00, 8/10 of -\$3.20	2/10 of -\$7.70, 8/10 of -\$0.20	-\$1.66
3/10 of -\$4.00, 7/10 of -\$3.20	3/10 of -\$7.70, 7/10 of -\$0.20	-\$0.99
4/10 of -\$4.00, 6/10 of -\$3.20	4/10 of -\$7.70, 6/10 of -\$0.20	-\$0.32
5/10 of -\$4.00, 5/10 of -\$3.20	5/10 of -\$7.70, 5/10 of -\$0.20	\$0.35
6/10 of -\$4.00, 4/10 of -\$3.20	6/10 of -\$7.70, 4/10 of -\$0.20	\$1.02
7/10 of -\$4.00, 3/10 of -\$3.20	7/10 of -\$7.70, 3/10 of -\$0.20	\$1.69
8/10 of -\$4.00, 2/10 of -\$3.20	8/10 of -\$7.70, 2/10 of -\$0.20	\$2.36
9/10 of -\$4.00, 1/10 of -\$3.20	9/10 of -\$7.70, 1/10 of -\$0.20	\$3.03

Since the two payoffs for the  $S$  lottery are of roughly the same magnitude, this lottery is relatively “safe” (that is, the variance of outcomes is low relative to the  $R$  lottery). Therefore, increases in risk aversion will tend to cause one to switch to the  $S$  side before Decision 6. For example, with absolute risk aversion of 0.1 ( $\pm 0.05$ ) and the payoffs shown in Table 1, it is a matter of straightforward calculation to show that the expected-utility maximizing choice is to choose  $R$  in the first four decisions, and then switch to  $S$ . Conversely, risk loving preferences

will cause a person to wait longer before switching to  $S$ , for example to choose  $R$  in the first six decisions for an absolute risk aversion coefficient of  $-0.1 (\pm 0.05)$ .<sup>2</sup>

The gain treatment was obtained from Table 1 by replacing each loss with the corresponding gain, so that Decision 1 involves a choice between certain earnings of \$3.20 for  $S$  and a certain gain of \$0.20 for  $R$ . This reverses the signs of the expected payoff differences shown in the final column of Table 1, so a risk neutral person will choose  $S$  for the first five decisions before switching to Lottery  $R$ . A risk averse person will wait longer to switch, therefore choosing more than five safe choices.

To summarize, risk neutrality implies five safe choices in each treatment, risk aversion implies more than five safe choices in either treatment, and the reflection effect (risk aversion over gains and risk preference in the loss domain) would show up as more than five safe choices in the gain treatment and fewer than five safe choices in the loss treatment. It is useful to distinguish the notion of a reflection effect of this type, which is an empirical pattern, from the predictions of a formal version of prospect theory, the derivation of which will require a slight digression.

### *Prospect Theory*

We begin by reviewing the essential components of prospect theory. A prospect consists of a set of money prizes,  $x_i$ , with associated probabilities,  $p_i$ . In its simplest form, prospect theory specifies an expected valuation expression:  $\sum_i w(p_i)u(x_i)$ , where  $u(x_i)$  is concave over gains (positive  $x_i$ ) and convex over losses, and  $w(p_i)$  is a nonlinear weighting function of the probabilities. It is typically asserted that small probabilities are over-weighted:  $w(p_i) > p_i$ , and that the reverse holds for large probabilities.

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<sup>2</sup> These calculations are meant to be illustrative; we do not mean to imply that absolute risk aversion will be constant over a wide range of payoffs. The lottery choice experiments in Holt and Laury (2002) involve scaling up payoffs by factors of 20, 50, and 90, and we find evidence of decreasing absolute risk aversion when utility is expressed as a function of income, not wealth. This result is not surprising since it is well known that the absolute risk aversion needed to explain choices between low stakes gambles implies absurd amounts of risk aversion over high stakes (Rabin, 2000). Rabin's theorem pertains to a standard utility of final wealth function, but similar considerations apply when utility is a function of only gains and losses around a reference point (utility of income). To see this, consider the utility function  $u(x) = -\exp(-rx)$ , which exhibits a constant absolute risk aversion of  $r$ . Notice that scaling up all money prizes by a factor of, say, 100, yields utilities of  $-\exp(-100rx)$ , so this is equivalent to leaving the stakes the same and increasing risk aversion by a factor of 100, which yields an absurd amount of risk aversion.

Tversky and Kahneman (1992) use nonlinear regression to estimate parameters for the functions:  $u(x) = (x)^\alpha$  for  $x > 0$  and  $u(x) = -\lambda(-x)^\beta$  for  $x < 0$ , where  $\lambda$  is a “loss aversion” parameter, which is greater than one to accentuate the negative aspect of losses. They report identical estimates of 0.88 for  $\alpha$  and  $\beta$ , which makes the utility function concave for gains and convex for losses. With  $\alpha = \beta$ , the utility for losses is just the (negative) reflection of the utility for gains, scaled down by  $\lambda$ . In particular, this estimated utility function exhibits reflection in the sense that:

$$u(-x) = -\lambda u(x), \quad \text{for } x > 0. \quad (1)$$

Next, we will show that this reflection property of utility implies reflection of lottery choices when gains are transformed into losses of equal absolute value. The safe option is preferred in the gain domain if  $w(p)u(4.00) + w(1-p)u(3.20) > w(p)u(7.70) + w(1-p)u(0.20)$ , or equivalently:

$$\text{Option } S \text{ preferred if } \frac{w(p)}{w(1-p)} < \frac{u(3.20) - u(0.20)}{u(7.70) - u(4.00)} \quad (2)$$

Similarly, in the loss domain it is straightforward to show that:

$$\text{Option } S \text{ preferred if } \frac{w(p)}{w(1-p)} > \frac{u(-0.20) - u(-3.20)}{u(-4.00) - u(-7.70)} \quad (3)$$

But it follows from (1) that the right side of (3) is the same as the right side of (2), since the  $\lambda$  expressions in the numerator and denominator cancel. The reversal of inequalities in (2) and (3) means that if Lottery  $S$  is preferred in the gain domain for any particular value of  $p$ , the Lottery  $R$  will be preferred in the loss domain for that probability. Thus an exact reflection in the value function (equation 1) results in an exact reflection in lottery choices. Such a reflection occurs when, for example,  $\alpha = \beta = 0.88$ , as noted above. Although exact reflection (for example, seven safe choices in the gain domain and seven risky choices in the loss domain) can be predicted under these strong parametric conditions, such behavior is not pervasive in our data. Following Kahneman and Tversky, we will focus on the qualitative predictions: whether there is risk aversion in the gain domain, and if so, whether this aversion becomes a preference in the loss

domain. As noted above, the observation of more than five safe choices in either treatment implies risk aversion, and fewer than five safe choices implies risk preference.<sup>3</sup>

### 3. Procedures

All experiments were conducted at Georgia State University; participants responded to classroom and campus announcements about an opportunity to earn money in an economics research experiment. We recruited a total of 253 subjects in 25 groups, ranging in size from 4 to 16. No subject participated in more than one session. Subjects were separated by privacy dividers and were instructed not to communicate with each other after we began reading the instructions. Losses typically cannot be deducted from participants' out-of-pocket cash reserves, so it was necessary to provide an initial cash balance. For example, Myagkov and Plott (1997) began by giving each participant a cash balance of \$60. We chose to have subjects earn their initial balance; therefore all first participated in another decision-making task. We hoped that by doing so they would not view these earnings as windfall gains.<sup>4</sup> Therefore, we appended the lottery choices for losses and gains to the end of research experiments being used for other projects.<sup>5</sup>

Instructions (contained in Appendix A) and the choice tasks were identical between the real and hypothetical sessions. At the beginning of the hypothetical-payment sessions, subjects were given a handout (contained in Appendix A) that informed them that all earnings were hypothetical. The instructions read, in part, "The instructions ... describe how your earnings depend on your decisions (and sometimes on the decisions of others). It is important that you understand that you will not actually be receiving any of this additional money (other than your

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<sup>3</sup> To clarify these qualitative predictions, consider the Arrow-Pratt coefficient of risk aversion,  $r(x) = -u''(x)/u'(x)$ , and suppose that  $r(x)$  is higher for one utility function than for another on some interval of payoffs, with strict inequality holding for at least one point. Then it is a direct implication of parts (a) and (e) of Pratt's (1964) theorem 1 that the right side of (2) is higher for the more risk averse utility function. Since the left side is increasing in  $p$ , this increases the range of probabilities for which the safe option is preferred. Conversely, Pratt's Theorem 1 implies that the right side of (3) is lower for the more risk averse utility function, which again raises the interval of probabilities over which the safe option is preferred.

<sup>4</sup> If time permits, we prefer this approach because, as Camerer (1989) notes, losses from such a windfall stake obtained without any effort may be coded as gains.

<sup>5</sup> This initial phase involved a sequential search task in about half of the sessions, and a public goods experiment in the other half.

\$45 participation fee).” All subjects signed a statement indicating that they understood this. All sessions (real and hypothetical) began with a simple lottery choice to acquaint them with the procedures and the ten-sided die that was used to determine the random outcomes. The payoffs in this initial lottery choice task differed from those used later.

After finishing these initial tasks, subjects knew their earnings up to that point. In the real payment sessions, these initial earnings averaged \$43, and ranged from \$21.68 to \$92.08. As noted above, subjects in hypothetical sessions received a \$45 participation fee. The experiments reported here consisted of four choice tasks. The first and third of these were the lottery-choice menus shown in Table 1, with alternation in the order of the gain and loss treatments in each pair of sessions to ensure that approximately the same number of subjects encountered each order. These lottery-choice tasks were separated by an intentionally neutral decision, a symmetric matching pennies game with (real or hypothetical) payoffs of \$3.00 for the “winner” or \$2.00 for the “loser” in each cell.<sup>6</sup> In the lottery choice parts, all ten choices were presented as in Table 1, but with the lotteries labeled as Option A and Option B, and without the expected payoff calculations that might bias subjects toward risk neutral decisions. Option A was always listed on the left side of the decision sheet. For about half of these subjects, Option A was the safe lottery and it was the risky lottery for the remaining subjects. Table 2 shows the number of subjects in each treatment and presentation order.

**Table 2. Number of Subjects by Treatment and Order**

Payoff Treatment	Initial Earnings	Option A “Safe”		Option A “Risky”	
		Gains First	Losses First	Gains First	Losses First
Low Hypothetical	\$45	19	19	23	20
Low Real	\$43	19	19	22	16
High Hypothetical	\$45	0	16	0	16
High Hypothetical <sup>a</sup>	\$132	0	16	0	16
High Real	\$140	0	16	0	16

<sup>a</sup> Decisions in this hypothetical-payoff experiment followed another experiment that used very high real earnings.

Probabilities were presented in terms of the outcome of a throw of a 10-sided die, e.g. “\$3.20 if the throw is 1 or 2, ...” The instructions also specified that payoffs would be

<sup>6</sup> The instructions for the one-shot matching pennies game with random matching are contained in the appendix to Goeree and Holt (2000). The data from these games are not interesting and will not be used.

determined by one decision selected *ex post* (again with the throw of a 10-sided die).<sup>7</sup> We collected decisions for all four parts (the gain and loss menus and the two matching pennies games) before determining earnings for any of them. While this does not exactly hold (anticipated) wealth effects constant, it does control for emotional responses to good or bad outcomes in each part. Moreover, wealth effects do not matter in prospect theory, since the utility valuations are based on gains and losses from the current wealth position.

#### 4. Results

Recall that each choice task involved 10 paired choices, and that a risk neutral person would choose the safe lottery five times before switching to the lottery with a wider range of payoffs. Some people are risk neutral in this sense, particularly when payoffs involve losses or are hypothetical. Figure 1 shows cumulative choice frequencies for the number of safe choices for hypothetical payoffs (top) and real payoffs (bottom). In each panel, the thin line shows the risk neutral prediction, for which the cumulative probability of four or fewer safe choices is zero, and the cumulative probability goes to one at five safe choices. The actual cumulative distributions for the gain treatment are below those of the loss treatment, indicating the tendency to make more safe choices in the gain domain, regardless of whether payoffs are real or hypothetical. In general, people are risk averse in the gain domain and approximately risk neutral in the loss domain. Because each subject made choices in both the gain and the loss treatments, we use a matched-pairs Wilcoxon test (one-tailed) and find that choices are significantly different between the gain and loss treatments, both for real and hypothetical payoffs. We do not observe any significant effect from the order in which the loss and gain treatments were done. This can be seen by comparing the top two rows of Table 3.<sup>8</sup>

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<sup>7</sup> Similarly, Myagkov and Plott (1997) told subjects that cash earnings would be based on the outcome of one market period, selected at random *ex post*. Laury (2002) finds no significant difference in behavior between lottery choice treatments where subjects are paid for one of 10 decisions, or paid for all 10 decisions.

<sup>8</sup> In the hypothetical treatment, the presentation of the *S/R* lotteries has some effect on behavior. However, as shown in Table 2, observations are about equally divided between these orders. Moreover, Kahneman and Tversky (1979, 1992) alternated their presentation of lotteries in a similar manner and did not separate their data by presentation order. For consistency, we do not do so either.

**Table 3. Mean Number of Safe Choices by Treatment**

Key: 1x (low payoff treatment); 15x (high payoff treatment); Loss-Gain (losses presented first, then gains)

Treatment	Real Payoffs		Hypothetical Payoffs	
	Gains	Losses	Gains	Losses
1x, All Data	5.91	5.21	5.53	4.98
1x, Loss-Gain	5.71	5.26	5.62	5.13
15x, Loss-Gain	6.31	5.22	5.69	5.13
15x, Loss-Gain <sup>a</sup>	--	--	4.91	5.31

<sup>a</sup> Decisions in this hypothetical-payoff experiment followed an experiment that used very high real earnings.

Next, we discuss the relationship between *individual* choices in the gain and loss treatments. The top panel of Figure 2 summarizes the choice data for the low-payoff hypothetical choice sessions. We use the number of safe choices to categorize individuals as being risk averse, risk neutral, or risk seeking, both in the loss domain (left to right) and the gain domain (back to front). The “spike” at the back-right corner of the graph represents those who exhibit the predicted reflection effect: risk seeking for losses and risk aversion for gains. Fifty percent of the subjects are risk averse over gains (back row of the figure); of these, just over half are risk-loving for losses. Of those subjects who do reflect, 40 percent involve *exact* reflection; that is, the number of safe choices in the gain domain exactly matches the number of risky choices in the loss domain. The modal choice pattern under hypothetical payoffs is reflection, and in this sense we are able to replicate the predicted choice pattern using our lotteries, neither of which involves a certain prospect.

However, when real cash payments are used, the results are quite different, as shown in the lower panel of Figure 2. The modal outcome (shown in the back left corner) involves risk aversion for both gains and losses. Over gains, there is a little more risk aversion with real payoffs: 60 percent of subjects exhibit risk aversion in the gain condition (back row of Figure 2). Of these only about one-fifth are risk seeking for losses (see the bar in the back right corner). The rate of reflection in the bottom panel with real payoffs (13 percent) is half the rate of reflection observed under hypothetical payoffs (26 percent).

Recall that the predicted choice pattern involves switching between the safe lottery and the risky lottery once, with the switch point determining the inferred risk attitude. In total, there were 44 out of 157 subjects who switched more than once in either the gain or loss treatment (or

both).<sup>9</sup> Since such multiple switching introduces some noise due to confusion or other considerations, it is instructive to look at choice patterns for those who switch only once in either treatment. These data produce a little more risk aversion in the gain domain, but the basic patterns shown in Figure 2 remain unchanged. With real payoffs, for example, 67 percent are risk averse in the gain domain, but less than one-fifth of these subjects exhibit reflection. Using hypothetical payoffs, the modal decision is still reflection; half who are risk averse in the gain domain are risk seeking in the loss domain. Just as when the full dataset is used, we find about twice as much reflection with hypothetical payoffs as with real payoffs (26 percent compared with 12 percent, respectively).

## 5. High Payoffs

Kahneman and Tversky's initial tests of prospect theory used high hypothetical payoffs, and questioned the generality of data derived from small stakes lotteries (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992). One might also suppose that large gains and losses have a higher emotional impact than low-payoff lotteries, so the predicted effects of a psychologically motivated theory like prospect theory might be more apparent with very high payoffs. Given this, we decided to scale up the stakes to levels that had a clear effect on risk attitudes in Holt and Laury (2002). To do this, we ran high payoff treatments (with gains and losses, real and hypothetical) where the payoff numbers shown in Table 1 were multiplied by a factor of 15. This multiplicative scaling of all payoff amounts does not alter the risk-neutral crossover point at five safe choices.

The result of this scaling was that the safe lottery had payoffs of \$60 and \$48 (positive or negative) and the risky lottery had payoffs of \$115.50 and \$3.00. The real-incentive sessions were quite expensive, since pre-lottery-choice earnings had to be built up to high levels in order to make real losses credible. Initial earnings were therefore built up with a high-payoff public goods experiment. The real-payoff sessions were preceded by a high real payoff experiment, and the hypothetical payoff sessions were preceded by a high hypothetical payoff experiment. The initial earnings in the high real payoff sessions averaged about \$140 (and ranged from \$112 to

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<sup>9</sup> For example, in the lotteries over gains, subjects should initially choose the safe lottery and then switch to the risky lottery when the probability of the high-payoff outcome is high enough. Some subjects initially chose the safe lottery, switched to the risky lottery, then switched *back* to the safe lottery before returning to the risky lottery.

\$190). We did not provide a higher initial payoff for the high-hypothetical sessions, since losses were hypothetical.<sup>10</sup> Because of the additional expense associated with these high payoff sessions, we have about half the number of observations as for the low-payoff sessions. Given that we did not observe any systematic effect of the order in which gains and losses were presented to subjects, we chose to use only one treatment order in the high payoff sessions. Therefore in all sessions, the lottery over losses was given first. As before, the lotteries over losses and gains were separated by a matching pennies game, and the results for choices under both treatments were not announced until all decisions had been made. There were 32 subjects who faced high real payoffs and 32 who faced high hypothetical payoffs, and in both cases exactly half of the observations were for the treatment with the risky lottery listed on the left, and half with the risky lottery listed on the right (see Table 2).

In Table 3, rows 2 and 3 (for the 1x and 15x Loss-Gain treatment) allow a comparison of the average number of safe choices, holding the treatment order (losses first) constant. There are no obvious effects of scaling up payoffs, except for an increase in risk aversion in the real gain domain. Figure 3 shows the cumulative choice frequencies of high hypothetical (top) and high real (bottom) payoffs. Notice that the gain and loss lines are closer together for hypothetical payoffs, shown in the top panel. However, a matched-pairs Wilcoxon test (using the difference between an individual's choice in the gain and loss treatment as the unit of observation) rejects the null hypothesis of no difference in favor of the one-tailed alternative that fewer safe choices are made in the loss treatment.

The top panel of Figure 4 summarizes individual data for the 32 subjects in the high-hypothetical payoff sessions. As before, the number of safe choices is used to categorize risk attitudes. Just as we observed for low payoffs, about half of these subjects are risk averse over gains (53 percent), however reflection is no longer the modal outcome. Only about one-third of those who are risk averse for gains turn out to be risk preferring for losses, while the majority of subjects (28 percent in all) are risk averse over gains and losses.

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<sup>10</sup> We chose this treatment order (real preceded by real, and hypothetical preceded by hypothetical) for consistency with the low-payoff experiments reported above. Of course, if differences are observed between our high payoff real and hypothetical reflection experiments, it could be because one was preceded by a real payoff experiment, and the other by a hypothetical experiment (where total earnings were \$45, regardless of one's choices). We consider this below.

The outcomes for high real cash payoffs are shown in the bottom panel of Figure 4. About two-thirds of subjects are risk averse over gains (back row); of these only about 15 percent are also risk preferring for losses. Overall, we observe less reflection when we scale up payoffs, both real and hypothetical. And as before, we observe about twice the rate of reflection for high hypothetical payoffs (19 percent) as for high real payoffs (9 percent). In these high payoff sessions, 49 of 64 subjects exhibited a clean switch-point between the safe and risky lotteries. With real payoffs, 73 percent of these subjects exhibit risk aversion over gains. Of these, only about 10 percent also show risk preference over losses. Little difference is observed in the hypothetical data. As before, reflection occurs about twice as often with hypothetical payoffs (17 percent of subjects) as with real payoffs (8 percent).

There is one potentially important procedural difference between these high real and high hypothetical payoff sessions. The high real payoff sessions were preceded by a real payoff experiment in which earnings averaged about \$140. In contrast, the high hypothetical payoff sessions were preceded by a hypothetical choice task, with earnings set equal to \$45 for the entire session (which is identical to earnings in the low hypothetical payoff sessions). If previously-earned high payoffs affect risk attitudes, this could bias the comparison between these real and hypothetical payoff sessions.

In order to address this, we ran two additional high hypothetical payoff sessions.<sup>11</sup> All procedures were identical to those described above (32 subjects participated, all faced the loss condition first, and half of the subjects saw the risky lottery on the left of their decision sheet), however both sessions were preceded by a high real payoff experiment. Earnings in these sessions were quite close to those that preceded the high real payoff sessions. Average earnings were \$132 (compared with \$140 for the real payment sessions reported above), and ranged from \$111 to \$182 (\$112 to \$190 for the real payment sessions).

This high initial stake had a large effect on choices in the hypothetical gain treatment, but only a small effect in the loss domain. On average, individuals are very slightly risk seeking in the gain domain (4.9 safe choices), as shown in the bottom row of Table 3, while they are still somewhat risk averse over losses. This pattern (higher risk aversion over losses than gains) is opposite that predicted by prospect theory, although the difference in choices between the gain

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<sup>11</sup> We thank Colin Camerer for suggesting this treatment.

and loss treatments is not significant. Overall, only 25 percent of subjects are risk averse over gains; of these, about one-third are risk seeking over losses. The rate of reflection (9 percent) is comparable to that observed with high real payoffs. Using the subset of data from those subjects who switch only one time strengthens these conclusions: 29 percent of subjects are risk averse over gains, however only 8 percent of all subjects in this treatment reflect.

At the end of each session, we asked subjects to complete a demographic questionnaire. Our subject pool was almost equally divided among men and women (46 percent male and 54 percent female). Looking at our data by gender does not change our primary conclusion: the modal outcome is reflection only for low hypothetical payoffs. All sessions were held at Georgia State University, which is an urban campus located in downtown Atlanta and has a very diverse student body. Almost half of these subjects (43 percent) were raised outside of North America (Europe, South America, Asia, and Africa). The rate of reflection is generally higher among subjects from North America (the notable exception to this is in the low hypothetical treatment, where reflection occurs 50 percent more often among those raised outside of North America). However, none of our main results are changed when looking only at those raised in North America or only those raised abroad.

The interpretation of our data is complicated by those individuals classified as being risk neutral over gains or losses. Recall that (for low payoffs) five safe choices is consistent with constant absolute risk aversion in the interval  $(-0.05, 0.05)$ . This is symmetric around zero (risk neutrality), but is also consistent with a very small degree of risk aversion or risk preference. An alternative interpretation of this is to assume that those we classified as risk neutral are evenly divided between being risk averse and risk seeking. If we eliminate the risk neutral category and classify subjects in this manner, our primary conclusions stand. When payments are real, the modal outcome under high and low incentives is risk aversion under gains and losses. For low hypothetical payments, the modal outcome is reflection; however for high hypothetical payoffs (preceded by an experiment that uses hypothetical payments), the modal outcome is risk aversion under gains *and* losses. Using high hypothetical payoffs (preceded by a high real payoff experiment) the modal outcome is the reverse pattern of reflection: risk preference over gains and risk aversion over losses.

Of course, those who are most supportive of prospect theory's reflection effect might suggest that those individuals in the category centered around risk neutrality are *not* evenly distributed between risk aversion and risk preference. Instead, they might classify risk neutral individuals in the manner most supportive of prospect theory. We can do so by classifying anyone risk neutral over gains as being risk averse, and anyone risk neutral over losses as risk seeking. Under this interpretation, the four upper-right bars in Figures 2 and 4 are combined to create the category for reflection. This includes those classified as risk neutral for both gains and losses.

When risk-neutral individuals are reclassified in this manner, the modal choice pattern is reflection in all treatments. However, as reported by Camerer (1989) and Battalio et al. (1990), reflection is far from universal. In our low real payoff treatment, only 45 percent of all subjects exhibit reflection (compared with 38 percent who are risk averse for both gains and losses). There is a little more reflection in the high real payoff treatment when risk neutral subjects are reclassified in this manner: 56 percent reflect, while 31 percent are risk averse over gains and losses. As before, the strongest support for the reflection effect comes from subjects who faced low hypothetical payoffs; 63 percent of these (reclassified) subjects exhibited the predicted risk aversion for gains and risk preference over losses. When high hypothetical payoffs follow a hypothetical payoff experiment, 44 percent of subjects reflect (and 34 percent are risk averse over both gains and losses). Following a high real payoff experiment, only 41 percent of subjects exhibit reflection under high hypothetical payoffs.

Because the risk neutral data are categorized in the way most favorable to prospect theory it isn't surprising that there is much more support for reflection when the data are presented in this manner. Moreover, this would indicate that the strongest support for the reflection effect comes from those who are at best very slightly risk averse over gains and very slightly risk loving over losses.

## **6. Conclusion**

This paper adds to the literature of experimental tests of elements of prospect theory, which in its various versions is probably the leading alternative to expected utility theory. The design uses a menu of lottery choices structured to allow an inference about risk aversion as

gains are transformed into losses, holding payoff probabilities constant. When hypothetical payoffs are used, we do see that the modal choice pattern is for subjects to “reflect” from risk averse behavior over gains to risk seeking behavior over losses. This reflection rate is reduced by more than half when we use lotteries with real money payoffs, and the modal tendency is to be risk averse for both gains and losses. There is a significant difference in risk attitudes, however, with less risk aversion observed in the loss domain. When payoffs are scaled up by a factor of 15 (yielding potential gains and losses of over \$100), there is even less support for reflection.

Sharper results are obtained when we remove the “noisy” subjects who switch between the safe and risky lotteries more than once. There is a little more risk aversion with the no-switch data, and the scaling up of payoffs cuts reflection rates by almost half (for both real and hypothetical payoffs). In fact, the incidence of reflection with high real payoffs is only about 7 percent, and is lower than the rate of “reverse reflections” (risk seeking for gains and risk aversion for losses) that is opposite of the pattern predicted by prospect theory.

The lack of a clear reflection effect in our data is a little surprising given the results of other studies that report reflection effects with real money incentives (Camerer, 1989; Battalio et al., 1990). One procedural difference is the nature of what was held constant between treatments. Instead of holding initial wealth roughly constant in both treatments as we did, these studies provided a high initial stake in the loss treatment, so the *final* wealth position is constant across treatments. For example, a lottery over gains of \$20 and \$0 could be replaced with an initial payoff of \$20 and a choice involving -\$20 and \$0. Each “frame” yields the same possible final wealth positions (\$0 or \$20), but the framing is in terms of gains in one treatment and in terms of losses in the other. A setup like this is precisely what is needed to isolate a “framing effect.” Such an effect is present since both studies report a tendency for subjects to be risk averse in the gain frame and risk seeking in the loss frame. Whether these results indicate a reflection effect is less clear, since the higher stake provided in the loss treatment may have induced more risk seeking behavior, just as gifts of candy and money tend to increase risk seeking in some contexts (see Arkes et al., 1988).

Finally, we should note that our experiments are silent on loss aversion, which is another plausible aspect of prospect theory, because all lotteries that we consider involve only gains or only losses.

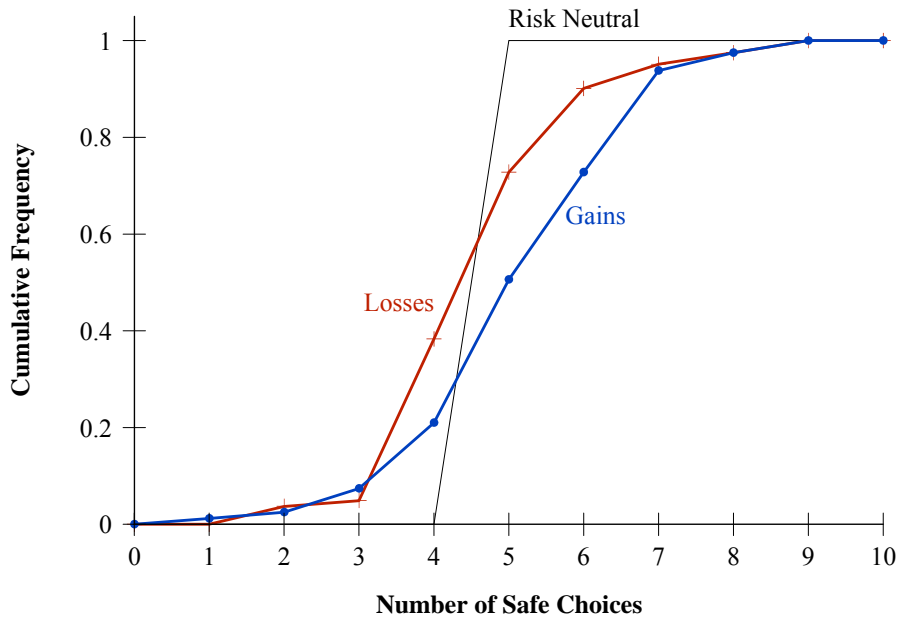
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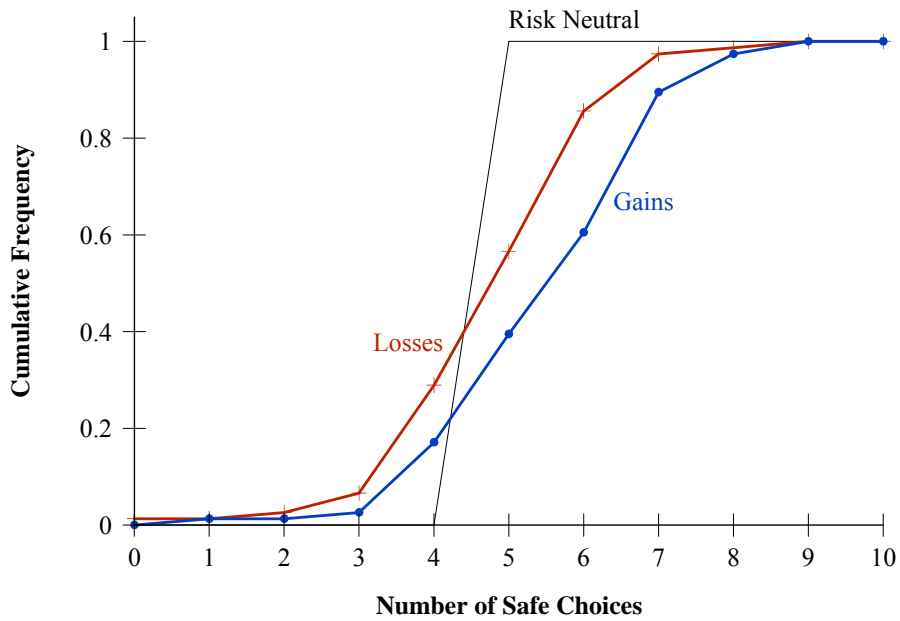
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**Figure 1. Cumulative Choice Frequencies**

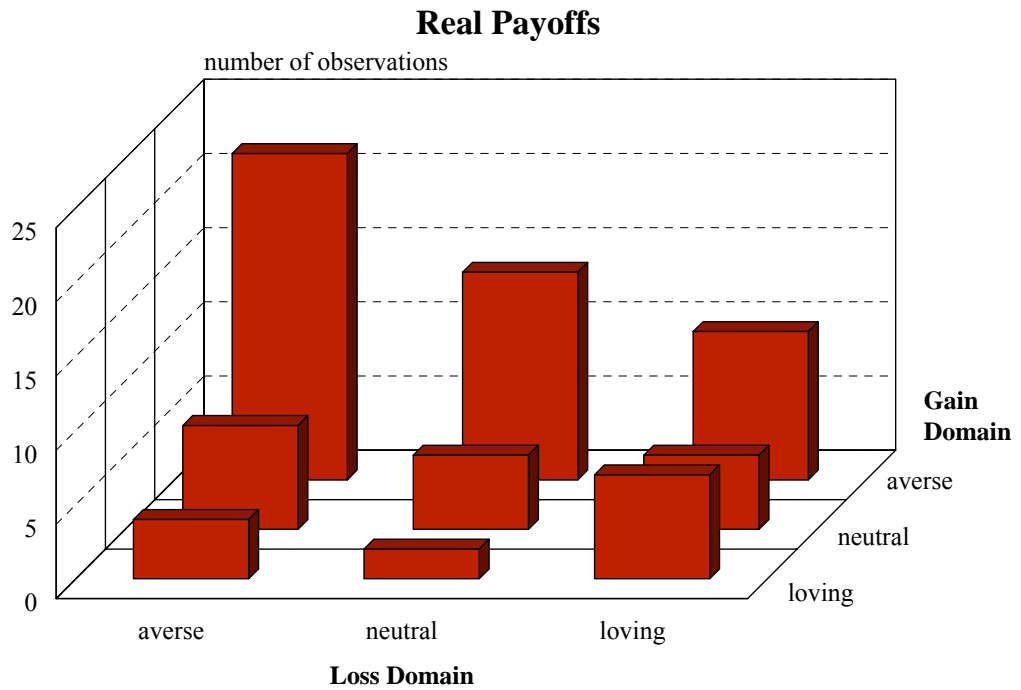
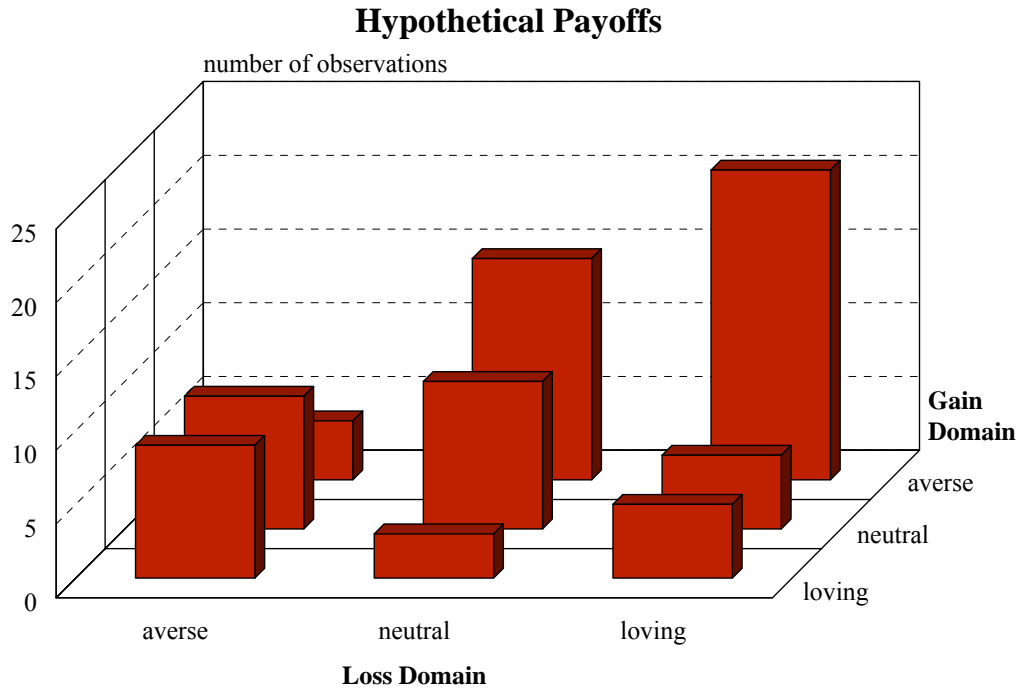
Hypothetical Payments



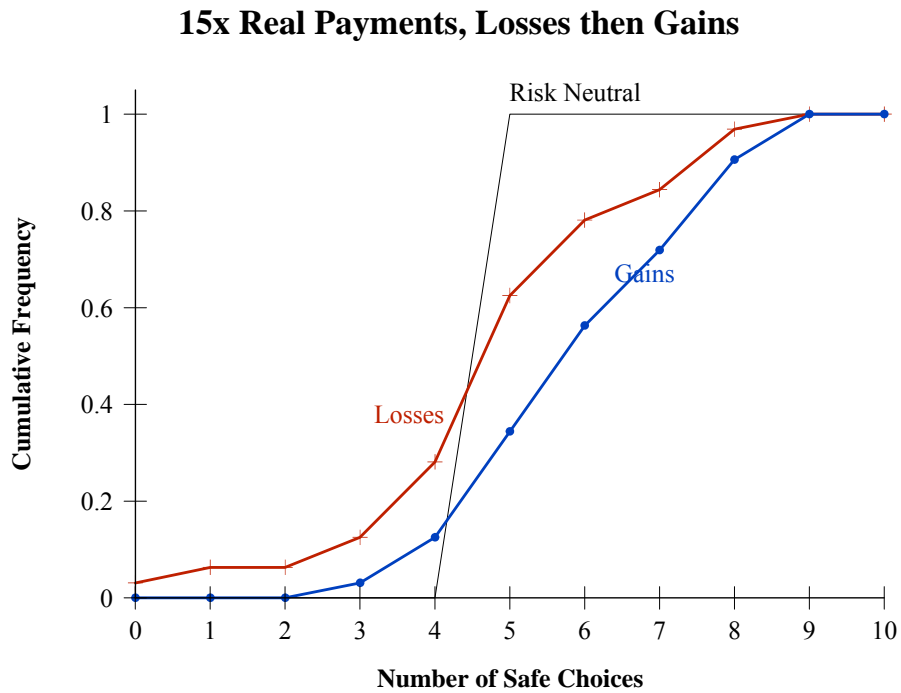
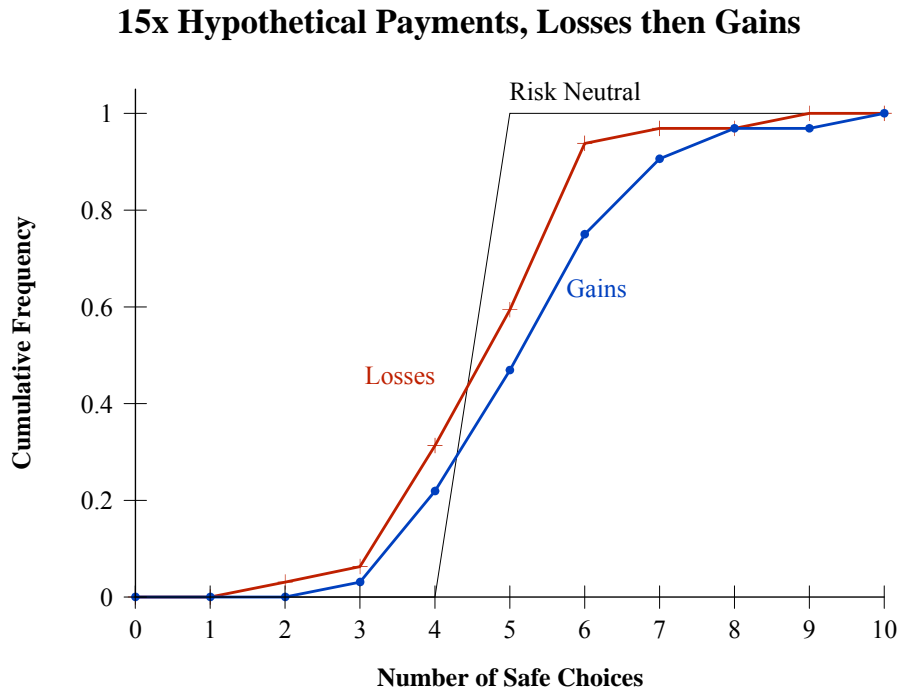
Real Payments



**Figure 2. Risk Aversion Categories for Losses and Gains**

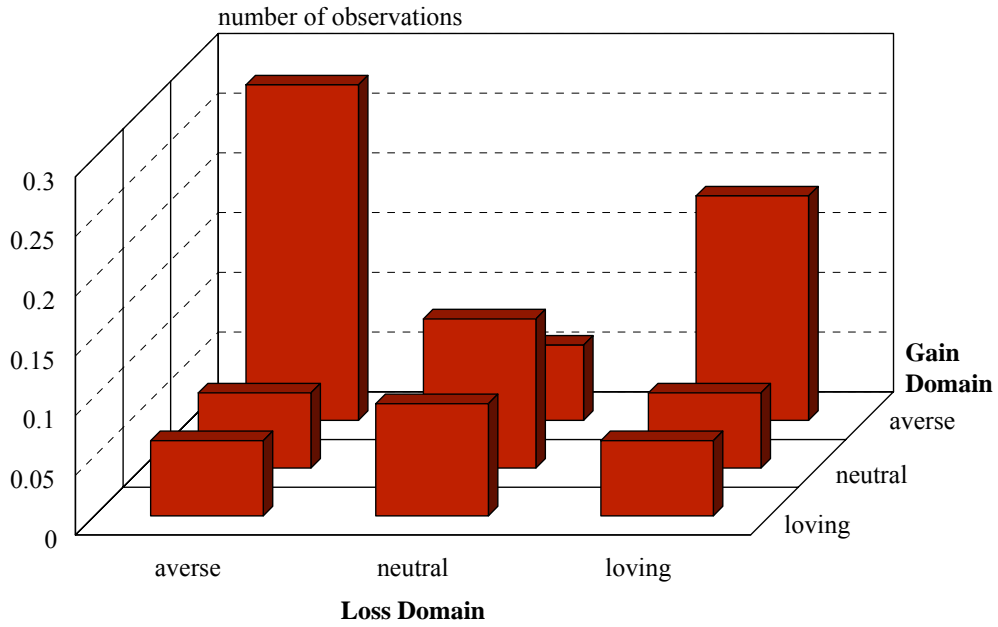


**Figure 3. Cumulative Choice Frequencies for High Losses and High Gains**

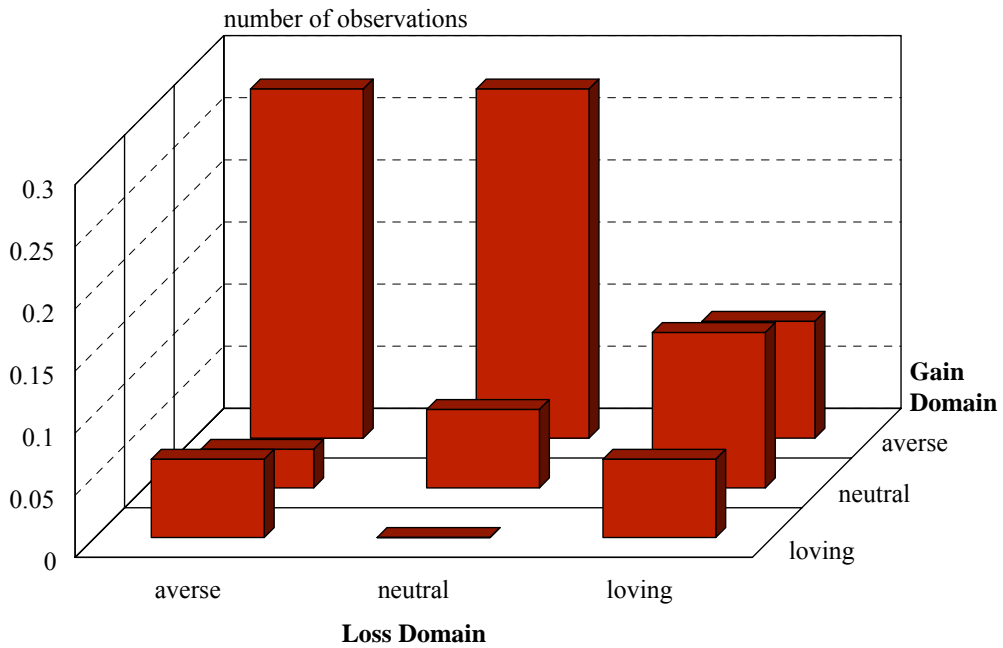


**Figure 4. Risk Aversion Categories for High Losses and High Gains**

**15x Hypothetical Payoffs, Losses then Gains**



**15x Real Payoffs, Losses then Gains**



## Appendix A. Experiment Instructions

### Initial Instructions for Hypothetical Payment Sessions

Today you will be participating in several experiments about decision-making. Typically, in an experiment like this one, you would earn money. The amount of money that you would earn would depend on the choices that you and the other participants would make. In the experiment today, however, you will be paid \$45 for participating in the experiment. You can write this amount now on your receipt form.

You will not earn any additional money today based on the choices that you and the other participants make. The instructions for each part of the today's experiment will describe how your earnings depend on your decisions (and sometimes on the decisions of others). It is important that you understand that you will not actually be receiving any of this additional money (other than your \$45 participation fee). We would like for you to sign the statement below indicating that you understand this.

I understand that I will be paid \$45 for participation in today's experiment. All other earnings described in the instructions that I receive are hypothetical and will not actually be paid to me.

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Signature

Although you will not actually earn any additional money today, we ask that you make choices in the following experiments *as if* you could earn more money, and the amount that you could earn would depend on choices that you and the others make. You will not actually be paid any additional money, but we want you to make decisions as if you would be paid additional money.

### **Instructions for Lottery Choice Tasks (Real and Hypothetical)**

The remaining part of today's experiment will consist of a series of choices given to you one at a time. Although each part will count toward your final earnings, you will not find out how much you have earned for any of these decisions until you have completed all of them. For one of these decision tasks, all payoffs are negative; for this decision, payoffs will be subtracted from your earnings in the other parts of today's experiment. For all of the other decision tasks, payoffs are positive and will be added to your earnings in the other parts of today's experiment.

## Instructions

Your decision sheet shows ten decisions listed on the left. Each decision is a paired choice between "Option A" and "Option B." You will make ten choices and record these in the final column, but only one of them will be used in the end to determine your earnings. Before you start making your ten choices, please let me explain how these choices will affect your earnings for this part of the experiment.

Here is a ten-sided die that will be used to determine payoffs; the faces are numbered from 1 to 10 (the "0" face of the die will serve as 10.) After you have made all of your choices, we will throw this die twice, once to select one of the ten decisions to be used, and a second time to determine what your payoff is for the option you chose, A or B, for the particular decision selected. Even though you will make ten decisions, only one of these will end up affecting your earnings, but you will not know in advance which decision will be used. Obviously, each decision has an equal chance of being used in the end.

Now, please look at Decision 1 at the top. Option A yields a sure gain of \$0.20 (20 cents), and option B yields a sure gain of \$3.20 (320 cents). Next look at Decision 2 in the second row. Option A yields \$7.70 if the throw of the ten sided die is 1, and it yields \$0.20 if the throw is 2-10. Option B yields \$4.00 if the throw of the die is 1, and it yields \$3.20 if the throw is 2-10. The other decisions are similar, except that as you move down the table, the chances of the better payoff for each option increase.

To summarize, you will make ten choices: for each decision row you will have to choose between Option A and Option B. You may choose A for some decision rows and B for other rows, and you may change your decisions and make them in any order. When you are finished, we will come to your desk and throw the ten-sided die to select which of the ten Decisions will be used. Then we will throw the die again to determine your payoff for the Option you chose for that Decision. Payoffs for this choice are positive and will be added to your previous earnings, and you will be paid the sum of all earnings in cash when we finish.

So now please look at the empty boxes on the right side of the record sheet. You will have to write a decision, A or B in each of these boxes, and then the die throw will determine which one is going to count. We will look at the decision that you made for the choice that counts, and circle it, before throwing the die again to determine your earnings for this part. Then you will write your earnings in the blank at the bottom of the page. Please note that these gains will be added to your previous earnings up to now.

Are there any questions? Now you may begin making your choices. Please do not talk with anyone while we are doing this; raise your hand if you have a question.

	Option A	Option B	Your Choice A or B
Decision 1	\$3.20 if throw of die is 1-10	\$0.20 if throw of die is 1-10	
Decision 2	\$4.00 if throw of die is 1 \$3.20 if throw of die is 2-10	\$7.70 if throw of die is 1 \$0.20 if throw of die is 2-10	
Decision 3	\$4.00 if throw of die is 1-2 \$3.20 if throw of die is 3-10	\$7.70 if throw of die is 1-2 \$0.20 if throw of die is 3-10	
Decision 4	\$4.00 if throw of die is 1-3 \$3.20 if throw of die is 4-10	\$7.70 if throw of die is 1-3 \$0.20 if throw of die is 4-10	
Decision 5	\$4.00 if throw of die is 1-4 \$3.20 if throw of die is 5-10	\$7.70 if throw of die is 1-4 \$0.20 if throw of die is 5-10	
Decision 6	\$4.00 if throw of die is 1-5 \$3.20 if throw of die is 6-10	\$7.70 if throw of die is 1-5 \$0.20 if throw of die is 6-10	
Decision 7	\$4.00 if throw of die is 1-6 \$3.20 if throw of die is 7-10	\$7.70 if throw of die is 1-6 \$0.20 if throw of die is 7-10	
Decision 8	\$4.00 if throw of die is 1-7 \$3.20 if throw of die is 8-10	\$7.70 if throw of die is 1-7 \$0.20 if throw of die is 8-10	
Decision 9	\$4.00 if throw of die is 1-8 \$3.20 if throw of die is 9-10	\$7.70 if throw of die is 1-8 \$0.20 if throw of die is 9-10	
Decision 10	\$4.00 if throw of die is 1-9 \$3.20 if the throw of die is 10	\$7.70 if throw of die is 1-9 \$0.20 if the throw of die is 10	

Decision used: \_\_\_\_\_, Die Throw: \_\_\_\_\_ Your earnings: \_\_\_\_\_

## Instructions

Your decision sheet shows ten decisions listed on the left. Each decision is a paired choice between "Option A" and "Option B." You will make ten choices and record these in the final column, but only one of them will be used in the end to determine your earnings. Before you start making your ten choices, please let me explain how these choices will affect your earnings for this part of the experiment.

Here is a ten-sided die that will be used to determine payoffs; the faces are numbered from 1 to 10 (the "0" face of the die will serve as 10.) After you have made all of your choices, we will throw this die twice, once to select one of the ten decisions to be used, and a second time to determine what your payoff is for the option you chose, A or B, for the particular decision selected. Even though you will make ten decisions, only one of these will end up affecting your earnings, but you will not know in advance which decision will be used. Obviously, each decision has an equal chance of being used in the end.

Now, please look at Decision 1 at the top. Option A yields a sure loss of ! \$0.20 (minus 20 cents), and option B yeilds a sure loss of ! \$3.20 (minus 320 cents). Next look at Decision 2 in the second row. Option A yields ! \$7.70 if the throw of the ten sided die is 1, and it yields ! \$0.20 if the throw is 2-10. Option B yields ! \$4.00 if the throw of the die is 1, and it yields ! \$3.20 if the throw is 2-10. The other decisions are similar, except that as you move down the table, the chances of the worse payoff for each option increase.

To summarize, you will make ten choices: for each decision row you will have to choose between Option A and Option B. You may choose A for some decision rows and B for other rows, and you may change your decisions and make them in any order. When you are finished, we will come to your desk and throw the ten-sided die to select which of the ten Decisions will be used. Then we will throw the die again to determine your payoff for the Option you chose for that Decision. Payoffs for this choice are negative and will be subtracted from your previous earnings, and you will be paid the sum of all earnings in cash when we finish.

So now please look at the empty boxes on the right side of the record sheet. You will have to write a decision, A or B in each of these boxes, and then the die throw will determine which one is going to count. We will look at the decision that you made for the choice that counts, and circle it, before throwing the die again to determine your earnings for this part. Then you will write your earnings in the blank at the bottom of the page. Please note that losses will be subtracted from your previous earnings up to now.

Are there any questions? Now you may begin making your choices. Please do not talk with anyone while we are doing this; raise your hand if you have a question.

	Option A	Option B	Your Choice A or B
Decision 1	! \$3.20 if throw of die is 1-10	! \$0.20 if throw of die is 1-10	
Decision 2	! \$4.00 if throw of die is 1 ! \$3.20 if throw of die is 2-10	! \$7.70 if throw of die is 1 ! \$0.20 if throw of die is 2-10	
Decision 3	! \$4.00 if throw of die is 1-2 ! \$3.20 if throw of die is 3-10	! \$7.70 if throw of die is 1-2 ! \$0.20 if throw of die is 3-10	
Decision 4	! \$4.00 if throw of die is 1-3 ! \$3.20 if throw of die is 4-10	! \$7.70 if throw of die is 1-3 ! \$0.20 if throw of die is 4-10	
Decision 5	! \$4.00 if throw of die is 1-4 ! \$3.20 if throw of die is 5-10	! \$7.70 if throw of die is 1-4 ! \$0.20 if throw of die is 5-10	
Decision 6	! \$4.00 if throw of die is 1-5 ! \$3.20 if throw of die is 6-10	! \$7.70 if throw of die is 1-5 ! \$0.20 if throw of die is 6-10	
Decision 7	! \$4.00 if throw of die is 1-6 ! \$3.20 if throw of die is 7-10	! \$7.70 if throw of die is 1-6 ! \$0.20 if throw of die is 7-10	
Decision 8	! \$4.00 if throw of die is 1-7 ! \$3.20 if throw of die is 8-10	! \$7.70 if throw of die is 1-7 ! \$0.20 if throw of die is 8-10	
Decision 9	! \$4.00 if throw of die is 1-8 ! \$3.20 if throw of die is 9-10	! \$7.70 if throw of die is 1-8 ! \$0.20 if throw of die is 9-10	
Decision 10	! \$4.00 if throw of die is 1-9 ! \$3.20 if the throw of die is 10	! \$7.70 if throw of die is 1-9 ! \$0.20 if the throw of die is 10	

Decision used: \_\_\_\_\_, Die Throw: \_\_\_\_\_ Your earnings: \_\_\_\_\_