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Risk Aversion and Incentive Effects

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A menu of paired lottery choices is structured so that the crossover point to the high-risk lottery can be used to infer the degree of risk aversion. With "normal" laboratory payoffs of several dollars, most subjects are risk averse and few are risk loving. Scaling up all payoffs by factors of twenty, fifty, and ninety makes little difference when the high payoffs are hypothetical. In contrast, subjects become sharply more risk averse when the high payoffs are actually paid in cash. A hybrid "power/expo" utility function with increasing relative and decreasing absolute risk aversion nicely replicates the data patterns over this range of payoffs from several dollars to several hundred dollars.

Keywords: lottery choice, risk aversion, incentive effects, hypothetical payoffs.

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Risk Aversion and Incentive Effects

Abstract: A menu of paired lottery choices is structured so that the crossover point to the high-risk lottery can be used to infer the degree of risk aversion. With "normal" laboratory payoffs of several dollars, most subjects are risk averse and few are risk loving. Scaling up all payoffs by factors of twenty, fifty, and ninety makes little difference when the high payoffs are hypothetical. In contrast, subjects become sharply more risk averse when the high payoffs are actually paid in cash. A hybrid "power/expo" utility function with increasing relative and decreasing absolute risk aversion nicely replicates the data patterns over this range of payoffs from several dollars to several hundred dollars.

Although risk aversion is a fundamental element in standard theories of lottery choice, asset valuation, contracts, and insurance (e.g. Daniel Bernoulli, 1738; John Pratt, 1964; Kenneth Arrow, 1965), experimental research has provided little guidance as to how risk aversion should be modeled. To date, there have been several approaches used to assess the importance and nature of risk aversion. Using lottery choice data from a field experiment, Hans Binswanger (1980) concluded that most farmers exhibit a significant amount of risk aversion that tends to increase as payoffs are increased. Alternatively, risk aversion can be inferred from bidding and pricing tasks. In auctions, overbidding relative to Nash predictions has been attributed to risk aversion by some and to noisy decision-making by others, since the payoff consequences of such overbidding tend to be small (Glenn Harrison, 1989). Vernon Smith and James Walker (1993) assess the effects of noise and decision cost by dramatically scaling up auction payoffs. They find little support for the noise hypothesis, reporting that there is an insignificant *increase* in overbidding in private value auctions as payoffs are scaled up by factors of 5, 10, and 20. Another way to infer risk aversion is to elicit buying and/or selling prices for simple lotteries. Steven Kachelmeier and Mohamed Shehata (1992) report a significant increase in risk aversion (or, more precisely, a decrease in risk seeking behavior) as the prize value is increased. However, they also obtain dramatically different results depending on whether the choice task involves buying or selling, since subjects tend to put a high selling price on something they "own" and a lower buying price on something they do not, which implies

risk seeking behavior in one case and risk aversion in the other.[1] Independent of the method used to elicit a measure of risk aversion, there is widespread belief (with some theoretical support discussed below) that the degree of risk aversion needed to explain behavior in low-payoff settings would imply absurd levels of risk aversion in high-payoff settings. The upshot of this is that risk aversion effects are controversial and often ignored in the analysis of laboratory data. This general approach has not caused much concern because most theorists are used to bypassing risk aversion issues by assuming that the payoffs for a game are already measured as utilities.

The nature of risk aversion (to what extent it exists, and how it depends on the size of the stake) is ultimately an empirical issue, and additional laboratory experiments can produce useful evidence that complements field observations by providing careful controls of probabilities and payoffs. However, even many of those economists who admit that risk aversion may be important have asserted that decision makers should be approximately risk neutral for the low-payoff decisions (involving several dollars) that are typically encountered in the laboratory. The implication, that low laboratory incentives may be somewhat unrealistic and therefore not useful in measuring attitudes toward "real-world" risks, is echoed by Daniel Kahneman and Amos Tversky (1979), who suggest an alternative:

> Experimental studies typically involve contrived gambles for small stakes, and a large number of repetitions of very similar problems. These features of laboratory gambling complicate the interpretation of the results and restrict their generality. By default, the method of hypothetical choices emerges as the simplest procedure by which a large number of theoretical questions can be investigated. The use of the method relies of the assumption that people often know how they would behave in actual situations of choice, and on the further assumption that the subjects have no special reason to disguise their true preferences. (Kahneman and Tversky, 1979, p. 265)

In this paper, we directly address these issues by presenting subjects with simple choice tasks that

[1] This is analogous to the well-known "willingness to pay/willingness to accept bias." Asking for a high selling price implies a preference for the risk inherent in the lottery, and offering a low purchase price implies an aversion to the risk in the lottery. Thus the way that the pricing task is framed can alter the implied risk attitudes in a dramatic manner. The issue is whether seemingly inconsistent estimates are due to a problem with the way risk aversion is conceptualized, or to a behavioral bias that is activated by the experimental design. We chose to avoid this possible complication by framing the decisions in terms of choices, not purchases and sales.

may be used to estimate the degree of risk aversion as well as specific functional forms. We use lottery choices that involve large cash prizes that are actually to be paid. To address the validity of using high hypothetical payoffs, we conducted this experiment under both real and hypothetical conditions. We were intrigued by experiments in which increases in payoff levels seem to increase risk aversion, e.g. Binswanger's (1980) experiments with low-income farmers in Bangladesh, Hal Arkes, Lisa Herren and Alice Isen (1988) with hypothetical payoffs, and Antoni Bosch-Domenech and Joaquim Silvestre (1999), who report that willingness to purchase actuarially fair insurance against losses is increasing in the scale of the loss. Therefore we elicit choices under both low and high money payoffs, increasing the scale by 20, 50, and finally 90 times the low payoff level.

In our experiment we present subjects with a menu of choices that permits measurement of the degree of risk aversion, and also estimation of its functional form. We are able to compare behavior under real and hypothetical incentives, for lotteries that range from several dollars up to several hundred dollars. The wide range of payoffs allows us to specify and estimate a hybrid utility function that permits both the type of increasing relative risk aversion reported by Binswanger and decreasing absolute risk aversion needed to avoid "absurd" predictions for the high-payoff treatments. The procedures are explained in Section I, the effects of incentives on risk attitudes are described in Section II, and our hybrid utility model is presented in Section III.

I. Procedures

The low-payoff treatment is based on ten choices between the paired lotteries in Table 1. Notice that the payoffs for Option A, \$2.00 or \$1.60, are less variable than the potential payoffs of \$3.85 or \$0.10 in the "risky" option B. In the first decision, the probability of the high payoff for both options is 1/10, so only an extreme risk seeker would choose Option B. As can be seen in the far right column of the table, the expected payoff incentive to choose Option A is \$1.17.[2] When the probability of the high payoff outcome increases enough (moving down the table), a person should cross over to Option B. For example,

[2] Expected payoffs were not provided in the instructions to subjects, which are available on the web at http://www.gsu.edu/~ecoskl/research.htm. The probabilities were explained in terms of throws of a ten-sided die.

a risk neutral person would choose A four times before switching to B. Even the most risk averse person should switch over by Decision 10 in the bottom row, since option B yields a sure payoff of $3.85 in that case.

Table 1. The Ten Paired Lottery-Choice Decisions with Low Payoffs

Option A	Option B	Expected Payoff Difference
1/10 of $2.00, 9/10 of $1.60	1/10 of $3.85, 9/10 of $0.10	$1.17
2/10 of $2.00, 8/10 of $1.60	2/10 of $3.85, 8/10 of $0.10	$0.83
3/10 of $2.00, 7/10 of $1.60	3/10 of $3.85, 7/10 of $0.10	$0.50
4/10 of $2.00, 6/10 of $1.60	4/10 of $3.85, 6/10 of $0.10	$0.16
5/10 of $2.00, 5/10 of $1.60	5/10 of $3.85, 5/10 of $0.10	-$0.18
6/10 of $2.00, 4/10 of $1.60	6/10 of $3.85, 4/10 of $0.10	-$0.51
7/10 of $2.00, 3/10 of $1.60	7/10 of $3.85, 3/10 of $0.10	-$0.85
8/10 of $2.00, 2/10 of $1.60	8/10 of $3.85, 2/10 of $0.10	-$1.18
9/10 of $2.00, 1/10 of $1.60	9/10 of $3.85, 1/10 of $0.10	-$1.52
10/10 of $2.00, 0/10 of $1.60	10/10 of $3.85, 0/10 of $0.10	-$1.85

The literature on auctions commonly assumes constant relative risk aversion for its computational convenience and its implications for bid function linearity with uniformly distributed private values. With constant relative risk aversion for money x, the utility function is $u(x) = x^{1-r}$ for $x > 0$. This specification implies risk preference for $r < 0$, risk neutrality for $r = 0$, and risk aversion for $r > 0$.[3] The payoffs for the lottery choices in the experiment were selected so that the crossover point would provide an interval estimate of a subject's coefficient of relative risk aversion. We chose the payoff numbers for the lotteries so that the risk neutral choice pattern (four safe choices followed by six risky choices) was optimal for constant relative risk aversion in the interval (-0.15, 0.15). The payoff numbers were also selected to make the choice pattern of six safe choices followed by four risky choices optimal for an interval (0.41, 0.68), which is approximately symmetric around a coefficient of 0.5 (square root utility) that has been reported in econometric analysis of auction data cited below. For our analysis, we do not assume that individuals exhibit constant relative risk aversion; these calculations will provide the basis for a null hypothesis to be

[3] When $r = 1$, the natural logarithm is used; division by $(1-r)$ is necessary for increasing utility when $r > 1$.

tested. In particular, if all payoffs are scaled up by a constant, *k*, then this constant factors out of the power function that has constant relative risk aversion. In this case, the number of safe choices would be unaffected by changes in payoff scale. A change in choice patterns as payoffs are scaled up would be inconsistent with constant relative risk aversion. In this case, we can use the number of safe choices in each payoff condition to obtain risk aversion estimates for other functional forms.

In our initial sessions, subjects began by indicating a preference, Option A or Option B, for each of the ten paired lottery choices in Table 1, with the understanding that *one* of these choices would be selected at random *ex post* and played to determine the earnings for the option selected. The second decision task involved the same ten decisions, but with hypothetical payoffs at 20 times the levels shown in Table 1 ($40 or $32 for Option A, and $77 or $2 for Option B). The third task was also a high-payoff task, but the payoffs were paid in cash. The final task was a "return to baseline" treatment with the low money payoffs shown in Table 1. The outcome of each task was determined before the next task began. Incentives are likely diluted by the random selection of a single decision for each of the treatments, which is one motivation for running the high-payoff condition. Subjects did seem to take the low-payoff condition seriously, often beginning with the easier choices at the top and bottom of the table, with choices near their switch point more likely to be crossed out and changed.

To control for wealth effects between the high and low real-payoff treatments, subjects were required to give up what they had earned in the first low-payoff task in order to participate in the high-payoff decision. They were asked to initial a statement accepting this condition, with the warning:

> Even though the earnings from this next choice may be very large, they may also be small, and differences between people may be large, due to choice and chance. Thus we realize that some people may prefer not to participate, and if so, just indicate this at the top of the sheet.... Let me reiterate, even though some of the payoffs are quite large, there is no catch or chance that you will lose any money that you happen to earn in this part. We are prepared to pay you what you earn. Are there any questions?

Nobody declined to participate, so there is no selection bias. For comparability, subjects in the high-hypothetical treatment were required to initial a statement acknowledging that earnings for that decision

would not be paid. The hypothetical choice does not alter wealth, but the high real payoffs altered the wealth positions a lot for most subjects, so the final low-payoff task was used to determine whether risk attitudes are affected by large changes in accumulated earnings. Comparing choices in the final low-payoff task with the first may also be used to assess whether any behavioral changes in the high-payoff condition were due to changes in risk attitude or from more careful consideration of the choice problem.

Table 2. Summary of Lottery Choice Treatments

Treatment	Number of Subjects	Average Earnings	Minimum Earnings	Maximum Earnings
20x Hypothetical Only	25	$25.74	$19.40	$40.04
20x Real Only	57	$67.99	$20.30	$116.48
20x Hypothetical and Real	93	$68.32	$11.50	$105.70
50x Hypothetical and Real	19	$131.39	$111.30	$240.59
90x Hypothetical and Real	18	$226.34	$45.06	$391.65

All together, we conducted the initial sessions (with low and 20x payoffs) using 175 subjects, in groups of 9-16 participants per session, at three universities (two at Georgia State University, four at the University of Miami, and six at the University of Central Florida). About half of the students were undergraduates, one third were M.B.A. students, and 17 percent were business school faculty. Table 2 presents a summary of our experimental treatments. In these sessions, the low payoff tasks were always done, but the high payoff condition was for hypothetical payoffs in some sessions, for real money in others, and in about half of the sessions we did both in order to obtain a within-subjects comparison. Doing the high hypothetical choice task before high real allows us to hold wealth constant and to evaluate the effect of using real incentives. For our purposes, it would not have made sense to do the high real treatment first, since the careful thinking would bias the high hypothetical decisions.[4] We can compare choices in the high

[4] Of course, the order that we did use could bias the high real decision toward what is chosen under hypothetical conditions, but a comparison with sessions using one high-payoff treatment or the other indicates no such bias.

real payoff treatment with either the first or last low payoff task to alleviate concerns that learning occurred as subjects worked through these decisions.

In order to explore the effect of even larger increases in payoffs we next ran some very expensive sessions in which the 20x payoffs were replaced with 50x payoffs and 90x payoffs. In the two 50x sessions (19 subjects), the "safe" payoffs were $100 and $80, while the "risky" payoffs were $192.50 and $5. In the 90x sessions (18 subjects) the safe and risky payoffs were ($180, $144) and ($346.50, $9), respectively. All of these sessions were conducted at Georgia State University. The number of subjects in these treatments was necessarily much smaller due to the large increase in payments required to conduct them. All subjects were presented with both real and hypothetical choices in these two treatments, allowing for a within-subjects comparison. Average earnings were about $70 in the 20x sessions using real payments, $130 in the 50x sessions, and $225 in the 90x sessions.[5] All individual lottery choice decisions, earnings, and responses to fifteen demographic questions (given to subjects at the conclusion of the experiment) can be found on the web at http://www.gsu.edu/~ecoskl/research.htm.

II. Incentive Effects

In all of our treatments, the majority of subjects chose the safe option when the probability of the higher payoff was small, and then crossed over to option B without ever going back to option A. In all sessions, only 28 of 212 subjects ever switched back from B to A in the first low-payoff decision, and only 14 switched back in the final low-payoff choice. Fewer than 1/4 of these subjects switched back from B to A more than once. The number of such switches was even lower for the high payoff choices, although this difference is small (6.6 percent of choices in the last low-payoff task, compared with about 5.5 percent in the 50x and 90x real payoff treatments). More subjects switched back in the hypothetical treatments:

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[5] All of the lottery choice tasks reported in this paper were preceded by an unrelated experiment. Those sessions conducted at the Universities of Miami and Central Florida followed a repeated individual decision (tax compliance) task conducted by a colleague, for which earnings averaged about $18. The lottery choice sessions conducted at Georgia State university followed a different set of (individual choice) tasks for which average earnings were a somewhat higher (about $27). We conclude that these differences are probably not relevant; in the 20x payoff sessions, including Georgia State data does not alter the means, medians, or modes of the number of safe choices in any of the treatments by more than 0.05.

between 8 and 10 percent.

Even for those who switched back and forth, there is typically a clear division point between clusters of A and B choices, with few "errors" on each side. Therefore, the total number of “safe” A choices will be used as an indicator of risk aversion.[6] Figure 1 displays the proportion of A choices for each of the ten decisions (as listed in Table 1). The horizontal axis is the decision number, and the dashed line shows the predictions under an assumption of risk neutrality, i.e. the probability that the safe option A is chosen is 1 for the first four decisions, and then this probability drops to 0 for all remaining decisions. The thick line with dots shows the observed frequency of Option A choices in each of the ten decisions in the low-real-payoff (1x) treatment.[7] This series of choice frequencies lies to the right of the risk neutral prediction, showing a tendency toward risk averse behavior among these subjects. The thin lines in the figure show the observed choice frequencies for the hypothetical (20x, 50x, and 90x) treatments; these are quite similar to one another and are also very close to the line for the low real payoff condition. Actual choice frequencies for the initial (20x payoff) sessions, along with the implied risk aversion intervals, are shown in the “low real” and “20x hypothetical” columns of Table 3. Even for low payoff levels, there is considerable risk aversion, with about two thirds of subjects choosing more than the four safe choices that would be predicted by risk neutrality. However, there is no significant difference between behavior in the low real and high (20x, 50x, or 90x) hypothetical payoff treatments.

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[6] The analysis reported in this paper changes very little if we instead drop those subjects who switch from B back to A. The average number of safe choices increases slightly in some treatments when we restrict our attention to those who never switch back, but typically by less than 0.2 choices.

[7] For this figure, and other frequencies reported below, the full sample of available observations was used. For example, in Figure 1, the choices of all 212 subjects are reported in the low payoff series. This includes those in the 20x, 50x, and 90x sessions. Similarly, when choices involving 20x payoffs are reported, we do not limit our attention to the 93 subjects who made choices under real *and* hypothetical conditions. A Kolmogorov-Smirnov test fails to reject the null hypothesis of no difference in the distribution of the number of safe choices between the full sample and the relevant restricted sample for any of our comparisons. Moreover, the actual difference in distributions is very small in all cases.

Table 3. Risk Aversion Classifications Based on Lottery Choices

Number of Safe Choices	Range of Relative Risk Aversion for $U(x) = x^{1-r}/(1-r)$	Risk Preference Classification	Proportion of Choices		
			Low real[a]	20x hypothetical	20x real
0-1	$r < -0.95$	highly risk loving	.01	.03	.01
2	$-0.95 < r < -0.49$	very risk loving	.01	.04	.01
3	$-0.49 < r < -0.15$	risk loving	.06	.08	.04
4	$-0.15 < r < 0.15$	risk neutral	.26	.29	.13
5	$0.15 < r < 0.41$	slightly risk averse	.26	.16	.19
6	$0.41 < r < 0.68$	risk averse	.23	.25	.23
7	$0.68 < r < 0.97$	very risk averse	.13	.09	.22
8	$0.97 < r < 1.37$	highly risk averse	.03	.03	.11
9-10	$1.37 < r$	stay in bed	.01	.03	.06

[a] Average over first and second decisions.

Figure 2 shows the results of the 20x real payoff treatments (the solid line with squares). The increase in payoffs by a factor of 20 shifts the locus of choice frequencies to the right in the figure, with more than 80 percent of choices in the risk averse category (see Table 3). Of the 150 subjects who faced the 20x real payoff choice, 84 showed an increase in risk aversion over the low payoff treatment. Only 20 subjects showed a decrease (the others showed no change). This difference is significant at any standard level of confidence using a Wilcoxon test of the null hypothesis that there is no change.[8] The risk aversion categories in Table 3 were used to design the menu of lottery choices, but the clear increase in risk aversion as all payoffs are scaled up is inconsistent with constant relative risk aversion. One notable feature of the frequencies in Table 3 is that nearly 40 percent of the choice patterns in the 20x real payoff condition

[8] Following Sydney Siegel (1956), observations with no change were not used. In addition, a one-tailed Kolmogorov-Smirnov test applied to the aggregate cumulative frequencies, based on all observations, allows rejection of the null hypothesis that the choice distributions are the same between the low (either first or last) and 20x real payoff treatments ($p < 0.01$).

involve 7 or more safe choices, which indicates a very high level of risk aversion for those individuals. The overall message is that there is a lot of risk aversion, centered around the 0.3-0.5 range, which is roughly consistent with estimates implied by behavior in games, auctions, and other decision tasks.[9] Both Table 3 and the treatment averages displayed in Table 4 show how risk aversion increases as real payoffs are scaled up.

Table 4. Average Number of Safe Choices by Treatment

Treatment	Number of Subjects	First Low Real	High Hypothetical	High Real	Second Low Real
20x All	175	5.2	4.9[a]	6.0[b]	5.3
20x Hypothetical and Real	93	5.0	4.8	5.8	5.2
50x Hypothetical and Real	19	5.3	5.1	6.8	5.5
90x Hypothetical and Real	18	5.3	5.3	7.2	5.5

[a] N=118; [b] N=150.

Given the increase in risk aversion observed when payoffs are scaled up by a factor of 20, we were curious as to how a further increase in payoffs would affect choices. The increase in payoffs from their original levels (shown in Table 1) by factors of 50 and 90, produced even more dramatic shifts toward the safe option. In the latter treatment, the safe option provides either \$144 or \$180, whereas the risky option provides \$346.50 or \$9. One-third of subjects who faced this choice (6 out of 18) avoided any chance of the \$9 payoff, only switching to the risky option in decision 10 where the high payoff outcome was

[9] In a classic study, Binswanger (1980) finds moderate to high levels of constant relative risk aversion (above 0.32), especially for high stakes gambles (increasing relative risk aversion). Some recent estimates for relative risk aversion are: $r = 0.67$, 0.52 and 0.48 for private-value auctions (James Cox and Ronald Oaxaca, 1996; Jacob Goeree, Charles Holt, and Thomas Palfrey, 1999; and Kay-Yut Chen and Charles Plott, 1998, respectively), $r = 0.44$ for several asymmetric matching pennies games (Goeree, Holt, and Palfrey, 2000), $r = 0.45$ for 27 one-shot matrix games (Goeree and Holt, 2000). Sandra Campo, Isabelle Perrigne, and Quang Vuong (2000) estimate $r = 0.56$ for field data from timber auctions. One thing to note is that risk aversion estimates can be quite unstable when inferred from willingness-to-pay prices as compared with much higher willingness-to-accept prices that subjects place on the same lottery (Steven Kachelmeier and Mohamed Shehata, 1992, R. Mark Isaac and Duncan James, 1999). The low willingness-to-pay prices imply risk aversion, whereas the high willingness-to-accept prices imply risk neutrality or risk seeking. One important implication of this measurement effect is that the same instrument should be used in making a comparison, as is the case for the comparison of risk attitudes of individuals and groups conducted by Robert Shupp and Arlington Williams (2000).

certain. There is an increase in the average number of safe choices (shown in Table 4) and a corresponding rightward shift in the distribution of safe choices (shown by the diamonds and triangles in Figure 2). The increase in the number of safe choices is also reflected by the median and modal choices. For payoff scales of 20x, 50x, and 90x the medians are, respectively, (6.0, 7.0, 7.5) and the modes are (6.0, 7.0, and 9.0). This increased tendency to choose the safe option when payoffs are scaled up is inconsistent with the notion of constant relative risk aversion (when utility is written as a function of income, not wealth). This increase in risk aversion is qualitatively similar to Smith and Walker's (1993) results. However, unlike the subjects in their auction experiments, our subjects exhibit much larger (and significant) changes in behavior as payoffs are scaled up. Kachelmeier and Shehata (1992) also observed a significant change in behavior when the payoff scale was increased, although their subjects (who demanded a relatively high price in order to sell the lottery) appeared to be risk preferring in their baseline treatment. As noted earlier, our design avoids any potential willingness to accept bias by framing the question in a neutral choice setting. To summarize: increases in all prize amounts by factors of 20, 50, and 90 cause sharp increases in the frequencies of safe choices, and hence, in the implied levels of risk aversion.

In contrast, successive increases in the stakes do not alter behavior very much in the hypothetical payoff treatments. Subjects are much more risk averse with high real payoff levels (20x, 50x, and 90x) than with comparable hypothetical payoffs. The clear treatment effect suggested by Figure 2 is supported by the within-subjects analysis. Of the 93 people who made both real and hypothetical decisions at the 20x level, 44 showed more risk aversion in the real-payoff condition, 42 showed no change, and 7 showed less risk aversion. The positive effect of real payoffs on the number of safe choices is significant using either a Wilcoxon test or a Kolmogorov-Smirnov test ($p < 0.01$). However, there is more risk seeking behavior (15 percent) in the 20x hypothetical-payoff condition than is the case in the other treatments (6-8 percent). A Kolmogorv-Smirnov test on the change in hypothetical distributions shows no change as payoffs are scaled up from 20x to 50x to 90x. Behavior is a little more erratic with hypothetical payoffs; for example, one person chose option A in all ten decisions, including the sure hypothetical $40 over the hypothetical $77 in decision 10. The only other case of option A being selected in decision 10 also occurred in the 20x hypothetical treatment.

This result raises questions about the validity Kahneman and Tversky's suggested technique of using hypothetical questionnaires to address issues that involve very high stakes. In particular, it casts doubt on their assumption that "people often know how they would behave in actual situations of choice" (Kahneman and Tversky, 1979, p. 265).

We can also address whether facing the high payoff treatment affected subsequent choices under low payoffs. Looking at Table 4, the roughly comparable choice frequencies for the "before" and "after" low-payoff conditions (an average of 5.2 versus 5.3 safe choices for 20x payoffs, and 5.3 versus 5.5 for the 50x and 90x treatments) suggests that the level of risk aversion is not affected by high earnings in the intermediate high-payoff condition that most subjects experienced. This invariance is supported by a simple regression in which the change in the number of safe choices between the first and last low-payoff decisions is regressed on earnings in the high real payoff condition that were obtained in between. The coefficient on earnings is near zero and insignificant. If we only consider the subset who won the $77 prize, 21 people did not change their number of safe choices, 11 increased, and 14 decreased. We observe similar patterns in the higher payoff treatments. In the 50x treatment, only one subject won the $192.50 prize, and this person *increased* the number of safe choices (from three to four). In the 90x payoff treatment, four subjects won the $346.50 prize. Three of these subjects did not change their decision in the last choice from the first, and the remaining subject decreased the number of safe choices from five to four. Thus high unanticipated earnings appear to have little or no effect on risk preferences in this context. This observation would be consistent with constant absolute risk aversion, but we argue in section III below that constant absolute risk aversion cannot come close to explaining the effects of increasing the stakes on observed choice behavior. Alternatively, the lack of a strong correlation between earnings in the high-payoff lottery and subsequent lottery choices could be due to an "isolation effect" or tendency to focus on the *status quo* and consider risks of payoff changes, i.e. changes in income instead of final wealth. In fact, there is no experimental evidence that we know of which supports the "asset integration" hypothesis that wealth affects risk attitudes (see Cox and Sadiraj, 2001).

It also appears unlikely that exposure to the high payoff choice task affected choices in the subsequent low payoff decision. Almost half of all subjects who face one of our high real payoff treatments

choose the same number of safe choices in the first and last low payoff task. About the same number of subjects change the number of safe choices by one (these are almost equally divided between increasing and decreasing by one choice). Very few individuals change the number of safe choices by more than one between the first and last decision tasks.

We distributed a post-experiment questionnaire to collect information about demographics and academic background. While the study was not designed to address demographic effects on risk aversion, the subject pool shows a wide variation in income and education, and some interesting patterns do appear in our data. Using the any of the real-payoff decisions to measure risk aversion, income has a mildly negative effect on risk aversion ($p < 0.06$). Other variables (major, MBA, faculty, age, etc.) were not significant. Using the low-payoff decisions only, we find that men are slightly less risk averse ($p < 0.05$), making about 0.5 fewer safe choices. This is consistent with findings reported by Eckel, Grossman, Lutz, and Padmanabhan (1998). The surprising result for our data is that this gender effect disappears in the three high-payoff treatments. Finally, although the white/non-white variable is not significant, in our 20x payoff sessions the Hispanic variable is; this effect is even stronger at the 20x level than at the low payoff level. There were almost no Hispanic subjects in our 50x and 90x sessions and so we cannot estimate a model including this variable for these sessions.[10]

III. Payoff Scale Effects and Risk Aversion

The increased tendency to choose the safe option as the stakes are raised is a clear indication of increasing relative risk aversion, which could be consistent with a wide range of utility functions, including those with constant absolute risk aversion, i.e. $u(x) = -\exp(-ax)$. The problem with constant absolute risk aversion is indicated by Figure 3, where an absolute risk aversion coefficient of $a = 0.2$ predicts five safe (Option A) choices under low payoff conditions, as shown by the thick dashed line with dots just to the right of the thin dashed line for risk neutrality. This prediction is approximately correct for the low real payoff treatment, which produces a treatment average of about 5.2 safe choices. But notice the dashed

[10] This Hispanic effect may be due to the narrow geographic basis of the sample. Most of the Hispanic subjects were students at the University of Miami, however we did not obtain information about their ancestry or where they were raised.

line with squares on the far right side of Figure 3; this is the corresponding prediction of 9 safe choices for $a = 0.2$ in the 20x payoff treatment. This is far more than the treatment average of 6.0 safe choices. The intuition for this "absurd" amount of predicted risk aversion can be seen by reconsidering the utility when payoffs, x, are scaled up by 20 under constant absolute risk aversion: $u(x) = -\exp(-a20x)$. Since the baseline payoff, x, and the risk aversion parameter enter multiplicatively, scaling up payoffs by 20 is equivalent to having 20 times as much risk aversion for the original payoffs. This is our interpretation of the "Rabin critique" that the risk aversion needed to explain behavior in low stakes situations implies an absurd amount of risk aversion in high stakes lotteries (Rabin, 2000). This observation raises the issue of whether *any* utility function will be consistent with observed behavior over a wide range of payoff stakes.[11] Obviously, such a function will have to exhibit decreasing absolute risk aversion, although constant absolute risk aversion (with the right constant) may yield good predictions for some particular level of stakes.

First, notice that the locus of actual frequencies is not as "abrupt" as the dashed line predictions in Figure 3, which indicates the need to add some "noise" to the model. This noise may reflect actual decision-making errors or unmodeled heterogeneity, among other factors. This addition is also essential if we want to be able to determine whether the apparent increase in risk aversion with high stakes is merely due to diminished noise. We do so by introducing a probabilistic choice function. The simplest rule specifies the probability of choosing option A as the associated expected payoff, U_A, divided by the sum of the expected payoffs, U_A and U_B, for the two options. Following Luce (1959), we introduce a noise parameter, μ, that captures the insensitivity of choice probabilities to payoffs via the probabilistic choice rule:

$$Pr(\textit{choose Option A}) = \frac{U_A^{1/\mu}}{U_A^{1/\mu} + U_B^{1/\mu}}, \qquad (1)$$

where the denominator simply ensures that the probabilities of each choice sum to one. Notice that the choice probabilities converge to one-half as μ becomes large, and it is straightforward to show that the probability of choosing the option with the higher expected payoff goes to 1 as μ goes to 0. Figure 4

[11] For a critical discussion of the Rabin critique, see Cox and Sadiraj (2001).

shows how adding some error in this manner (μ = 0.1, as an example) causes the dashed line predictions under risk neutrality to exhibit a smoother transition, i.e. there is some curvature at the corners.

Obviously, we must add some risk aversion to explain the observed preference for the safe option in decisions 5 and 6. As a first step, we keep the noise parameter fixed at 0.1 and add an amount of constant relative risk aversion of r = 0.3, which yields predictions shown by the dashed lines in Figure 5. The dashed lines for the three treatments cannot be distinguished, which is not surprising given the fact that payoff scale changes do not affect the predictions under constant relative risk aversion. However, under one specific payoff scale, constant relative risk aversion can provide an excellent fit for the data patterns. Given this, we see why this model has been useful in explaining laboratory data for "normal" payoff levels (see Goeree, Holt, and Palfrey, 1999, 2000).

The next step is to introduce a functional form that permits the type of increasing relative risk aversion seen in our data, but avoids the absurd predictions of the constant absolute risk aversion model. This can be done with a hybrid "power-expo" function (Saha, 1993) that includes constant relative risk aversion and constant absolute risk aversion as special cases:

$$U(x) = \frac{1 - \exp(-a x^{1-r})}{a}, \tag{2}$$

which has been normalized to ensure that utility becomes linear in x in the limit as a goes to 0. It is straightforward to show that the Arrow-Pratt index of relative risk aversion is:

$$\frac{-u''(x)\,x}{u'(x)} = r + a(1-r)x^{1-r}, \tag{3}$$

which reduces to constant relative risk aversion of r when a = 0, and to constant absolute risk aversion of a when r = 0. For intermediate cases (both parameters positive), the utility function exhibits increasing relative risk aversion and decreasing absolute risk aversion (Abdellaoui, Barrios, and Wakker, 2000).

Using the proportion of safe choices in each of the 10 decisions in the four real payoff treatments, we obtained maximum likelihood parameter estimates for this "power-expo" utility function: μ = .134

(.0046), r = .269 (.017), and a = .029 (.0025), with a log-likelihood of -315.68.[12] These parameter values were used to plot the theoretical predictions for the four treatments shown in Figure 6. This model fits most of the aggregate data averages quite closely, The amount of risk aversion needed to explain behavior in the low-stakes treatment does not imply absurd predictions in the extremely high stakes treatment. The largest prediction errors are for the 50x treatment, which is more erratic given the low number of observations used to generate each of the 10 choice frequencies for that treatment. Note that the model slightly under-predicts the extreme degree of risk aversion for decision 9 in the 90x treatment. Still, this three-parameter model does a remarkable job of predicting behavior over a payoff range from several dollars to several hundred dollars.

IV. Conclusion

This paper presents the results of a simple lottery choice experiment that allows us to measure the degree of risk aversion over a wide range of payoffs, ranging from several dollars to several hundred dollars. In addition, we compare behavior under hypothetical and real incentives.

Although behavior is slightly more erratic under the high hypothetical treatments, the primary incentive effect is in levels (measured as the number of safe lottery choices in each treatment). Even at the low payoff level, when all prizes are below $4.00, about two-thirds of the subjects exhibit risk aversion. With real payoffs, risk aversion increases sharply when payoffs are scaled up by factors of 20, 50, and 90. This result is qualitatively similar to that reported by Kachelmeier and Shehata (1992) and Smith and Walker (1993) in different choice environments. In contrast, behavior is largely unaffected when hypothetical payoffs are scaled up. This paper presents estimates of a hybrid "power-expo" utility function that exhibits: 1) increasing relative risk aversion, which captures the effects of payoff scale on the frequency of safe choices, and 2) decreasing absolute risk aversion, which avoids absurd amounts of risk aversion for high stakes gambles. Behavior across all treatments conforms closely to the predictions of this model.

One implication of these results is that, contrary to Kahneman and Tversky's supposition, subjects

[12] If we restrict our attention to those subjects who never switch back to Option A after choosing Option B, the noise parameter is smaller, and both risk aversion parameters are larger. The estimates (and standard errors) from this sample are μ=0.110 (.0041), r=0.293 (.017), and a=.032 (.003), with a log-likelihood of -247.8.

facing hypothetical choices cannot imagine how they would actually behave under high incentive conditions. Moreover, these differences are not symmetric: subjects typically under-estimate the extent to which they will avoid risk. Second, the clear evidence for risk aversion, even with low stakes, suggests the potential danger of analyzing behavior under the simplifying assumption of risk neutrality.

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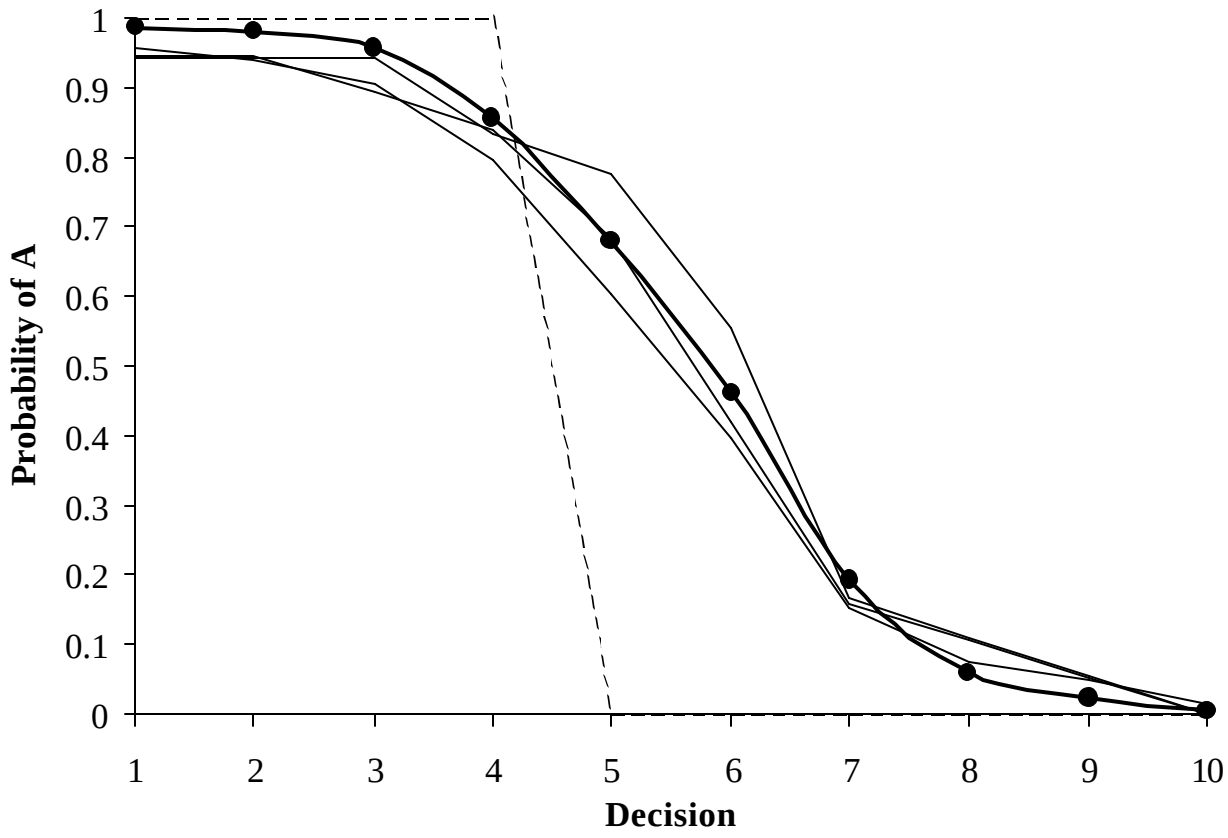

Figure 1. Proportion of Safe Choices in Each Decision: Data Averages and Predictions.
Key: Data Averages for Low Real Payoffs (Solid Line with Dots), 20x, 50x, and 90x Hypothetical Payoffs (Thin Lines), and Risk Neutral Prediction (Dashed Line).

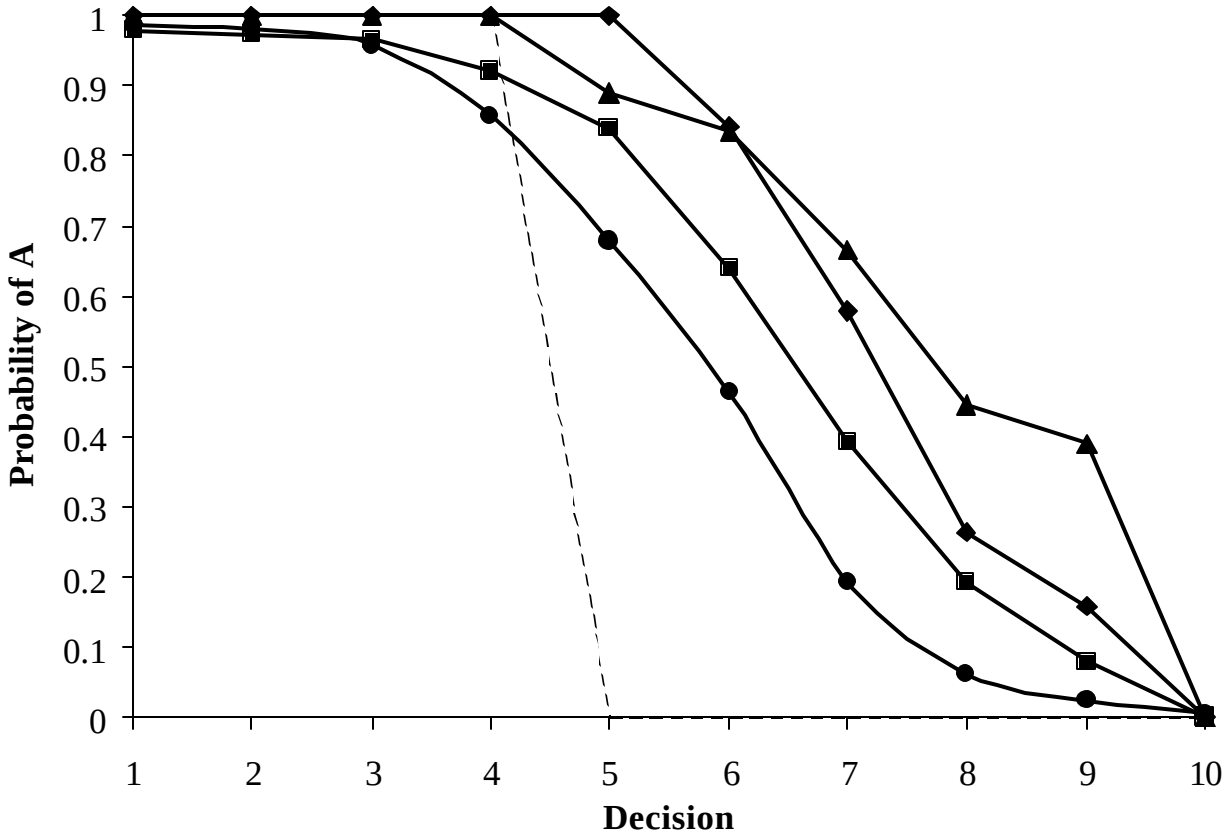

Figure 2. Proportion of Safe Choices in Each Decision: Data Averages and Predictions.
Key: Data Averages for Low Real Payoffs (Solid Line with Dots), 20x Real (Squares), 50x Real (Diamonds), 90x Real Payoffs (Triangles), and Risk Neutral Prediction (Dashed Line).

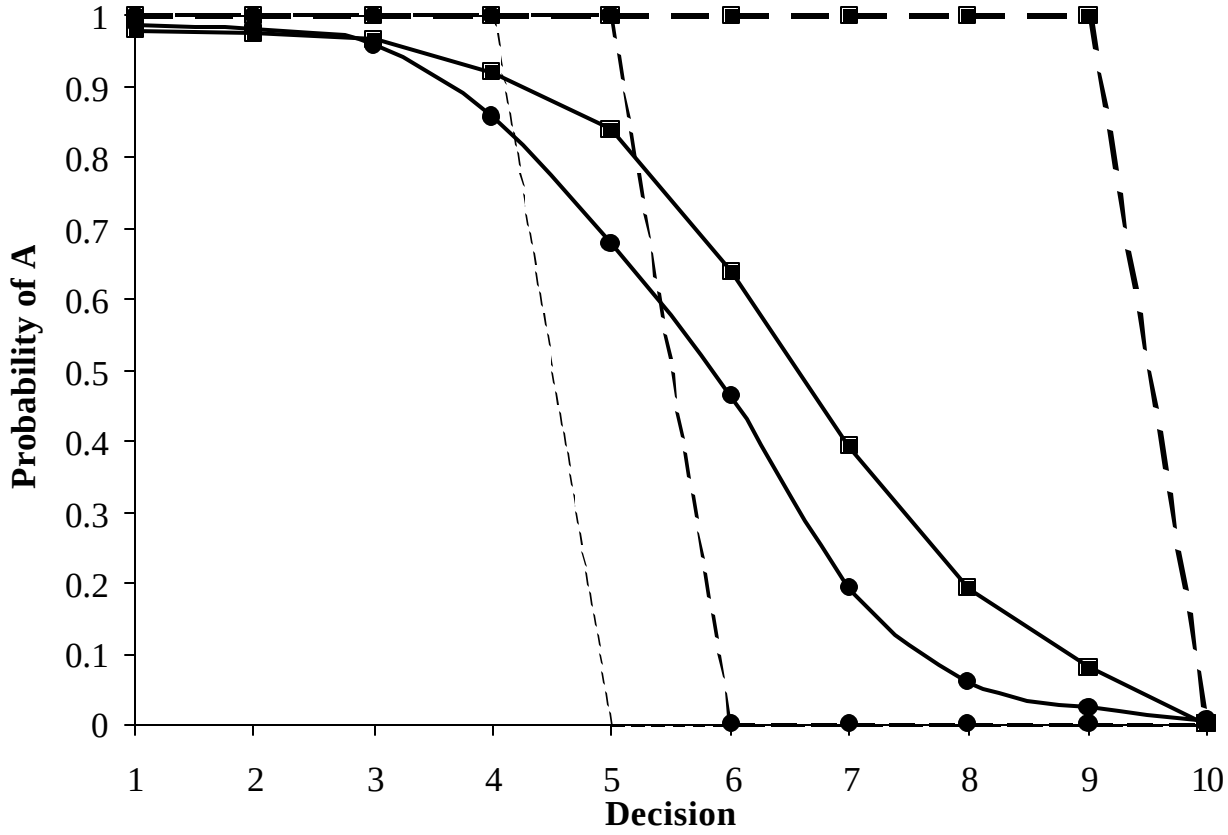

Figure 3. Proportion of Safe Choices in Each Decision: Data Averages and Predictions

Key: Data Averages for Low Real Payoffs (Solid Line with Dots) and 20x Real Payoffs (Squares), with Corresponding Predictions for Constant Absolute Risk Aversion with $a = 0.2$ (Thick Dashed Lines) and Risk Neutrality (Thin Dashed Line)

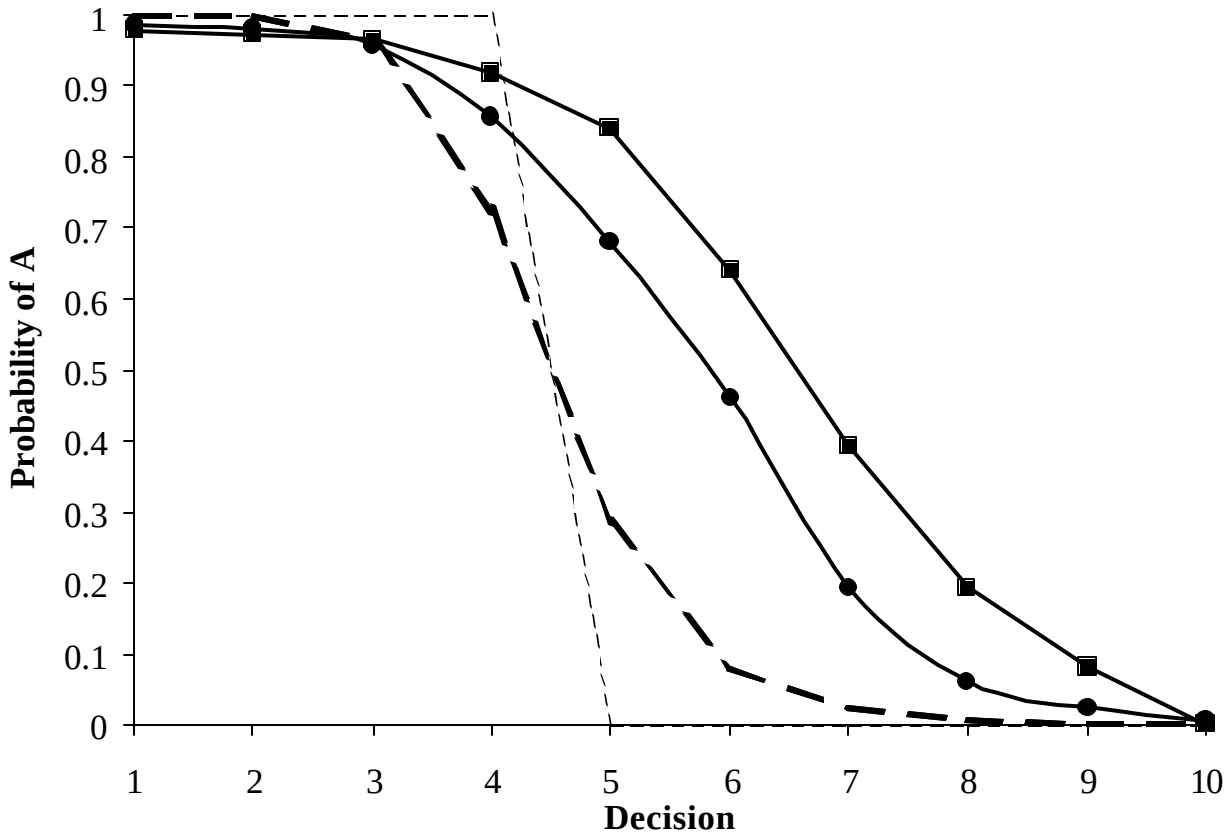

Figure 4. Proportion of Safe Choices in Each Decision: Data Averages and Predictions

Key: Data Averages for Low Real Payoffs (Solid Line with Dots) and 20x Real Payoffs (Squares), with Predictions for Risk Neutrality (Thin Dashed Line) and Noise Parameter of 0.1 (Thick Dashed Line)

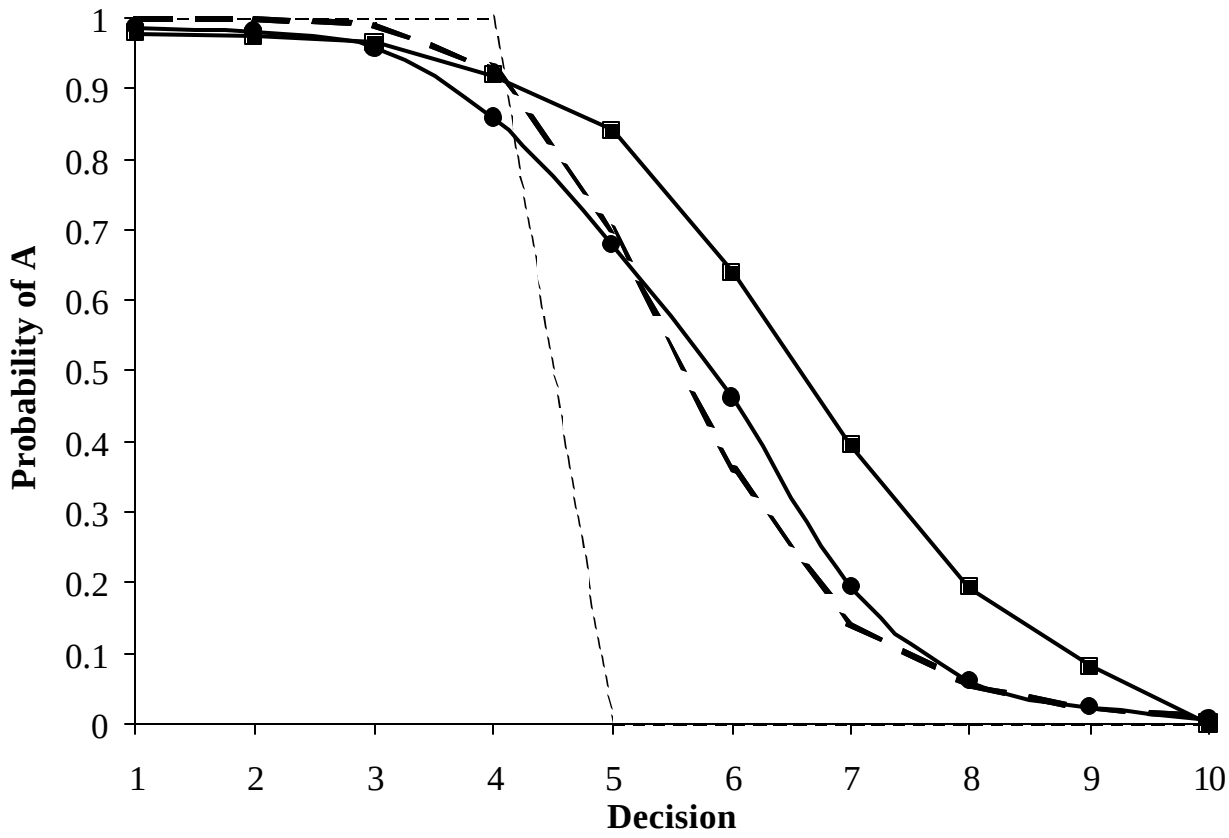

Figure 5. Proportion of Safe Choices in Each Decision: Data Averages and Predictions

Key: Data Averages for Low Real Payoffs (Solid Line with Dots) and 20x Real Payoffs (Squares), with Predictions for Risk Neutrality (Thin Dashed Line) and a Noise Parameter of 0.1 with Constant Relative Risk Aversion of 0.3 (Thick Dashed Line)

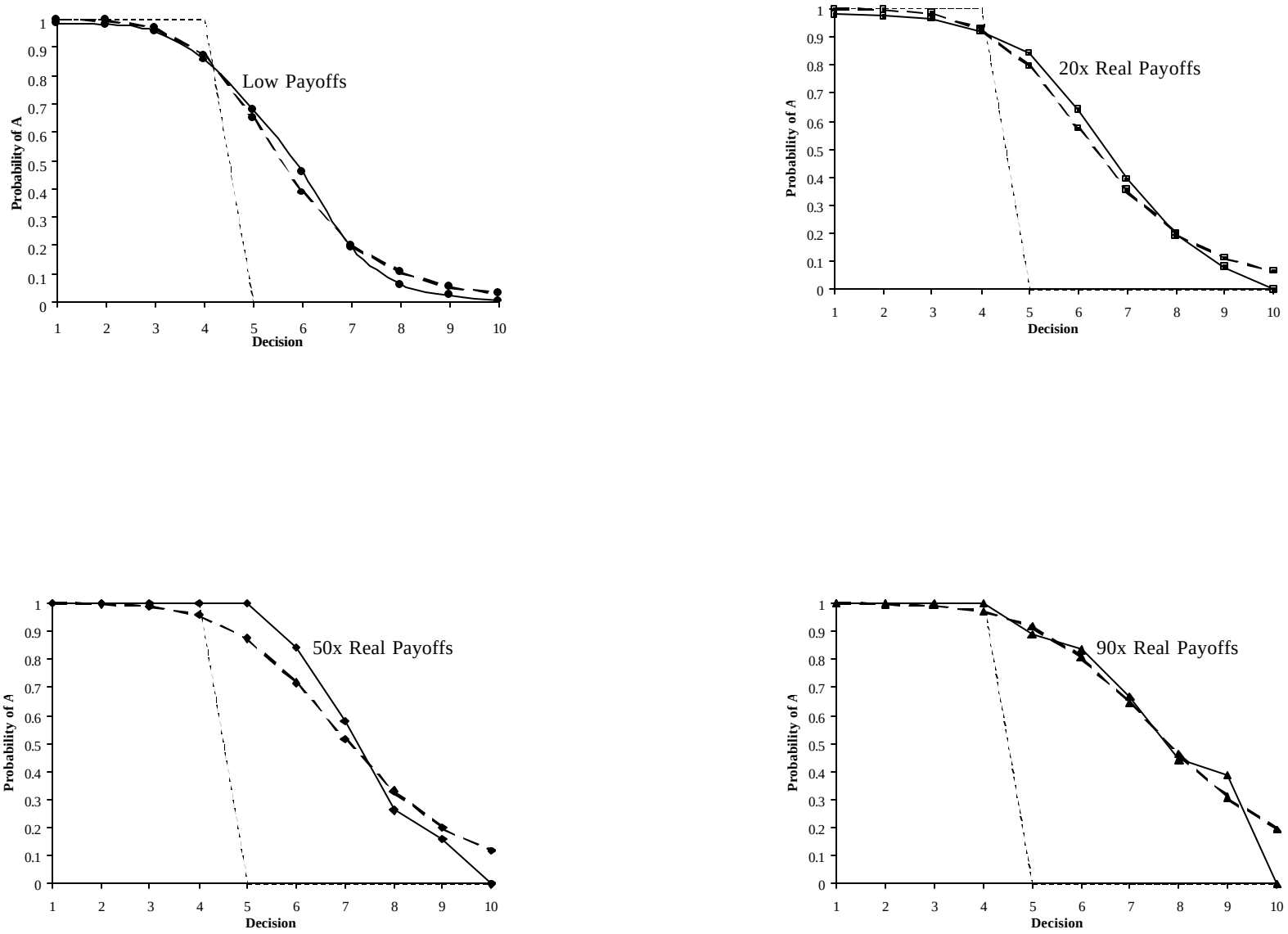

Figure 6. Proportion of Safe Choices in Each Decision: Data Averages and Predictions. Key: Data (Thick Lines), Risk Neutrality (Thin Dashed Lines), and Predictions (Thick Dashed Lines) with Noise, for the Hybrid "Power-Expo" Utility Function with r=.269, q =.029, and noise =.134.