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Decision biases in intertemporal choice and choice under uncertainty: Testing a common account

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Two experiments were performed to test a psychophysical account of parallels between biases in risky choice and intertemporal choice. Experiment 1 demonstrated the common difference effect in intertemporal choice and the common ratio effect in risky choice. As was predicted, these two biases were uncorrelated with each other, although each was correlated across monetary/health domains. This result is consistent with the supposition that these two biases result from psychophysical properties of two different dimensions (time and probability, respectively). Experiment 2 examined the magnitude effect in intertemporal choice and the peanuts effect in risky choice. These two biases were correlated with each other but were uncorrelated across monetary/health domains. This result is consistent with the supposition that these two biases result from psychophysical properties of the same dimension (utility of money or health).

Some decisions involve uncertain outcomes. For example, selecting an entrée at a restaurant entails uncertainty about how delicious each menu option would be. Other decisions involve delayed outcomes. For example, initiating an exercise program entails a delay until the positive results of exercise are observed. Both decision making under uncertainty and intertemporal choice have been the topic of much research. In the present article, we analyze potential parallels between these two types of choices.

Decision making under uncertainty can be characterized by risk preferences. A preference for a lottery over its expected value (EV) (e.g., preferring a 50% chance of $10 over $5 for sure) is considered *risk seeking*, whereas a preference for the expected value over the lottery (e.g., preferring the $5 for sure) is known as *risk aversion*. Intertemporal choice can be characterized by time preferences. A preference for a positive outcome now rather than for an equivalent outcome later (e.g., preferring $10 now to $10 in 1 month) is called a *positive time preference*, and the extent of the time preference can be quantified as a discount rate, or the percentage of increase in the magnitude of the payout needed to offset a delay. For example, a 20% monthly discount rate would mean that $10 now is equally preferable to $12 in 1 month (Frederick, Loewenstein, & O'Donoghue, 2003).

There are apparent parallels between choice under uncertainty and intertemporal choice—that is, seemingly analogous phenomena that could be explained if risk preferences and time preferences are driven by common factors (see Green & Myerson, 2004). A number of researchers have suggested that time and delay are parallel (e.g., Keren & Roelofsma, 1995; Rachlin, Logue, Gibbon, & Frankel, 1986) or have analogous effects on choice (Chapman, 1997; Gafni & Torrance, 1984; Myerson, Green, Hanson, Holt, & Estle, 2003).

The study of both choice under uncertainty and intertemporal choice has centered around the analysis of decision biases, or deviations from normative theory. Risky choice biases are deviations from expected utility theory (Neumann & Morgenstern, 1953). Intertemporal choice biases are deviations from discounted utility theory (Koopsman, 1960). Prelec and Loewenstein (1991; Loewenstein & Prelec, 1992) noted that some risky choice biases parallel intertemporal choice biases.

The purpose of the present experiments was to provide an empirical test of a particular account of the apparent parallels between biases in risky choice and biases in intertemporal choice. That is, we tested the idea that biases in the two domains that appear similar are the result of the same underlying mechanism. We first will describe two pairs of biases; we then will present a psychophysical account for parallels between the biases and, finally, an empirical test devised to evaluate this account.

Pairs of Parallel Biases

Common difference and common ratio effects. The common difference effect is a bias in intertemporal choice in which adding a constant delay to both choice op-

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tions shifts preference from the smaller, sooner outcome to the larger, later outcome (Christensen-Szalanski, 1984; Green, Fristoe, & Myerson, 1994; Kirby & Herrnstein, 1995). For example, suppose someone preferred to receive $10 in 2 weeks, rather than $20 in 4 weeks. If a delay of 10 weeks were added to both options, the person might then prefer $20 in 14 weeks over $10 in 12 weeks. Normatively speaking, both choices should be determined by a comparison between the two amounts ($10 vs. $20) and the difference between the two delays, which is 2 weeks in both cases. Thus, the preference reversal is nonnormative. A specific case of the common difference effect is the immediacy effect, where the smaller, sooner option in the first choice is immediate. For example, someone might prefer $10 immediately to $20 in 1 year but $20 in 3 years rather than $10 in 2 years. The common difference effect can be characterized by lower implicit temporal discounting for long delays than for short delays (Benzion, Rapoport, & Yagil, 1989; Bleichrodt & Johannesson, 2001; Cairns, 1994; Chapman, 1996; Chapman & Elstein, 1995; Redelmeier & Heller, 1993; Thaler, 1981).

A potentially parallel bias in the domain of choice under uncertainty is the common ratio effect. Here, reducing the probabilities for both choice options by a common ratio shifts preference from the smaller, more probable outcome to the larger, less probable outcome (Kahneman & Tversky, 1979). For example, someone might prefer a 50% chance of $100 to a 25% chance of $200. If both probabilities are divided by a factor of 10, the person might then prefer a 2.5% chance of $200 over a 5% chance of $100. Normatively speaking, dividing by 10 does not change the rank order of the two expected utilities, so the preference should not reverse. A specific case of the common ratio effect is the certainty effect, where the smaller, more probable option in the first choice is certain. For example (Kahneman & Tversky, 1979, 1984), someone might prefer $30 for sure to an 80% chance of $45 but also might prefer a 20% chance of $45 to a 25% chance of $30. The common ratio effect can be characterized by more risk-seeking preferences for small probabilities to win than for large probabilities.

In the common difference and common ratio effects, preference shifts toward the larger outcome when either delay or uncertainty increases for both options. In the case of the immediacy and certainty effects, immediate or certain outcomes are particularly appealing, suggesting that the delay or probability weighting function is nonlinear or discontinuous (with a qualitative distinction between immediacy and delay or between certainty and uncertainty). This weighting has been modeled as a hyperbolic discount function for intertemporal choice (Ainslie, 1975; Kirby & Maraković, 1995; Loewenstein & Prelec, 1992) and as the prospect theory probability weighting function for decision making under uncertainty (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992).

Do the common ratio and common difference effects have a common underlying mechanism? Such a relationship would require a type of equivalence between probability and delay and between certainty and immediacy. Some researchers have argued exactly that. Rachlin and colleagues (Rachlin et al., 1986; Rachlin, Raineri, & Cross, 1991; Rachlin, Siegel, & Cross, 1994), for instance, argued that the probability of winning can be recoded as the expected time delay until a win across repeated gambles; thus, the smaller the probability, the larger the number of repeated plays (and hence, the longer the delay) needed, on average, until a win. Keren and Roelofsma (1995) took the converse approach and argued that because a delay involves uncertainty that the outcome will ever occur, delay affects utility by way of uncertainty. Thus, immediacy is appealing because it implies certainty.

Magnitude and peanuts effects. The magnitude effect is a bias in intertemporal choice in which increasing the magnitudes of the outcomes by a constant factor shifts preference from the smaller, sooner option to the larger, later option (Benzion et al., 1989; Chapman, 1996, 1998; Chapman & Elstein, 1995; Chapman & Winquist, 1998; Green, Myerson, & McFadden, 1997; Kirby & Maraković, 1996; Thaler, 1981). For example, someone might prefer $10 now over $20 in 1 year. When both outcomes are increased by a factor of 10, however, the person may prefer $200 in 1 year to $100 now. Both of these choices offer a 100% increase in the monetary outcome in exchange for waiting 1 year, so normatively, preferences in the two choices should be consistent. The magnitude effect is characterized by less discounting of large outcomes than of small outcomes.

The magnitude of outcomes also influences choice under uncertainty, although fewer studies have been conducted to examine this effect. In the *peanuts effect*, increasing the magnitudes of the outcomes by a constant factor shifts preference to the smaller, more probable outcome from the larger, less probable outcome (Du, Green, & Myerson, 2002; Green, Myerson, & Ostaszewski, 1999; Holt, Green, & Myerson, 2003; Markowitz, 1952; Myerson et al., 2003; Rachlin, Brown, & Cross, 2000). That is, decision makers are more willing to take risks for small stakes ("peanuts"). For example, someone might prefer a 50% chance of $2 to a 100% chance of $1. When both outcomes are increased by a factor of 100, however, the person might prefer $100 for sure over a 50% chance of $200. Both choices offer the chance of twice the money in exchange for a probability that is half as great. Under constant risk aversion (i.e., the same amount of risk aversion at all points on the utility curve), expected utility theory would prescribe consistent preferences across the two choices.

Both the magnitude effect and the peanuts effect demonstrate a change in preferences when the stakes are increased. In the magnitude effect, temporal discounting becomes less severe as the magnitude is increased. In the peanuts effect, risk aversion increases as the magnitude is increased. The magnitude and peanuts effects appear to run in opposite directions, if risk seeking corresponds to less temporal discounting (Du et al., 2002; Green et al., 1999; Holt et al., 2003; Myerson et al., 2003).

Psychophysical Account of the Biases

A psychophysical account offers a plausible account for the four parallels described. We use the term *psychophysi-*

cal, as Kahneman and Tversky (1984) do, to describe the shape of the function relating an objective attribute, such as dollars or probability, to a psychological dimension, such as utility or decision weights. The basic claim of this type of theory is that biases in intertemporal choice, as well as biases in choice under uncertainty, can be explained in terms of the psychophysical functions for three objective dimensions: money (or other sources of utility), probability, and time. Prelec and Loewenstein (1991; Loewenstein & Prelec, 1992) have offered a specific version of this type of account.

Each of the four decision biases just reviewed can be explained in terms of the psychophysics of one dimension. The common difference effect can be explained by the psychophysics of time. The difference between 0 and 1 year, for example, is more influential than is the difference between 2 and 3 years, even though the size of the difference (1 year) in each case is objectively the same. This explains why a decision maker might prefer, say, \$10 now to \$20 in 1 year but also might prefer \$20 in 3 years to \$10 in 2 years. This psychophysical function for time is captured by the hyperbolic discount function (Ainslie, 1975; Kirby & Maraković, 1995; Loewenstein & Prelec, 1992).

The common ratio effect can be explained by the psychophysical function for probability. For example, the ratio between probabilities of 50% and 25% is more influential than the ratio between 5% and 2.5%, even though the objective ratio is 2 in both cases. That is, doubling the probability to win from 25% to 50% has more of an effect on decision weights than does doubling from 2.5% to 5%. This explains why a decision maker might prefer a 50% probability of \$100 over a 25% probability of \$200 but also might prefer a 2.5% probability of \$200 over a 5% probability of \$100. This psychophysical function for probability is captured by prospect theory's decision weight function, which is steeper near certainty than at intermediate probabilities (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992).

The magnitude effect in intertemporal choice is explained by the psychophysical function for the payout. One might alternatively describe this psychophysical function as the utility function for money or some other payout attribute. Because of the curvature of the utility function, in a choice between monetary magnitudes of \$1,500 and \$1,000, for example, the monetary attribute has more influence on choice than it would in a choice between \$15 and \$10, even though the objective ratio is the same in both cases. That is, a certain shape of the utility function would imply that the 50% increase from \$1,000 to \$1,500 has more of an influence on utility (in ratio terms) than does the 50% increase from \$10 to \$15. This explains why a decision maker would be willing to wait a year to receive \$1,500, rather than \$1,000 now, but would be unwilling to wait a year to receive \$15, rather than \$10 now.

The psychophysics of money (or some other payout) should have a similar effect on risky decisions. Several authors have noted (Du et al., 2002; Green et al., 1999; Holt et al., 2003; Myerson et al., 2003; Prelec & Loewenstein, 1991) that the peanuts effect pattern found for risky decisions goes in the direction opposite to that of the magnitude effect in intertemporal choice. If decision makers are more willing to wait for large amounts than for small, one would think that a decision maker should be more willing to accept a risk for large amounts of money than for small amounts. That is, decision makers should be more likely to choose a 50% chance of \$200 over \$100 for sure (since the ratio between the two large monetary amounts seems large) than to choose a 50% chance of \$2 over \$1 for sure (since the ratio between the two small monetary amounts seems small). This choice pattern is the opposite of that for the peanuts effect, where decision makers are more willing to take risks for small stakes. Because few studies on the peanuts effect have been conducted, it was of considerable interest in the present study whether a peanuts effect or a *reverse peanuts effect* would obtain. A reverse peanuts effect would have the same explanation as the magnitude effect.

Predictions

The present experiments were performed to test predictions that follow from a psychophysical account. We predicted that biases that are explained by the psychophysics of the same dimension would be related—that is, correlated across subjects. That is, two biases that originate from the psychophysics of the same dimension should be related, whereas two biases that originate from the psychophysics of two different dimensions need not be related to one another.

A number of previous studies have been conducted to examine time preference and risk preference in the same subjects (Du et al., 2002; Green et al., 1999; Holt et al., 2003; Myerson et al., 2003; Richards, Zhang, Mitchell, & de Wit, 1999). These previous studies, however, have not examined the correlation in the sizes of *biases* in risky choice and intertemporal choice. Consequently, they have not tested the hypothesis that risky choice biases have the same mechanisms as biases in intertemporal choice. The present experiments are the first to do that.

The magnitude effect and the reverse peanuts effect both result, according to this account, from the psychophysics for money (or some other source of utility). Consequently, these two effects should be related. Subjects who show an especially large magnitude effect for money are expected also to show a larger than average reverse peanuts effect for money. The common difference effect and the common ratio effect, in contrast, have different explanations, according to the psychophysical account. The common difference effect results from the psychophysics of time, whereas the common ratio effect results from the psychophysics of probability. Because the two effects result from the psychophysical properties of two different dimensions, we predict that these two biases will be unrelated. The size of the common difference effect will not be correlated across subjects with the size of the common ratio effect.

In the present experiments, we examined both decisions for monetary outcomes and decisions for health outcomes (relief from headache pain). The use of two value dimensions allowed us to make another set of predictions. Two value dimensions need not have the same psychophysical function. That is, a person's utility function for monetary outcomes need not have the same shape as the person's utility function for health outcomes. For this reason, we predicted that the magnitude effect for money decisions would not be related to the magnitude effect for health decisions. Similarly, the reverse peanuts effect for money decision would be unrelated to the reverse peanuts effect for health decisions. Both of these biases can be explained by the psychophysics of the value dimension; consequently, a change in the value dimension might result in a change in the size of the bias. Thus, the magnitude and reverse peanuts effects were not expected to be related across money and health decisions.

The common difference and common ratio effects, in contrast, were expected to be related across money and health decisions. These effects are explained in terms of the psychophysics of time and probability, respectively. When the value dimension is shifted from money to health, the time or probability dimension does not change. We therefore predicted that the common difference effect for health would be correlated across subjects with the common difference effect for money. Likewise, the common ratio effect for health should be correlated across subjects with the common ratio effect for money.

These predictions are shown in Tables 1A and 1B. Table 1A shows the predictions for the common difference and common ratio effects. We expected high correlations within a bias across value dimensions but low correlations within a value dimension but across biases. Table 1B shows the predictions for the magnitude and reverse peanuts effects. This predicted pattern is the opposite of that shown in Table 1A. We expected high correlations within a value dimension across biases but low correlations within a bias across value dimensions. The predictions in Table 1A were tested in Experiment 1, whereas those in Table 1B were tested in Experiment 2.

EXPERIMENT 1

In Experiment 1, we examined the common difference and common ratio effects. Subjects answered health and money choice questions designed to reveal these effects. We calculated the size of each effect in each domain (health and money) and computed correlations between effect sizes across subjects.

Method

Subjects. The study subjects were 102 undergraduates who participated in a computer-based study for partial fulfillment of the requirements of an introductory psychology class at Rutgers University.

Scenarios. The decisions presented to the subjects were embedded in two scenarios. One concerned monetary outcomes, and the other health outcomes. Within each scenario, the subjects made some choices under uncertainty and some intertemporal choices. The monetary scenario read as follows:

> Imagine that on the same day each month you receive a paycheck for \$500. Tomorrow is the day you will receive this month's paycheck. You have been randomly chosen to receive a one-time bonus over and above this \$500.

Table 1A
Predicted Correlations Between the Common Ratio and the Common Difference Effects

	Money		Health	
Domain	Common Ratio Effect for Risk	Common Difference Effect for Time	Common Ratio Effect for Risk	Common Difference Effect for Time
Money				
Common ratio		low	high	
Common difference				high
Health				
Common ratio				low
Common difference				

Table 1B
Predicted Correlations Between the Magnitude and the Reverse Peanuts Effects

	Money		Health	
Domain	Magnitude Effect for Time	Peanuts Effect for Risk	Magnitude Effect for Time	Peanuts Effect for Risk
Money				
Magnitude effect		high	low	
Reverse peanuts effect				low
Health				
Magnitude effect				high
Reverse peanuts effect				

For choices under uncertainty, the subjects were then told the following:

> The bonus will be added to the paycheck you receive tomorrow. It will not apply to any other paychecks. The size of the bonus that will be added to this paycheck will be either the outcome of a gamble or a certain increase. You should choose which of the two options you would prefer.

For intertemporal choices, the subjects were told the following:

> Your bonus will either be added to the paycheck you receive tomorrow, or it will be added to a paycheck that you will receive in the future: It is certain that you will receive the specified amount with the paycheck indicated. However, the bonus will apply to that one paycheck only. You should choose which of the two options you would prefer.

The health scenario read as follows:

> Imagine that once every month, on the same day each month, you get a headache. Tomorrow is the day you will experience this month's headache. The headache involves severe pain that lasts 24 hours.

For choices under uncertainty, the subjects were then told the following:

> You are being given a one-time opportunity to decrease the number of hours that your next 24-hour headache will last. The decrease will apply only to the headache you experience tomorrow. The number of hours this headache will be decreased will be either the outcome of a gamble or a certain decrease. You should choose which of the two options you would prefer.

For intertemporal choices, the subjects were told the following:

> You are being given a one-time opportunity to decrease the number of hours that one of your 24-hour headaches will last—either your next headache or a headache that occurs in the future. Either way, it is certain that you will receive the specified decrease at the time indicated. However, the decrease will apply to only that one headache. You should choose which of the two options you would prefer.

Design. The subjects completed four blocks of choices: monetary choices under uncertainty, monetary intertemporal choices, health choices under uncertainty, and health intertemporal choices. The order of the four blocks was randomized for each subject.

Each block contained four questions. Each question, in turn, consisted of a series of choices designed to identify an indifference point. Two of the four questions in each block were fillers and will not be analyzed here. The remaining two questions in each block made up the present experiment and are shown in Table 2. The questions in the choice under uncertainty blocks assessed the common ratio effect, whereas those in the intertemporal choice blocks assessed the common difference effect.

Two questions were used to assess each bias. The Level 1 question contained a higher probability or shorter delay than did the Level 2 question. For the common ratio effect questions, the probabilities in Level 2 were one fourth those in Level 1. For the common difference effect questions, the delays in Level 2 were 4 months longer than those in Level 1. Technically speaking, the question pairs did not comprise the common difference effect (because they did not use the same choice pair after a 4-month delay was added to both options) or the common ratio effect (because they did not use the same choice pair after the probability to win for both options was divided by 4).[1] They did, however, assess whether risk seeking increased when probabilities were reduced and whether time discounting became less steep when delays increased. These are the patterns that correspond to the common ratio and common difference effects.

The subjects were randomly assigned to one of two conditions that determined the exact monetary or headache payoff that was presented. For half the subjects, the uncertain outcomes were 1.0473 times the values shown in Table 2, and the delayed outcomes were 0.9527 times the values shown in Table 2. The remaining subjects saw uncertain outcomes that were 0.9527 times those shown in Table 2 and delayed outcomes that were 1.0473 times those shown in Table 2. The purpose of this weighting system will become apparent in Experiment 2, where it was necessary to reduce the similarity between outcomes presented in the intertemporal choices and choices under uncertainty. The weighting system was not strictly necessary in Experiment 1 but was employed in order to make the procedures for the two experiments comparable.

Table 2
Questions Included in Experiment 1

Effect	Domain: Money	Domain: Health
Common ratio effect for risk		
Level 1	80% chance of \$154	80% chance of 11.90-h reduction
Level 2	20% chance of \$154	20% chance of 11.90-h reduction
Common difference effect for time		
Level 1	\$110 in 1 month	8.50-h reduction in 1 month
Level 2	\$110 in 5 months	8.50-h reduction in 5 months

Indifference points. For each uncertainty question, we identified a certainty equivalent—that is, the amount of money (or headache relief) to be received for certain that was just as good as the uncertain amount. For the intertemporal questions, we identified the present value—that is, the amount of money (or headache relief) to be received now that was just as good as the delayed amount. Certainty equivalents and present values were identified via a series of choices, using a bisection algorithm where the certain or immediate amount was adjusted in response to the subject's previous choice. The first choice in each series presented the gamble or delayed amount versus a certain or immediate amount. For example, for the first question shown in Table 1, the first choice in the series would be a choice between an 80% chance of \$154 and \$77 for sure (\$77 being the midpoint between \$0 and \$154). If the subject chose the gamble, indicating that \$77 was too low to be the certainty equivalent to the gamble, the certain amount was increased on the next trial to \$115.50 (the midpoint between \$154 and \$77); but if the subject chose the certain amount on the first choice, indicating that \$77 was too high to be the certainty equivalent, the certain amount on the second choice would be \$38.50 (the midpoint between \$77 and \$0). Titration choices for the intertemporal choice questions proceeded the same way, with choices between a delayed amount and an immediate amount. The immediate amount presented on the first choice of each series was the midpoint between \$0 and 1.5 times the delayed amount, in order to allow for negative discounting. Each titration series continued for six choices, and the indifference point was assumed to be the certain or immediate amount that would have been presented on a seventh choice. Thus, indifference points were identified to within a margin of 3.1% of the risky payout for the risky questions and 4.7% of the delayed payout for the intertemporal questions. Previous studies have shown that certainty equivalents obtained through this type of choice procedure are more reliable (i.e., less prone to preference reversals) than are judged certainty equivalents (Bostic, Herrnstein, & Luce, 1990; Tversky, Sattath, & Slovic, 1988).

Check questions. After a certainty equivalent or present value had been identified, the subject was presented with two check questions that presented a certain or immediate amount slightly higher or lower than the inferred indifference point. If a subject's response to either check question was inconsistent with the estimated indifference point, a message box was displayed informing the subject that he or she had responded inconsistently, and the series of choices was presented again from the beginning. Each question was repeated until the subject produced a consistent series of responses or until the question had been presented three times.

One subject who failed to produce a consistent answer on seven of the eight questions was excluded from analysis. Seven other subjects failed to produce a consistent answer on one of the eight questions, and two more failed to produce consistent answers on two questions. In these cases, the indifference point estimated from the most recent repetition of the question was used as the subject's indifference point.

Procedure. Each subject completed a Web-based questionnaire from a campus computer center or library. After the subject had finished reading some instructions, a new browser window opened, showing two sections. In the top half of the window, a description of the current scenario appeared. In the bottom half, the choices were presented to the subject, one choice at a time. The two options for the current choice were presented side by side, with radio buttons under each option. The subject could click on the buttons to select his or her preferred option, then click on a larger button labeled "Make Your Choice" to finalize the decision, at which point the next choice in the series was presented.

Results and Discussion

To determine whether the subjects were attending to and understanding the task, we compared the responses for the two levels of the common ratio effect questions for each subject. A certainty equivalent for the lower probability level that was greater than or equal to that of the higher probability level for either of the two questions indicated a violation of dominance (e.g., placing a higher value on a 20% chance of $154 than on an 80% chance of $154). Each subject had two opportunities to violate dominance, and the 23 subjects who showed one or more dominance violations were eliminated from data analysis.[2] With these 23 subjects eliminated and 1 subject (described earlier) eliminated for failing to make consistent choices on seven of the eight questions, 78 subjects were retained in the analyses.

We first tested to see whether each of the two decision biases occurred in the money and health domains. We then quantified the size of the decision biases and computed correlations between the sizes of the two biases in each domain.

In order to identify whether each decision bias had occurred, we compared the mean observed certainty equivalent or present value for the Level 2 question with the certainty equivalent or present value for Level 2 that would normatively be predicted on the basis of responses to the Level 1 question. For risky choices, a Level 2 response that was larger than would be predicted on the basis of the Level 1 question indicated more risk seeking or less risk aversion for smaller probabilities. For intertemporal choices, a Level 2 response that was larger than would be predicted on the basis of the Level 1 question indicated a lower temporal discount rate for longer delays.

As is shown in Table 3, the predicted and observed values were compared with a 2 (predicted vs. observed) $\times$ 2 (weight condition) mixed ANOVA with repeated measure on the first factor. For example, consider the questions that assessed the common ratio effect in the monetary domain. For Weight Condition 1, the Level 1 question presented a gamble with an 80% chance of winning $146.72. The mean certainty equivalent assigned to this gamble, $93.99, is smaller than the EV of $117.38, indicating risk aversion. The Level 2 question presented a gamble with a 20% chance to win $146.72. This gamble is the same as the first, except that the probability has been reduced by a factor of 4. The mean certainty equivalent for this gamble, $29.89, is a little larger than the EV of $29.34, indicating risk seeking. Thus, decision makers switched from risk aversion to risk seeking when the probability to win was reduced by a common factor. We compared the certainty equivalent assigned to the Level 2 gamble to one fourth of that assigned to the Level 1, or $23.49.[3] This is the value that we would normatively expect if money were linear in utility. If the utility function for money is risk averse (as the Level 1 responses imply), we would normatively expect a Level 2 certainty equivalent even smaller than $23.49. The mean observed Level 2 certainty equivalent was actually larger than that ($29.89). The same pattern

Table 3
Bias Results From Experiment 1

	Level 1			Level 2						
		CE or PV			Predicted† CE or PV		Observed CE or PV			
Domain	Uncertain or Delayed Outcome	*M*	*SD*	Uncertain or Delayed Outcome	*M*	*SD*	*M*	*SD*	$F(1,76)$‡	MS_e
Common Ratio Effect for Risk										
Money (in dollars)										
Weight Condition 1	80%, 146.72	93.99	29.06	20%, 146.72	23.49	7.26	29.89	20.66	12.07**	225.31
Weight Condition 2	80%, 161.28	113.23	30.67	20%, 161.28	28.31	7.68	39.19	24.43		
Health (in hours)										
Weight Condition 1	80%, 11.34	7.04	2.39	20%, 11.34	1.76	0.60	2.61	1.94	12.12**	2.07
Weight Condition 2	80%, 12.46	8.91	2.47	20%, 12.46	2.23	0.62	3.04	2.45		
Common Difference Effect for Time										
Money (in dollars)										
Weight Condition 1	1 month, 115.20	96.70	26.01	5 months, 115.20	71.77	44.02	87.45	33.13	38.18**	293.04
Weight Condition 2	1 month, 104.80	77.66	28.19	5 months, 104.80	47.45	41.66	66.83	31.55		
Health (in hours)										
Weight Condition 1	1 month, 8.90	6.18	2.72	5 months, 8.90	3.83	4.02	5.77	2.88	34.92**	3.58
Weight Condition 2	1 month, 8.10	5.17	2.27	5 months, 8.10	2.47	2.93	4.23	2.21		

Note—CE, certainty equivalent; PV, present value. †Predicted Level 2 responses for each subject for the common ratio effect were computed by dividing the Level 1 response by a factor of 4. For the common difference effect, predicted Level 2 responses were computed by applying the monthly discount rate exhibited in Level 1 responses. ‡Main effect of predicted versus observed in a 2 (predicted vs. observed) $\times$ (weight condition) ANOVA. All differences are in the predicted direction. $^*p < .05$. $^{**}p < .001$.

was observed for Weight Condition 2 [main effect of predicted vs. observed value, $F(1,76) = 12.07$, $MS_e = \$225.31$, $p < .001$]. Since larger certainty equivalents indicate more risk-seeking risk preferences, the comparison between the predicted and the observed Level 2 certainty equivalents indicates that the subjects were more risk seeking for small probabilities than for large probabilities, the pattern that characterizes the common ratio effect. The analogous health questions also showed more risk seeking for small than for large probabilities. Sixty-four percent of the subjects showed the common ratio effect in the money domain, and 65% showed it in the health domain.

Table 3 also shows the results for the common difference effect. For example, consider the Level 1 health question for Weight Condition 1, which presents an 8.90-h reduction in the headache that occurs in 1 month. The mean present value assigned to this outcome was 6.18 h, reflecting a 44% monthly discount rate. The Level 2 question presents an 8.90-h reduction to the headache in 5 months. Normatively, the same monthly discount rate should be applied; thus, the present value would be expected to be 3.83 h for the average subject.[4] Actually, the observed present value for the Level 2 question was much larger—5.77 h, representing only a 9% monthly discount rate. Larger present values indicate less temporal discounting; thus, the response pattern indicates less discounting over long delays than over short delays. This pattern characterizes the common difference effect. Responses in the other weight condition showed a similar pattern [main effect of predicted vs. observed values, $F(1,76) = 34.92$, $MS_e = 3.58$, $p < .001$], as did responses in the analogous money domain. Sixty-eight percent of the subjects showed the common difference effect in the money domain, and 74% showed it in the health domain.

The size of each effect in each domain was quantified for each subject by taking the difference between the predicted Level 2 response and the observed Level 2 response.[5] These effect sizes were submitted to correlational analysis. Four correlations were computed: correlations between the two biases in each of the two domains and

Table 4A
Observed Spearman Correlations (With 95% Confidence Intervals, in Parentheses) Between the Common Ratio and Common Difference Effects in Experiment 1

	Money		Health	
Domain	Common Ratio Effect for Risk	Common Difference Effect for Time	Common Ratio Effect for Risk	Common Difference Effect for Time
Money				
Common ratio		.02 (−.21–.24)	.32* (.10–.51)	
Common difference				.21** (−.02–.41)
Health				
Common ratio				−.15 (−.36–.07)
Common difference				

Note—$N = 78$ for all correlations. Positive correlations are in the predicted direction. *$p < .05$. **$p = .07$.

Table 4B
Observed Spearman Correlations (With 95% Confidence Intervals, in Parentheses) Between the Magnitude and the Peanuts Effects in Experiment 2

	Money		Health	
Domain	Magnitude Effect for Time	Peanuts Effect for Risk	Magnitude Effect for Time	Peanuts Effect for Risk
Money				
Magnitude effect		.13 (−.04–.30)	.07 (−.10–.24)	
Peanuts effect				.09 (−.08–.26)
Health				
Magnitude effect				.25* (.08–.40)
Peanuts effect				

Note—$N = 133$ for all correlations. Positive correlations are in the predicted direction. *$p < .05$.

correlations of each bias across domains. The predictions about the correlations are shown in Table 1A, and the actual correlations are shown in Table 4A.

The pattern of correlations was as predicted by the psychophysical account. The size of the common ratio effect in monetary decisions was correlated with the size of the common ratio effect in health decisions (Spearman r_s = .32, N = 78, p = .004). Because this effect results from the psychophysics of probability weighting and because probabilities are the same in the money and the health domains, this bias was expected to correlate across domains. Similarly, the size of the common difference effect in monetary decisions was marginally correlated with the size of the common difference effect in health decisions (r_s = .21, N = 78, p = .07). Because this effect results from the psychophysics of time delay weighting and because time delays are the same in the money and health domains, this bias was also expected to correlate across domains.

The common ratio and common difference effect sizes were not correlated with each other in either domain (r_ss < .02). The former bias results from the psychophysics of probability, and the latter bias results from the psychophysics of time. Because these two biases derive from the psychophysical properties of different dimensions, these two biases were not expected to be correlated, according to the psychophysical account.

We also subjected the common ratio and common difference effect sizes for health and money to a principal components analysis with varimax rotation. Two factors accounted for 73% of the variance. As is shown in Table 5A, the common difference effect sizes for health and money loaded on the first factor (factor loadings > .60), whereas the common ratio effect sizes for health and money loaded on the second factor (factor loadings > .70). Thus, this analysis supported the predicted patterns of correlations.

The results pattern obtained here supports the notion that a common set of psychophysical principles underlies biases in both risky choice and intertemporal choice. Because the common ratio and common difference effects derive from psychophysical principles of two different dimensions, these two effects are separate phenomena and not simply two manifestations of the same bias.

Table 5A
Rotated Principal Components Factor Loadings for Experiment 1 (N = 78)

Variable	Factor: Probability	Factor: Time
Common ratio effect, health	.78	.06
Common ratio effect, money	.75	−.08
Common difference effect, health	.20	.86
Common difference effect, money	−.42	.62

Table 5B
Rotated Principal Components Factor Loadings for Experiment 2 (N = 133)

Variable	Factor: Health	Factor: Money
Health magnitude effect	.80	−.28
Health reverse peanuts effect	.67	.25
Money magnitude effect	.43	.41
Money reverse peanuts effect	−.04	.89

EXPERIMENT 2

In Experiment 2, we examined the magnitude and reverse peanuts effects. Our predictions for these effects are the mirror image of those for Experiment 1. As is shown in Table 1B, the psychophysical account predicts that the size of the magnitude effect for money will be correlated with that of the reverse peanuts effect for money. Similarly, the two effects should be correlated in the health domain. In contrast, neither effect is expected to correlate across domains. The explanation for both the magnitude effect and the reverse peanuts effect is the psychophysical properties of the utility dimension (money or health). If the psychophysics of money (or health) produce a strong magnitude effect, those same psychophysical properties should produce a reverse peanuts effect in money (or health). Because the psychophysics of money need not mirror the psychophysics of health, there is no reason to expect that either bias will be correlated across domains.

Method

Subjects. The study subjects were 145 Rutgers University undergraduates who participated for partial fulfillment of the requirements of an introductory psychology class.

Procedure. The procedure was the same as that in Experiment 1, except for the questions included. Table 6 shows the eight questions included in Experiment 2. Unlike Experiment 1, this experiment contained no filler questions, in order to shorten the experiment.

Experiment 2 also differed from Experiment 1 in that comprehension check questions were included to ensure that the subjects understood the scenarios. After reading each scenario and before making choices, the subjects answered three comprehension questions. For example, in the monetary scenario for choices under uncertainty, the subjects had to report that each paycheck was $500 and that the next paycheck would arrive tomorrow.

As in Experiment 1, the subjects were randomly assigned to one of two weight conditions that determined the exact monetary or headache payoff that was presented. For half the subjects, the uncertain outcomes were 1.0427 times the values shown in Table 6, and the delayed outcomes were 0.9527 times the values shown in Table 6. Weights for the remaining subjects were the reverse. The purpose of this weighting system was to reduce the similarity between outcomes presented in the intertemporal choices and the choices under uncertainty. Both types of choices used payouts that varied by a factor of 8 across levels, and the specific payouts were exactly the same for the magnitude and the reverse peanuts effects. To reduce the likelihood that the subjects would notice that the same payouts were being repeated across questions, the exact value of the payouts was varied slightly, using the weight conditions.

Results

As in Experiment 1, we examined the subjects' responses and eliminated subjects who displayed dominance violations. In Experiment 2, there were four opportunities

Table 6
Questions Included in Experiment 2

Effect	Domain: Money	Domain: Health
Reverse peanuts effect for risk		
Level 1	60% chance of $33.11	60% chance of 2.56-h reduction
Level 2	60% chance of $264.88	60% chance of 20.48-h reduction
Magnitude effect for time		
Level 1	$33.11 in 4 months	2.56-h reduction in 4 months
Level 2	$264.88 in 4 months	20.48-h reduction in 4 months

to display dominance violations: For both the reverse peanuts and the magnitude effect questions, responses should increase as the magnitude of the payout increased. For example, a 60% chance of $264.88 should be valued higher than a 60% chance of $33.11. Nine subjects were eliminated for one or more dominance violations. An additional 3 subjects were eliminated because they failed to produce consistent answers on three questions (i.e., failed the check items at the end of the choice series three times for each of three questions). Twenty other subjects failed to produce a consistent answer on one or two of the eight questions. These subjects were retained in the analysis, and the indifference point estimated from the most recent repetition of the question was used as the subject's indifference point. Thus, 12 of the 145 subjects were eliminated, leaving 133 subjects in the analyses.

We first examined whether the magnitude and reverse peanuts effects occurred. As in Experiment 1, we calculated the response to the Level 2 question that would be normatively predicted on the basis of the response to the Level 1 question (see Table 7). We then compared that predicted response with the observed response on the Level 2 question.

Consider the reverse peanuts effect in the money domain for Weight Condition 1. The Level 1 question presented a 60% chance to gain $31.54. The mean certainty equivalent assigned to this lottery was $16.88. The Level 2 lottery was a 60% chance to win $252.35, a payout that is eight times larger than the Level 1 payout. Normatively (under constant risk aversion), we would therefore expect the Level 2 certainty equivalent to be eight times the Level 1 certainty equivalent, or $135.08. The observed Level 2 certainty equivalent was very close—$135.82, a value that was not significantly different from the predicted value. Thus, no peanuts or reverse peanuts effect occurred. The reverse peanuts effect would be characterized by a Level 2 certainty equivalent that is larger (indicating more risk seeking) than would be expected from the Level 1 response. The observed nonsignificant difference was in this direction, but for Weight Condition 2, the nonsignificant difference was in the opposite direction, that of a peanuts effect. In the health domain, the observed Level 2 certainty equivalent was slightly larger than the predicted value (in the direction of a reverse peanuts effect), but not significantly so (see Table 7). Fifty percent of the subjects showed the reverse peanuts effect in the money domain; in the health domain, 59% did so.

The magnitude effect did occur in both health and money intertemporal decisions. In the money domain with Weight Condition 1, the Level 1 question presented $34.52 to be received in 4 months. The mean present value was $24.32. The Level 2 question presented an outcome eight times greater: $277.41 to be received in 4 months. If the same temporal discount rate were applied to both questions, the present value for Level 2 would be predicted to be $194.57 (eight times the Level 1 present value). The observed Level 2 present value was larger, however ($219.56), indicating less temporal discounting

Table 7
Bias Results From Experiment 2

Domain	Level 1: Uncertain or Delayed Outcome	Level 1: CE or PV *M*	Level 1: CE or PV *SD*	Level 2: Uncertain or Delayed Outcome	Level 2: Predicted† CE or PV *M*	Level 2: Predicted† CE or PV *SD*	Level 2: Observed CE or PV *M*	Level 2: Observed CE or PV *SD*	$F(1,131)$‡	MS_e
Reverse Peanuts Effect for Risk										
Money (in dollars)										
Weight Condition 1	60%, 31.54	16.88	6.20	60%, 252.35	135.08	49.61	135.82	55.82	0.55	1,161.73
Weight Condition 2	60%, 34.52	17.29	8.24	60%, 277.41	138.34	65.92	131.41	81.94		
Health (in hours)										
Weight Condition 1	60%, 2.44	1.30	0.58	60%, 19.51	10.41	4.61	11.40	4.15	1.92	12.48
Weight Condition 2	60%, 2.68	1.52	0.74	60%, 21.45	12.15	5.91	12.36	5.39		
Magnitude Effect for Time										
Money (in dollars)										
Weight Condition 1	4 months, 34.52	24.32	8.01	4 months, 277.41	194.57	64.09	219.56	72.24	20.95**	1,159.37
Weight Condition 2	4 months, 31.54	22.80	7.93	4 months, 252.35	182.46	63.49	195.70	69.68		
Health (in hours)										
Weight Condition 1	4 months, 2.68	1.77	0.74	4 months, 21.45	14.12	5.90	15.28	5.53	4.85*	10.17
Weight Condition 2	4 months, 2.44	1.72	0.66	4 months, 19.51	13.79	5.32	14.36	5.57		

Note—CE, certainty equivalent; PV, present value. †Predicted Level 2 responses for each subject were computed by multiplying the Level 1 response by a factor of 8. ‡Main effect of predicted versus observed in a 2 (predicted vs. observed) × (weight condition) ANOVA. All significant effects are in the predicted direction. *$p < .05$. **$p < .001$.

of larger magnitude outcomes. This pattern characterizes the magnitude effect. The same pattern was observed in the other weight condition and in health decisions. Sixty-nine percent of the subjects showed the magnitude effect in the money domain; in the health domain, 56% did so.

The size of each effect for each domain and each subject was computed as in Experiment 1. Note that although the mean size of the reverse peanuts effect was near zero, there was still variation in effect size across subjects. Consequently, we could compute correlations between effects and domains.

Table 1B shows the predicted correlation pattern, and Table 4B shows the obtained correlations. As was predicted, the size of the magnitude effect in the health domain was correlated with the size of the reverse peanuts effect in the health domain (Spearman $r_s = .25$, $N = 133$, $p = .0004$). The direction of this correlation was that predicted by the psychophysical account. Specifically, the subjects who showed a large magnitude effect were more likely to show a reverse peanuts effect than were the subjects who showed a small magnitude effect. The reverse peanuts and magnitude effects were not significantly correlated in the money domain, however ($r_s = .13$, $N = 133$, $p = .13$).

The size of the magnitude effect for money was unrelated to the size of the magnitude effect for health. Similarly, the size of the reverse peanuts effect for money was not correlated with the size of the reverse peanuts effect for health (r_ss $\leq .09$, ps $> .28$). Because different utility functions apply for health and money, these effects were not expected to show consistency across domains. Thus, the pattern of correlations was generally that predicted by the psychophysical account, but the pattern was not as robust as that seen in Experiment 1.

We subjected the magnitude and reverse peanuts effect sizes for health and money to a principal components analysis with varimax rotation. Two factors accounted for 59% of the variance. As is shown in Table 5B, the magnitude and reverse peanuts effects for health loaded on the first factor (factor loadings $> .67$). The magnitude effect for money loaded on the second factor (factor loading $=$ .89), whereas the reverse peanuts effect for money loaded evenly on the two factors (factor loadings $= .42$ and .41, respectively). When two outliers were removed, both the magnitude effect for money and the reverse peanuts effect for money loaded onto one factor (loadings $> .69$, with loadings on the alternate factor of $< .19$), with the two health biases loading onto the other factor (loadings $>$ .77, with loadings on the alternate factor of $< .06$). Thus, the four effects were divided into two factors—one for health and one for money. This result is consistent with the fact that three of the four correlations fit the pattern predicted by the psychophysical account.

Discussion

Experiment 2 revealed a magnitude effect similar to that seen in previous studies (Benzion et al., 1989; Chapman, 1996, 1998; Chapman & Elstein, 1995; Chapman & Winquist, 1998; Green et al., 1997; Kirby & Maraković, 1996; Thaler, 1981). Large magnitude outcomes were discounted less steeply than were small magnitude outcomes. Although time preferences varied with outcome magnitude in this experiment, risk preferences did not. Neither a peanuts effect nor a reverse peanuts effect occurred. The 8-fold difference in outcome magnitude may not have been sufficient to reveal an effect on risk preferences. In a subsequent study (Weber & Chapman, 2005), we found a peanuts effect with a 100-fold range in outcome magnitudes. Similarly, Myerson et al. (2003) found a peanuts effect with a 200-fold range in outcome magnitudes.

One might wonder why the reverse peanuts effect did not occur, given that the magnitude effect did occur. Prelec and Loewenstein (1991) proposed that the psychophysical properties of money that produce a magnitude effect and should produce a reverse peanuts effect are counteracted by a second factor—specifically, disappointment (Bell, 1985). With larger magnitude payouts, decision makers become more focused on the probability of obtaining the better outcome (and thus avoiding the disappointment of obtaining the worse outcome). Consequently, decision makers become more risk averse as outcome magnitude increases.

Given that the reverse peanuts effect apparently does not occur and that a theoretical account for this nonoccurrence can be offered outside the framework of the psychophysical account, why does it make sense to examine the relationship between the reverse peanuts effect and the magnitude effect? We argue that the effect of payout magnitude on risk preferences is governed by the combination of two factors. One is the psychophysics of money (or health), which pushes the preference pattern toward a reverse peanuts effect. The second is the amount of anticipated disappointment (or a similarly functioning factor), which pushes the preference pattern toward a peanuts effect. Because variation across subjects in the size and direction of the peanuts effect is determined, in part, by the psychophysical properties of the utility dimension (and in part, by the amount of anticipated disappointment), it is legitimate to examine the correlation between the sizes of the reverse peanuts and the magnitude effects. The correlation between the two biases suggests that the two result from a common factor (in addition to other factors that may differ between the biases). According to the psychophysical account, this common factor is the psychophysics of the utility function of the payout dimension. This two-factor account of the reverse peanuts effect would explain why the correlation pattern in Experiment 2 was weaker than that in Experiment 1.

The failure to find a reverse peanuts effect is a puzzle for any account that draws parallels between risky choice and intertemporal choice (e.g., Green & Myerson, 2004). If the present study had not revealed the predicted correlation pattern, one might conclude that risky choice and intertemporal choice biases are actually not parallel, thus explaining why the peanuts effect and the magnitude effect go in opposite directions. The fact that the present study *did* show the predicted correlation pattern supports the conclusion that risk and intertemporal choice biases are parallel in some manner due to psychophysics, thus requiring some additional nonpsychophysical explanation for why the reverse peanuts effect does not occur. This two-factor account is not very parsimonious, but it seems to be required by the data. In another study (Myerson et al., 2003), both the magnitude effect and the peanuts effect have been examined in the same experiment. Unlike in the present experiment, Myerson and colleagues assessed both effects in the monetary domain only. In addition, although these authors examined the correlation between risk preference and time preference, finding that steep temporal discounting was weakly associated with risk aversion, they did not examine the correlation between the sizes of the magnitude and the peanuts effects across subjects.

In order to compare the data from the present experiments with those from previous studies (Myerson et al., 2003; Richards et al., 1999), we examined the correlation between risk preference and time preference in the present experiments. Experiments 1 and 2 each elicited four time preference indifference points (Level 1 and Level 2 for health and money) and four risk preference indifference points. The Level 1 and Level 2 indifference points were first standardized by dividing by the risky or the delayed amount (as in Myerson et al., 2003) and then averaged together.[6] This resulted in four standardized indifference points for each experiment (money and health discounted for risk and time delay), among which correlations were computed.

Table 8 shows four correlations of interest for each experiment. The top of the table shows correlations between intertemporal indifference points and uncertainty indifference points, separately for money and heath outcomes. Positive correlations indicate that steep temporal discounting is associated with risk aversion. In line with previous studies (Myerson et al., 2003; Richards et al., 1999), these correlations were weak to moderate. For comparison purposes, the bottom of Table 8 shows correlations of risk preference for money with risk preference for health and of time preference for money with time preference for health. These correlations are notably larger. This type of comparison was not available in previous studies (Myerson et al., 2003; Richards et al., 1999), since they did not use both health and money domains.

GENERAL DISCUSSION

The results of the present experiments support the psychophysical account of parallels between biases in intertemporal choice and choice under uncertainty. According to this model, the four biases examined in the present experiments result from the psychophysical properties of time, probability, and utility dimensions, such as money and health.

In Experiment 1, the common difference effect for money was marginally correlated with the common difference effect for health. Similarly, the common ratio effect for money was correlated with the common ratio effect for health. In contrast, the common difference effect was not correlated with the common ratio effect in either the health or the money domain. This pattern suggests that the common difference and common ratio effects have different causes, based on the fact that they are uncorrelated. Furthermore, the common difference effect is due to a factor that is consistent across health and money decisions. According to the psychophysical account, that consistent factor is a psychophysical property of time delay. The common ratio effect is also due to a factor that is consistent across domains, which, according to the psychophysical account, is a psychophysical property of probability. Thus, the common difference and common ratio effects result from the psychophysical properties of different attributes.

In Experiment 2, the magnitude and reverse peanuts effects were examined. These two effects were correlated with each other in the health domain. In contrast, the magnitude effect for money was unrelated to the magnitude effect for health. Similarly, the reverse peanuts effect for money was not correlated with the reverse peanuts effect for health. This pattern indicates that both biases are due to a factor that is consistent across intertemporal and risky decisions but is not consistent across health and money domains. According to the psychophysical account, this factor is the shape of the utility functions for health or money. As was discussed in Experiment 2, the correlation pattern emerged even though the reverse peanuts effect was not demonstrated by the majority of the subjects.

Not every correlation predicted to be high was significantly greater than zero (see Tables 4A and 4B). We therefore conducted an omnibus test that compared the four correlations in Tables 4A and 4B predicted to be high with the four correlations predicted to be low. The pooled Spearman correlation coefficient for the four correlations predicted to be high was .22 ($N = 211$, 95%CI .09–.34), whereas the pooled coefficient for the four correlations predicted to be low was .03 ($N = 211$, 95%CI $-$.11–.16). These two coefficients were significantly different from one another ($z = 2.78$, $p = .005$). Thus, the overall pattern of correlations shown in Tables 4A and 4B fits the predictions of the psychophysical account.

Table 8
Spearman Correlations (With 95% Confidence Intervals) Between Risk Preference and Time Preference

	Experiment 1 ($N = 78$)		Experiment 2 ($N = 133$)	
	r_s	95%CI	r_s	95%CI
Money (risk vs. delay)	.18	($-$.05–.38)	.22*	(.05–.37)
Health (risk vs. delay)	.07	($-$.15–.29)	.37**	(.21–.50)
Risk (money vs. health)	.42**	(.21–.58)	.61**	(.49–.71)
Delay (money vs. health)	.74**	(.61–.82)	.68**	(.58–.76)

*$p < .05$. **$p < .0001$.

Parallels Between Risk and Time

Several parallels have been suggested between risky choice and choice over time. Rachlin and colleagues (Rachlin et al., 1986; Rachlin et al., 1991) argued that probability weighting is derivative of time discounting, because the lower the probability, the more plays of the gamble, on average, are needed before a winning outcome is obtained and, hence, the longer the delay. Keren and Roelofsma (1995) proposed that time discounting is derivative of probability weighting, because time delay entails uncertainty and longer delays entail more uncertainty than do short delays.

The present results represent a challenge to the idea that risk and delay are somehow psychologically equivalent. Experiment 1 indicates that the common difference and common ratio effects are not the same phenomenon but result from the psychophysical properties of different dimensions (time and probability). In addition, the correlations shown in Table 8 indicate that the relationship between risk preference and time preference is weaker than that between two risk preferences or two time preferences. The present results instead suggest that probability and time correspond to separate psychological dimensions.

Two alternative accounts of the results deserve consideration. One possibility is that the correlations between biases observed in the present study are due to the specific stimuli and design used, rather than to a more general mechanism. In Experiment 1, each block of questions varied either probability level or delay. This might have caused the subjects to form a consistent policy for responding to changes in delay (or probability) that they applied to both the money and the health blocks, thus resulting in the common different effect (or common ratio effect) correlating across money and health. In contrast, in Experiment 2, each block of questions varied payout magnitude, which may have caused the subjects to form a consistent policy for responding to changes in money (or health) magnitude, thus resulting in the magnitude effect correlating with the peanuts effect. Because examination of the common difference and common ratio effects requires variation in delay and probability values, and because examination of the magnitude and peanuts effects requires variation in payout magnitude, this type of design is difficult to avoid. It is possible, however, that a study that combined all question types into one block might yield different results.

Another account to consider is the possibility that the reason the common difference effect is uncorrelated with the common ratio effect is not because the former rests on the time dimension and the latter on probability but, rather, because the former rests on the psychophysics of differences, whereas the latter rests on the psychophysics of ratios. Perhaps time and risk are translated into a single psychological dimension, but the way this dimension incorporates differences is independent of the way it incorporates ratios. This account is unlikely, however, because collapsing time and risk onto a single psychological dimension entails a nonlinear transformation of at least one objective dimension. For example, Myerson et al. (2003) equated risk and delay by first transforming probability into the log of odds against. This transformation changes the ratios on the probability scale into differences on the log odds against scale. Consequently, the common ratio and common difference effects would be explained in terms of the psychophysics of absolute differences on this common risk/time dimension. Such a common dimension account would predict that the two effects would be correlated, and the present results clearly contradict that prediction.

Potential Limitations

The present experiments have several potential limitations that should be considered. As in many studies of decision processes, these experiments used hypothetical scenarios and imaginary outcomes (paycheck increases and headache reduction). In addition, the monetary outcomes were gains (pay increases), whereas the health outcomes were foregone losses (headache reductions), making them not quite parallel. It is possible that different types of outcomes might lead to different results or that the use of real outcomes might have motivated more consistency and, hence, fewer biases.

Another potential limitation of the present experiments stems from the assumption of linear utility made in computing the size of the common ratio effect in Experiment 1. As was explained in Experiment 1 (see also notes 3 and 5), for the purposes of computing the predicted response to the Level 2 questions making up the common ratio effect, we assumed that money and hours of headache were linear in utility. In reality, utility functions are often nonlinear, frequently demonstrating diminishing marginal utility. This assumption, although certainly an oversimplification, is unlikely to have influenced the conclusions drawn from the present experiments. The average subject in Experiment 1 was risk averse for the Level 1 probabilities but risk seeking for the Level 2 probabilities. Thus, the utility function did not show a consistent curvature that would have caused a consistent over- or underestimation of the predicted Level 2 certainty equivalents.

Conclusion

The present experiments support the conclusion that the magnitude effect in intertemporal choice and the reverse peanuts effect in risky choice have a common mechanism located in the utility function. In contrast, the common difference effect in intertemporal choice and the common ratio effect in risky choice have different mechanisms that are located in the time and probability weighting functions, respectively. These biases are consequently consistent across different utility dimensions, a characteristic that is not true of the magnitude and reverse peanuts effects. A psychophysical account (e.g., Loewenstein & Prelec, 1992; Prelec & Loewenstein, 1991) provides an explanation for these findings. According to this account, the four effects are the result of psychophysical properties of the time, probability, and payout dimensions.

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NOTES

1. This design was employed because it allowed all questions to elicit certainty equivalents and present values. Pilot studies revealed that subjects found such questions easier to answer than questions that required comparing two uncertain or delayed outcomes (e.g., what amount x makes a 25% chance of \$$x$ equivalent to a 20% chance of \$154?).

2. The percentage of dominance violations found in Experiment 1 is comparable to that in other studies of time and risk preferences. For example, Ahlbrecht and Weber (1997) excluded 25 of 132 student subjects for one or more dominance violations.

3. Formally, if an 80% chance of winning \$146.72 is equivalent to \$93.99, a 20% chance to win \$146.72 should be equivalent to ¼ u(\$93.99), which may not be equal to u(\$23.49) if money is not linear in utility. Because participants were risk averse for large probabilities but risk seeking for small ones, however, the conclusion that the common ratio effect occurred cannot be attributed to the assumption of linear utility. A linear utility approximation was used for the analysis of Experiment 1 because it allowed all questions to elicit certainty equivalents and present values (see note 1).

4. Actually, applying a 44% monthly discount rate to 8.9 h delayed by 5 months would result in a present value of 1.44 h. The predicted indifference point was computed individually for each subject, using the discount rate that that subject displayed on the Level 1 question. Because discount rate is a nonlinear function of the indifference point, the average of the discount rates individually computed from the indifference points of each subject is not the same as the discount rate computed from the average indifference point. Thus, in Table 3, the average Level 1 indif-

ference point and the average predicted Level 2 indifference point do not seem to reflect the same discount rate, when in fact the Level 2 prediction used the Level 1 discount rate for each individual subject.

5. Computation of the size of the common ratio effect for each subject was based on the assumption of linear utility (see notes 1 and 3). Although this is an oversimplification, it is a reasonable assumption, given that the average subject was risk averse for the Level 1 probabilities but risk seeking for the Level 2 probabilities.

6. This procedure is equivalent to Myerson et al.'s (2003) method of computing area under the discounting curve, because in each of the present experiments, only two delays and two probability levels were used.

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