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Individual Differences in Discounting Delayed Gains, Delayed Losses, and Probabilistic Losses

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by

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Table of Contents

List of Figures

List of Tables

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Dedicated to my family.

ABSTRACT OF THE THESIS

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Master of Arts in Psychological & Brain Sciences

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Professor Leonard Green

Many decisions in one's daily life involve the discounting of delayed or probabilistic losses: Should we pay off our credit-card balance in full or incur interest; should we buy more collision and liability insurance or risk having to pay more in case of an accident? Despite its importance, however, discounting of losses is understudied, and few studies have focused on individual differences. The current study recruited 407 on-line participants through Amazon's Mechanical Turk who completed three discounting questionnaires: delayed losses, probabilistic losses, and delayed gains. Magnitude effects were observed with delayed gains (i.e., larger delayed gains were discounted less steeply than smaller delayed gains), but there were no systematic effects of amount on the discounting of delayed losses or probabilistic losses. Almost all participants increasingly discounted the value of gains as the delay to their receipt increased. In contrast, although the majority of participants increasingly discounted the aversiveness of losses as the delay to the payment increased and as the probability of payment decreased, a number of participants showed different patterns of choice. More specifically, there was a subgroup of participants that discounted the aversiveness of losses substantially more when the payment

would be required after a relatively short delay or with a high probability but discounted the aversiveness less as the delay to the payment increased or the probability of payment decreased. Another subgroup of participants didn't discount the aversiveness of losses with delay or probability at all. When these individual differences in responding patterns were taken into account, differential relations between the choices of delayed gains, delayed losses, and probabilistic losses emerged. Taken together, the results show that people differ quantitatively in their discounting of delayed gains but differ qualitatively as well as quantitatively in their discounting of delayed and of probabilistic losses. These results suggest that the processes underlying the discounting of delayed gains, delayed losses, and probabilistic losses are different, and it is critical to consider individual differences in decision-making when studying loss discounting.

Chapter 1: Introduction

Why do many people choose to carry a credit-card balance with interest charges if they are able to pay the balance in full and thereby avoid paying the additional fees? This decision may be understood in terms of delay discounting: When a payment can be made after a delay, the aversiveness of the loss is discounted, thereby reducing its subjective negative value. In like fashion, running a red-light given the risk of getting a camera ticket may be understood as the discounting of the likelihood of the loss: When a penalty occurs probabilistically, the aversiveness of the possible loss is discounted. Although many everyday choices may be described by incorporating the concept of discounting, interestingly, the discounting of losses is largely understudied, certainly when compared to the amount of research on the discounting of gains. As Harris (2012) has noted, even though the study of choices involving negative outcomes is equally important, the literature on choice involving losses is meager and fraught with inconsistencies when compared to that on choices involving positive outcomes.

One major issue related to the study of loss discounting is that people appear to have greater ambivalence in choice involving losses. Unlike the vast majority of people who prefer an immediate gain to a delayed gain, and the majority of people who prefer to delay an aversive outcome, there appears to be a sizeable number of people who prefer to experience the aversive outcome straightaway. It may well be that the inconsistences noted by Harris (2012) are due, in part, to the concatenation of the different subgroups of people found with loss discounting. Few studies have explored individual differences in the discounting of delayed losses, and fewer still have systematically studied the discounting of probabilistic losses. The present effort examined individual differences in both delay and probability discounting of losses and compared the findings with those from the delay discounting of gains.

There are significant similarities in the discounting of gains and losses. For example, Mazur (1987) proposed a simple hyperbolic discounting function that well described the discounting of delayed gains:

$$V = A \,/\, (1 + kD), \tag{1}$$

where V represents the subjective value of the delayed gain, A is the amount of the delayed gain, D is the time until receipt of the delayed gain, and the parameter k governs the rate at which V decreases with increases in D, and is frequently used as a measure of individual differences in discounting and impulsivity (Green & Myerson, 2004). Previous studies have shown that the hyperbolic function also provides good fits to data from the discounting of delayed losses, although it is to be noted that the obtained fits were generally poorer than the fits to data from the discounting of delayed gains (e.g., Murphy, Vuchinich, & Simpson, 2001; Odum, Madden, & Bickel, 2002).

In like manner, Rachlin, Raineri, and Cross (1991) proposed a simple hyperbolic discounting function to describe the discounting of probabilistic gains:

$$V = A \,/\, (1 + h\Theta), \tag{2}$$

where V represents the subjective value of the probabilistic gain, A is the amount of the probabilistic gain, Θ is the odds against receiving the probabilistic gain ($\Theta = [1 - p] / p$, where p is the probability of its occurrence), and the parameter h governs the rate at which V decreases with increases in Θ, and is frequently used as a measure of individual differences in discounting and the extent to which individuals trust the stated odds against (Green & Myerson, 2004). Ohmura, Takahashi, and Kitamura (2005) found that this hyperbolic function also provided good fits to the data from the discounting of probabilistic losses. This similarity in the mathematical forms of the discounting functions suggests that the decision-making processes underlying the discounting of gains and losses share important similarities.[1]

Despite this notable similarity, however, significant differences between the discounting of gains and the discounting of losses have been reported. For example, it is well established that the same amount of gain and loss is discounted at different rates. More specifically, a loss is discounted at a lower rate than is an equivalent amount of a gain, a finding known as the *sign effect* (e.g., Benzion, Rapoport, & Yagil, 1989; Thaler, 1981). This difference in discounting rate has been observed with both delayed and probabilistic monetary gains and losses (Estle, Green, Myerson, & Holt, 2006; Frederick, Loewenstein, & O'Donoghue, 2002; Gonçalves & Silva, 2015; Mitchell & Wilson, 2010). In delay discounting, this difference also was observed with health and environmental outcomes (Baker, Johnson, & Bickel, 2003; Chapman, 1996; Hardisty & Weber, 2009). No previous study has used commodities other than monetary outcomes to determine whether the sign effect also occurs in probability discounting.

Another important finding in the discounting of gains is that the rate of discounting changes with the amount of the outcome, a finding known as the *magnitude effect* (Green & Myerson, 2004), but the effect is opposite in direction for delay and probability. Specifically, smaller delayed amounts are discounted more steeply than larger delayed amounts, whereas smaller probabilistic amounts are discounted less steeply than larger probabilistic amounts. The magnitude effect is one of the most robust findings in the literature on the discounting of delayed and probabilistic gains. In contrast to the consistent pattern of findings obtained with gains,

[1] A hyperbola-like discounting function in which the denominator of Equation 1 or Equation 2 is raised to a power, *s*, provides a better fit both to the discounting of gains and the discounting of losses than the hyperbolic discounting function. However, the measures in the current study followed Kirby et al. (1999), which utilized the hyperbolic discounting function. Hence, the current review mainly focuses on studies using hyperbolic discounting function. For a review of the hyperbola-like discounting function, see Green and Myerson (2004).

results from discounting of losses are less consistent. Some studies report a magnitude effect with delayed losses (Baker et al., 2003; Chapman, 1996; Hardisty, Appelt, & Weber, 2013) but not with probabilistic losses (Ostaszewski & Karzel, 2002), whereas other studies observed little or no effect of amount with either delayed or probabilistic losses (Estle et al., 2006; Green, Myerson, Oliveira, & Chang, 2014; McKerchar, Pickford, & Robertson, 2013; Mitchell & Wilson, 2010; Myerson, Baumann, & Green, 2017).

The correlation between delay and probability discounting also appears to differ when the outcomes are gains and when they are losses. Weak to moderate positive correlations are observed between the discounting of delayed and probabilistic gains (Green & Myerson, 2010), but no significant correlation has been found between the discounting of delayed and probabilistic losses (Green et al., 2014; Mitchell & Wilson, 2010). In addition, the correlation between the discounting of gains and the discounting of losses is not clear. Some studies find a positive correlation between the discounting of delayed gains and losses (Chapman, 1996; Mitchell & Wilson, 2010; Murphy et al., 2001) and negative correlations between the discounting of probabilistic gains and losses (Shead & Hodgins, 2009),whereas other studies fail to find a significant correlation either between the discounting of delayed gains and losses (Gonçalves & Silva, 2015; Hardisty & Weber, 2009; Harris, 2012; Myerson et al., 2017) or between the discounting of probabilistic gains and losses (Mitchell & Wilson, 2010). The cause for these inconsistent findings has yet to be established but, nonetheless, differences between the discounting of gains and losses and between the discounting of delayed and probabilistic losses are manifest.

Few studies have focused on individual differences in understanding the greater inconsistency reported in the discounting literature with losses than with gains. In the study by

Harris (2012), participants showed more similar behavior patterns when the outcome was a delayed monetary loss than when other types of delayed unpleasant experiences, such as social rejection and embarrassment, were studied. Most participants preferred to postpone monetary losses, but for other unpleasant experiences, some participants preferred to defer them as long as possible whereas many elected to experience them immediately.

It is important to note, however, that choice behavior still was more variable with the monetary losses than are typically observed with monetary gains. Myerson et al. (2017) identified three distinct patterns of responding in the discounting of delayed losses based on the way individuals chose between immediate, smaller payments and delayed, larger payments. In two samples of participants, a majority of participants (61% and 55%) were more likely to choose the delayed payment as the delay increased, and labeled *Loss Averse*. Some participants (18% and 23%), however, were less likely to choose the delayed payment as the delay increased, and were labeled *Debt Averse*. A third subgroup of participants (21% and 22%) always chose the immediate, smaller payment, and was labeled *Minimizers*. Despite their use of different research methods, Gonçalves and Silva (2015) reported a similar three-group classification in the discounting of delayed monetary losses. In their sample, about forty percent of participants showed a typical delay discounting pattern (loss becoming less aversive with delay), about forty percent of participants showed initial discounting followed by a decrease in degree of discounting at increasingly longer delays (loss becoming more aversive with delay), and about twenty percent of participants showed no discounting. The findings from Myerson et al. and Gonçalves and Silva suggest that there are subgroups of individuals who discount delayed losses in qualitatively different ways.

To our knowledge, there is no published study that has explored individual differences in the discounting of probabilistic losses. The aim of the current work, then, was to examine individual differences in both delay and probability discounting of losses. More specifically, we wanted first to replicate our previous findings of responding patterns with delayed losses while then determining whether different subgroups also would be observed when discounting involved probabilistic losses. To achieve this goal, we designed a new discounting questionnaire that was similar to that we developed previously for studying delayed losses (Myerson et al., 2017). We also included an established questionnaire for studying delay discounting of gains (Kirby, Petry, & Bickel, 1999). This arrangement provided us an opportunity to compare our findings with losses to those with gains and examine the correlations between the discounting of delayed gains, delayed losses, and probabilistic losses.

If subgroups were to be identified that captured meaningful individual differences, we would expect to see different relations between how individuals in the subgroups discounted the different types of outcomes. Based on Myerson et al. (2017), we predicted that three distinct subgroups would be observed in the delay discounting of losses. We also predicted an effect of amount on the delay discounting of gains, and no effect of amount on the delay discounting of losses. In the case of discounting of probabilistic losses, we predicted distinct subgroups would be observed and no effect of amount on the degree of discounting.

Chapter 2: Method

2.1 Participants

A sample of 428 US residents was recruited from the pool of workers maintained by Amazon's Mechanical Turk (Behrend, Sharek, Meade, & Wiebe, 2011). Participation was restricted to individuals who were 18 years of age or older, using a computer with an IP address in the United States, and having previous MTurk approval HIT rates of at least 85%.

Participants were compensated $0.50-0.60 based on the amount of time they spent in the study. The minimum amount of time needed to complete the study was established by three research assistants who were familiar with the research area. Among the MTurk participants, nine completed the study in less than the minimum amount of time needed by the research assistants and were, therefore, excluded from the analysis. The final sample consisted of 419 subjects (51.1% female; age: M = 34.9 years, SD = 11.4; education: M = 15.4 years, SD =2.5; individual annual income: M = $35,400, SD = 31,564; household annual income = $59,500, SD = 45,347; one participant did not report gender, 2 did not report their age, 5 did not report their education, 8 did not report their individual annual income, and 6 did not report their household annual income).

2.2 Materials

Three discounting questionnaires were used to measure the discounting of delayed gains, delayed losses, and probabilistic losses.

2.2.1 Delayed Gains Questionnaire

A 27-item questionnaire developed by Kirby et al. (1999) was used to evaluate individuals' discounting of delayed gains (see Table 1). The items in this measure are divided into three sets of 9 questions each, based on whether the delayed amount is small ($25, $30, or $35), medium ($50, $55, or $60), or large ($75, $80, or $85). The immediate amount and the delay corresponding to the delayed amount for each item are determined by nine logarithmically spaced values of the *k* parameter derived from Equation 1. The amount of the immediate gain ranged from $11 to $80, and the time until receipt of the delayed gain ranged from 7 to 186 days.

For each item, participants were asked to choose between an immediate, smaller gain and a delayed, larger gain (i.e., participants were asked, "Which would you prefer?"). Although based on the choice responses, an individual participant's *k* parameter values could be directly estimated using logistic regression (Wileyto, Audrain-McGovern, Epstein, & Lerman, 2004), we followed the approach of Myerson, Baumann, and Green (2014) and used the percentage of items on which the delayed reward was chosen to represent each individual participant's discounting rate. The proportion measure and the estimated *k* values are strongly correlated ($r > .97$) and can be used interchangeably. The proportion measure has the advantages that it does not require the assumption of a specific theoretical model (i.e., the simple hyperbola) and allows for the case of negative discounting like those reported by Hardisty et al. (2013), which is not possible with the simple hyperbolic discounting function that estimates an individual's *k* value.

2.2.2 Delayed Losses Questionnaire

A 27-item questionnaire directly analogous to the delayed gains questionnaire and developed by Myerson et al. (2017), was used to evaluate individuals' discounting of delayed losses (see Table 2.1). The items in this measure are divided into three sets of 9 questions each, based on whether the delayed amount is small ($75, $90, or $105), medium ($150, $165, or

Table 2.1 Question order (Q), immediate amount (V_i), delayed amount (A_d), duration of the delay (D), and values of k for questions involving small, medium, and large delayed outcomes on the Kirby et al. (1999) delayed gains questionnaire (left columns) and the Myerson et al. (2017) delayed losses questionnaire (right columns)

Gains					Losses				
Q	V_i($)	A_d($)	D(days)	k	Q	V_i($)	A_d($)	D(mos)	k
Small Delayed Outcome									
13	34	35	186	0.00016	15	102	105	108	0.0000090
20	28	30	179	0.00040	8	84	90	106	0.000022
26	22	25	136	0.0010	2	66	75	78	0.000057
22	25	30	80	0.0025	6	75	90	46	0.00014
3	19	25	53	0.0060	25	59	75	26	0.00034
18	24	35	29	0.016	10	72	105	17	0.00089
5	14	25	19	0.041	23	41	75	12	0.0023
7	15	35	13	0.10	21	45	105	8	0.0055
11	11	30	7	0.25	17	33	90	4	0.014
Medium Delayed Outcome									
1	54	55	117	0.00016	27	162	165	68	0.0000090
6	47	50	160	0.00040	22	141	150	94	0.000022
24	54	60	111	0.0010	4	159	180	76	0.000057
16	49	60	89	0.0025	12	147	180	52	0.00014
10	40	55	62	0.0060	18	120	165	36	0.00034
21	34	50	30	0.016	7	103	150	17	0.00088
14	27	50	21	0.041	14	81	150	12	0.0023
8	25	60	14	0.10	20	75	180	8	0.0058
27	20	55	7	0.25	1	60	165	4	0.014
Large Delayed Outcome									
9	78	80	162	0.00016	19	234	240	94	0.0000090
17	80	85	157	0.00040	11	240	255	92	0.000022
12	67	75	119	0.0010	16	201	225	69	0.000057
15	69	85	91	0.0025	13	207	255	54	0.00014
2	55	75	61	0.0060	26	165	225	35	0.00034
25	54	80	30	0.016	3	162	240	18	0.00088
23	41	75	20	0.041	5	123	225	15	0.0018
19	33	80	14	0.10	9	99	240	8	0.0059
4	31	85	7	0.25	24	93	255	4	0.014

Note: For purposes of comparison, values of k are given in days for both gains and losses even though the delays for the loss questions seen by participants were given in months.

$180), or large ($225, $240, or $255). The immediate amount and the delay corresponding to the delayed amount for each item were determined by nine logarithmically spaced values of the *k* parameter of Equation 1. The amount of the immediate loss ranged from $33 to $240, and the time until payment of the delayed loss ranged from 4 to 108 months. The time unit for delay and the amount are different from those used in the delayed gains questionnaire because losses are discounted at a much lower rate than gains (the sign effect; Frederick et al., 2002). For each item, participants were asked to choose between an immediate, smaller loss and a delayed, larger loss (i.e., they were asked, "Which would you prefer to pay?"). The percentage of choices of the immediate payment was used to estimate an individual participant's discounting rate of delayed losses.

2.2.3 Probabilistic Losses Questionnaire

Following the procedure for developing the delayed losses questionnaire (Myerson et al., 2017), we developed a 27-item questionnaire to evaluate individuals' discounting of probabilistic losses (see Table 2.2). The items in this measure also are divided into three sets of 9 questions each, based on whether the probabilistic amount is small ($50, $60, or $70), medium ($100, $110, or $120), or large ($150, $160, or $170). The amounts used are different from the other two questionnaires to minimize any carryover effect.

The certain amount and the probability corresponding to the probabilistic amount for each item were determined by nine logarithmically spaced values of the *h* parameter of Equation 2. The amount of the certain loss ranged from $9 to $48, and the probability of the loss ranged from .05 to .68. For each item, participants were asked to choose between a certain, smaller loss and a probabilistic, larger loss (i.e., they were asked, "Which would you prefer to pay?"). The

Table 2.2 Question order (Q), certain amount (V_c), probabilistic amount (A_p), probability of the payment (P), and values of h for questions involving small, medium, and large probabilistic outcomes on our new probabilistic losses questionnaire

		Losses		
Q	V_c($)	A_p($)	P	h
Small Probabilistic Outcome				
15	21	70	.05	0.1228
8	13	60	.05	0.1903
2	11	50	.08	0.3083
6	12	60	.11	0.4944
25	9	50	.15	0.8039
10	17	70	.29	1.2734
23	12	50	.39	2.0246
21	18	70	.53	3.2577
17	17	60	.67	5.1355
Medium Probabilistic Outcome				
27	33	110	.05	0.1228
22	24	100	.06	0.2021
4	26	120	.08	0.3144
12	24	120	.11	0.4944
18	22	110	.17	0.8193
7	21	100	.25	1.2540
14	25	100	.40	2.0000
20	27	120	.49	3.3094
1	32	110	.68	5.1797
Large Probabilistic Outcome				
19	48	160	.05	0.1228
11	42	170	.06	0.1945
16	36	150	.09	0.3132
13	28	170	.09	0.5016
26	29	150	.16	0.7947
3	36	160	.27	1.2740
5	35	150	.38	2.0138
9	36	160	.49	3.3094
24	46	170	.66	5.2327

percentage choice of the certain payment was used to estimate an individual participant's discounting rate of probabilistic losses.

2.3 Procedure

After reading information about the study and agreeing to participate, participants completed the three discounting questionnaires in the following order: probabilistic losses questionnaire, delayed gains questionnaire, and delayed losses questionnaire. Following completion of the questionnaires, the participants answered a series of demographic questions and then were given the password to arrange for compensation. All data were collected using the internet survey platform Qualtrics.

Since the main purpose of this study was to investigate individual differences in different types of discounting, all participants were arranged to receive the same order of treatment to prevent any confounder from sequence effects. By this design, if there was an effect of sequence, it would have the same impact on all participants without affecting their original ranking of performance.

2.4 Analyses

We first evaluated the reliability of our newly developed probabilistic losses questionnaire. Because of the construction of the questionnaire, the questions for the small, medium, and large amounts could be thought of as alternative forms. The correlations among the percentage choices for the three amounts were conducted. The same correlation analysis also was conducted for the delayed gains and the delayed losses questionnaires for comparison purposes.

At the group level, the proportion of participants' choosing the delayed gain, immediate payment, or certain payment was conducted on each item for each of the three questionnaires to determine choice as a function of the discounting parameter. At the individual level, we adapted the procedure proposed by Myerson et al. (2017) to objectively identify distinct preference patterns. For the delayed losses questionnaire, we summed the number of times that the immediate payment was chosen across the three amounts at the nine levels of *k*. Although the *k* values of the three amounts are not entirely identical at each level, the differences are insignificant after calculating the logarithms and, therefore, could be ignored for each participant. The summations ranged from 0 to 3 (choosing none to all three immediate payments at each *k* level) and were used to calculate the correlation of the logarithms of the *k* values representing each level. A positive correlation indicates that a participant chose fewer immediate payments on low-*k* questions (where the alternative involved a long delay) than on high-*k* questions (where the alternative involved a brief delay). In contrast, a negative correlation indicates that a participant chose more immediate payments when the alternative involved a long delay than when the delay was brief. We applied a similar identification procedure for the probabilistic losses questionnaire. We summed the number of times that the certain payment was chosen across the three amounts at each level of *h* for each participant, and then calculated the correlation between the summations and the nine logarithms of the *h* values.

The proportion of participants who chose the delayed gain, the immediate payment, and the certain payment at each of the three amount levels for each questionnaire was analyzed using a repeated measures ANOVA, followed by planned contrasts to evaluate whether there was a statistically significant linear relation consistent with a magnitude effect. Correlations between the proportion measures on each of the three discounting questionnaires also were calculated to examine the relations among the three different kinds of discounting.

Chapter 3: Results

3.1 Intercorrelations among Choices of Different Amounts

The correlations between the percentage choices for the different amounts ranged from .858 to .911 for the delayed gains questionnaire, .879 to .924 for the delayed losses questionnaire, and .768 to .879 for the probabilistic losses questionnaire (see Table 3.1). All the correlations were statistically significant (all *p*s < .001).

Table 3.1 Intercorrelations among choices of different amounts in each choice questionnaire

Questionnaire	Medium	Large
Delayed Gains		
Small	0.892	0.858
Medium		0.911
Delayed Losses		
Small	0.906	0.879
Medium		0.924
Probabilistic Losses		
Small	0.835	0.768
Medium		0.879

Note: All correlations significant at $p < .001$.

3.2 Choice Patterns

The proportion of participants' choosing the delayed gain, immediate payment, and certain payment on each item for all three questionnaires is shown in Figure 3.1. As may be seen in the left panel, the proportion of participants who chose the delayed gain increased systematically as a function of the *k* parameter for the corresponding questions. The data were well described by a logistic growth function (all R^2s > .97):

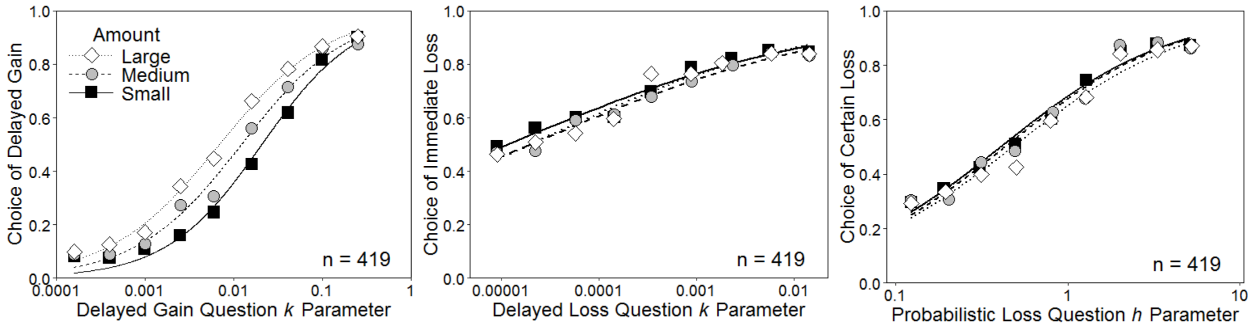

Figure 3.1 Proportion of participants who chose the delayed gain on each question of the delayed gains questionnaire (left panel), the immediate loss on each question of the delayed losses questionnaire (middle panel), and the certain loss on each question of the probabilistic losses questionnaire (right panel), plotted as a function of the discounting parameter associated with that question. Note the logarithmic scaling of the discounting parameter in all three panels.

$$P = 1 \,/\, [1 + e^{-(x - x_0)r}], \quad (3)$$

where P is the proportion of participants choosing the delayed gain, x is the logarithm of the discounting parameter values associated with the various questions, x_0 is an intercept parameter that shifts the curve horizontally, and r is a rate parameter that describes the rate of increase in the proportion of later choices. The fitted curves were plotted separately for each amount, and a clear magnitude effect for delayed gains is evident. The data for the delayed and probabilistic losses questionnaire also were well fitted by the logistic growth function (see the middle and right panels). As may be seen, there is no apparent magnitude effect.

When the data for each individual participant from the delayed losses questionnaire were analyzed, 240 of the participants (57.3%) showed a positive correlation between their choices and the logarithms of the *k* values and were labeled *Loss Averse* according to Myerson et al. (2017; see the top left panel of Figure 3.2). 64 (15.3%) showed a negative correlation and were

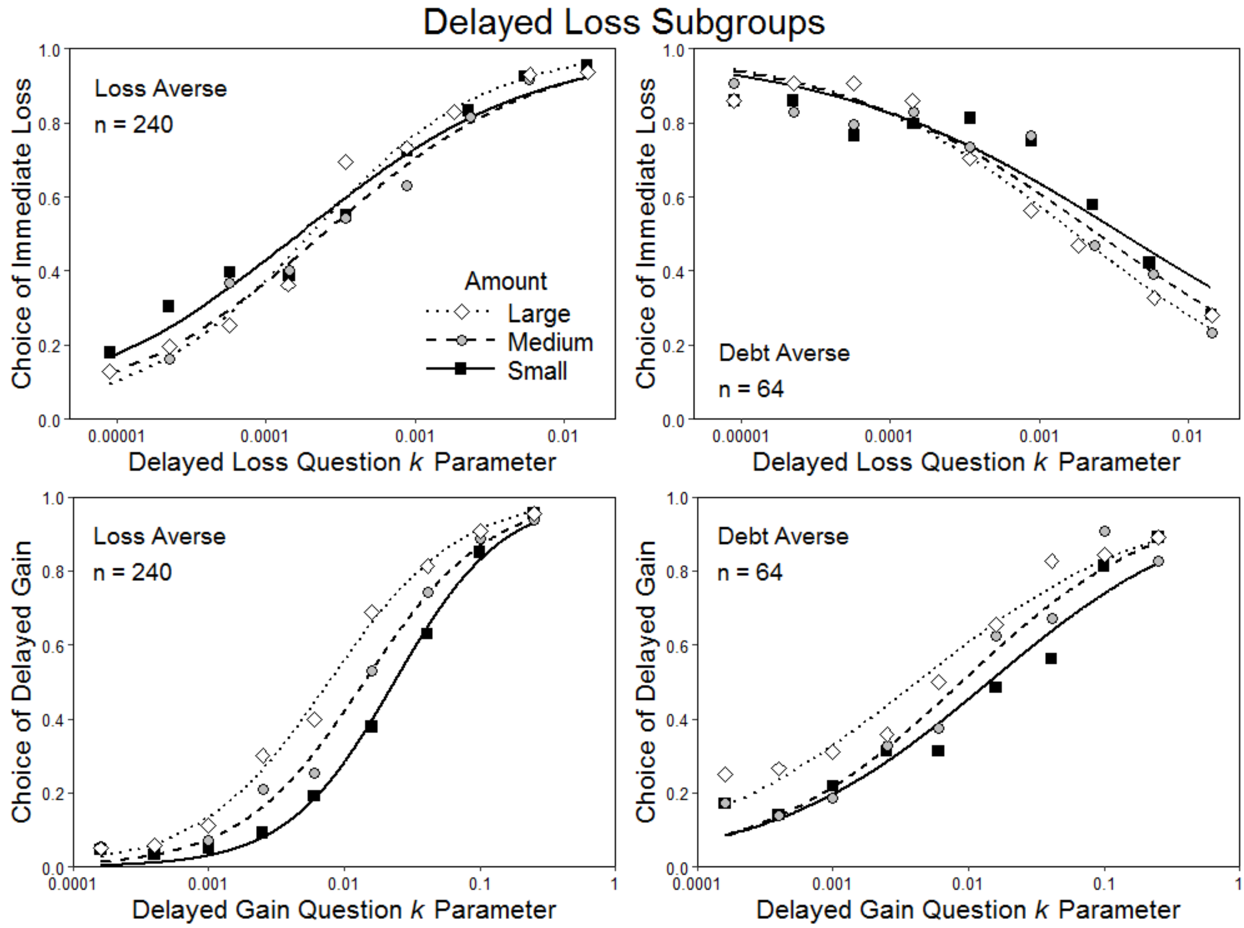

Figure 3.2 Proportion of participants in the Loss Averse (left panels) and Debt Averse (right panels) subgroups who chose the immediate loss on each question of the delayed losses questionnaire (top panels) and the delayed gain on each question of the delayed gains questionnaire, plotted as a function of the discounting parameter associated with that question.

labeled *Debt Averse* (see the top right panel of Figure 3.2). 108 of the participants (25.8%) always chose the immediate payment regardless of the *k* values and were labeled *Minimizers*. Only 7 participants (1.7%) always chose the delayed, larger losses, and their preference patterns were not further analyzed and discussed because of the limited sample size. To be noted, even though these subgroups showed different response patterns on the delayed losses questionnaire, they all discounted delayed gains in the same manner (i.e., decreased choice of the larger amount as delay increased), which minimized the possibility that these distinct choice patterns were simply a result of careless responding (the choice of delayed gains for the *Loss Averse* and *Debt Averse* subgroups may be seen in the bottom panels of Figure 3.2).

When the data for each individual participant from the probabilistic losses questionnaire were analyzed , 310 of the participants (74.0%) showed a positive correlation between their choices and the logarithms of the *h* values, which means that they were less likely to choose the certain payment on low-*h* questions (where the alternative had a low probability of occurrence) and more likely to choose the certain payment on high-*h* questions (where the alternative had a high probability of occurrence). We termed this preference pattern *Risk Averse* because the likelihood of choosing a probabilistic loss increases with the decrease in the probability of its occurrence (see the top left panel of Figure 3.3). 53 participants (12.6%) showed a negative correlation, and we termed this preference pattern *Uncertainty Averse* because the likelihood of choosing a probabilistic loss decreases with the decrease in the probability of occurrence (see the top right panel of Figure 3.3). 52 participants (12.4%) always chose the certain payment regardless of the *h* values, and we termed this preference pattern *Minimaxer* to reflect the consistent effort of avoiding the worst scenario. There were also 4 participants who always chose the probabilistic, larger losses. Since the members of this subgroup was so few and insufficient to conduct any meaningful statistical analysis, their preference patterns were not further discussed. Similar to delayed loss subgroups, even though these subgroups showed different response patterns on the probabilistic losses questionnaire, they all discounted delayed gains in the same manner (the choice of delayed gains for the *Risk Averse* and *Uncertainty Averse* subgroups may be seen in the bottom panels of Figure 3.3).

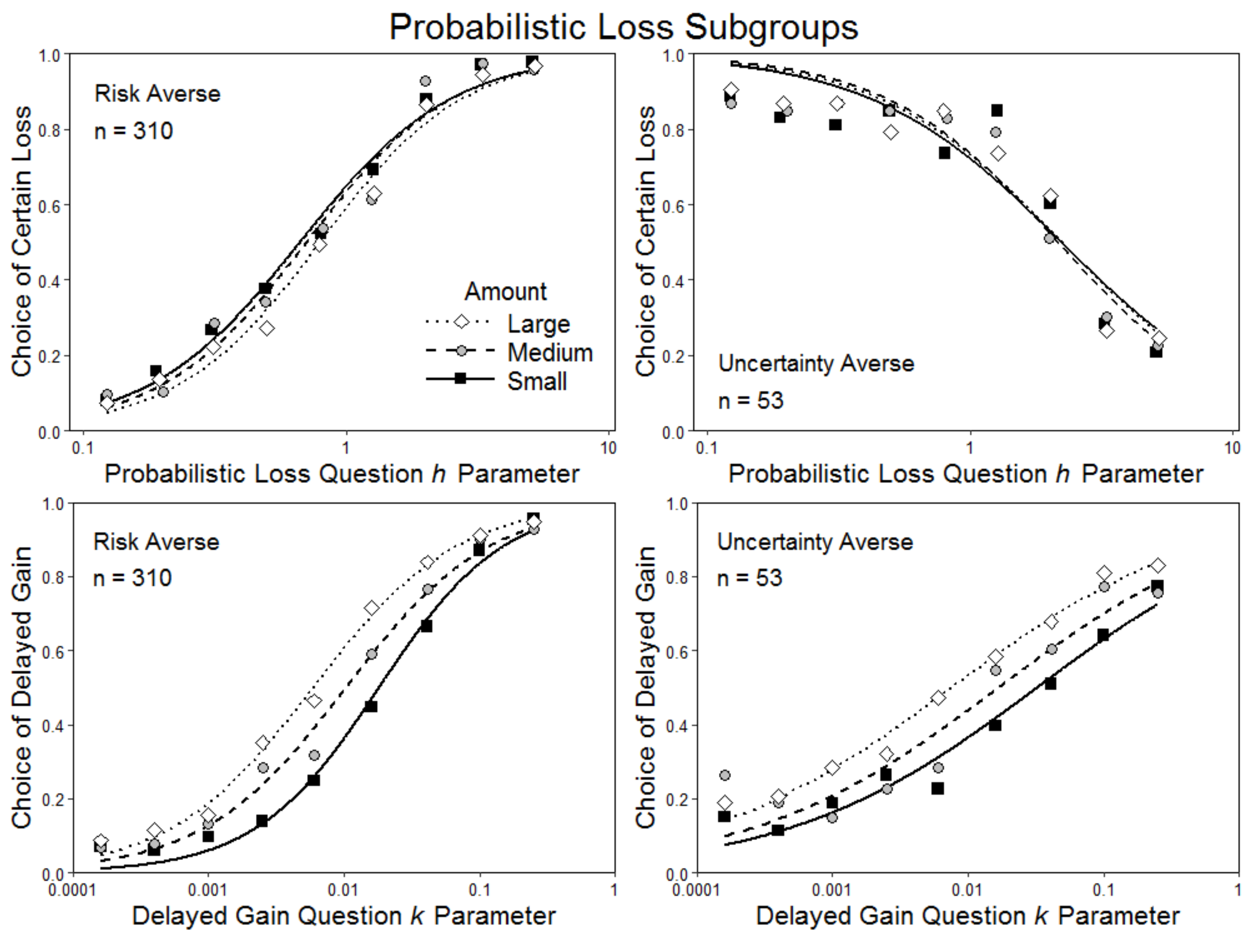

Figure 3.3 Proportion of participants in the Risk Averse (left panels) and Uncertainty Averse (right panels) subgroups who chose the certain loss on each question of the probabilistic losses questionnaire (top panels) and the delayed gain on each question of the delayed gains questionnaire, plotted as a function of the discounting parameter associated with that question.

Figures 3.4, 3.5, and 3.6 depict the choice responses from the first ten participants on the delayed gains, delayed losses, and probabilistic losses questionnaires respectively. As may be seen, most participants showed the same pattern of increasing choices of the delayed gains as the *k*s associated with the questions increased. However, these individuals' choice patterns on the

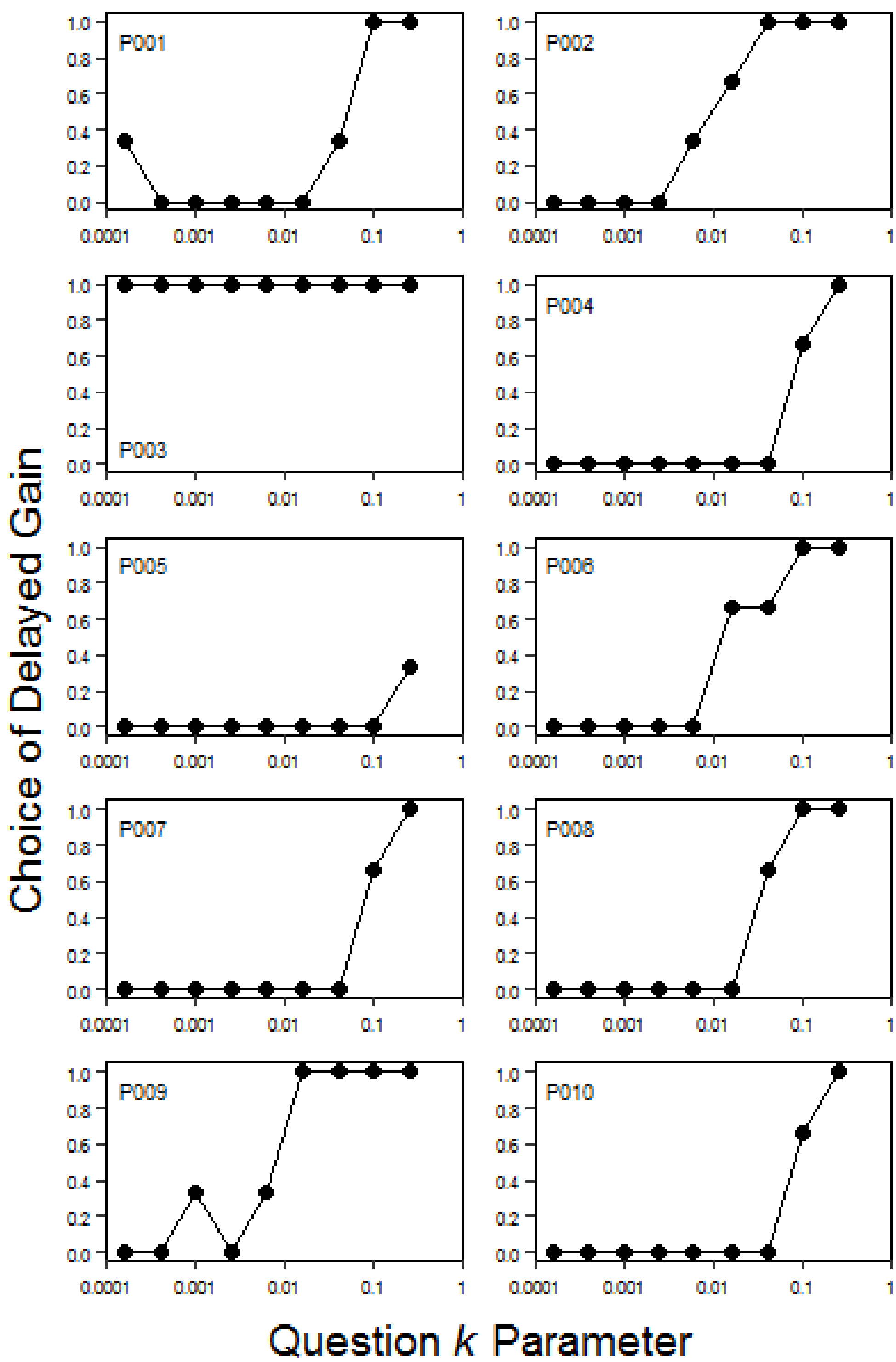

Figure 3.4 Choice responses of the first 10 participants on the delayed gains questionnaire, averaged across small, medium, and large amounts.

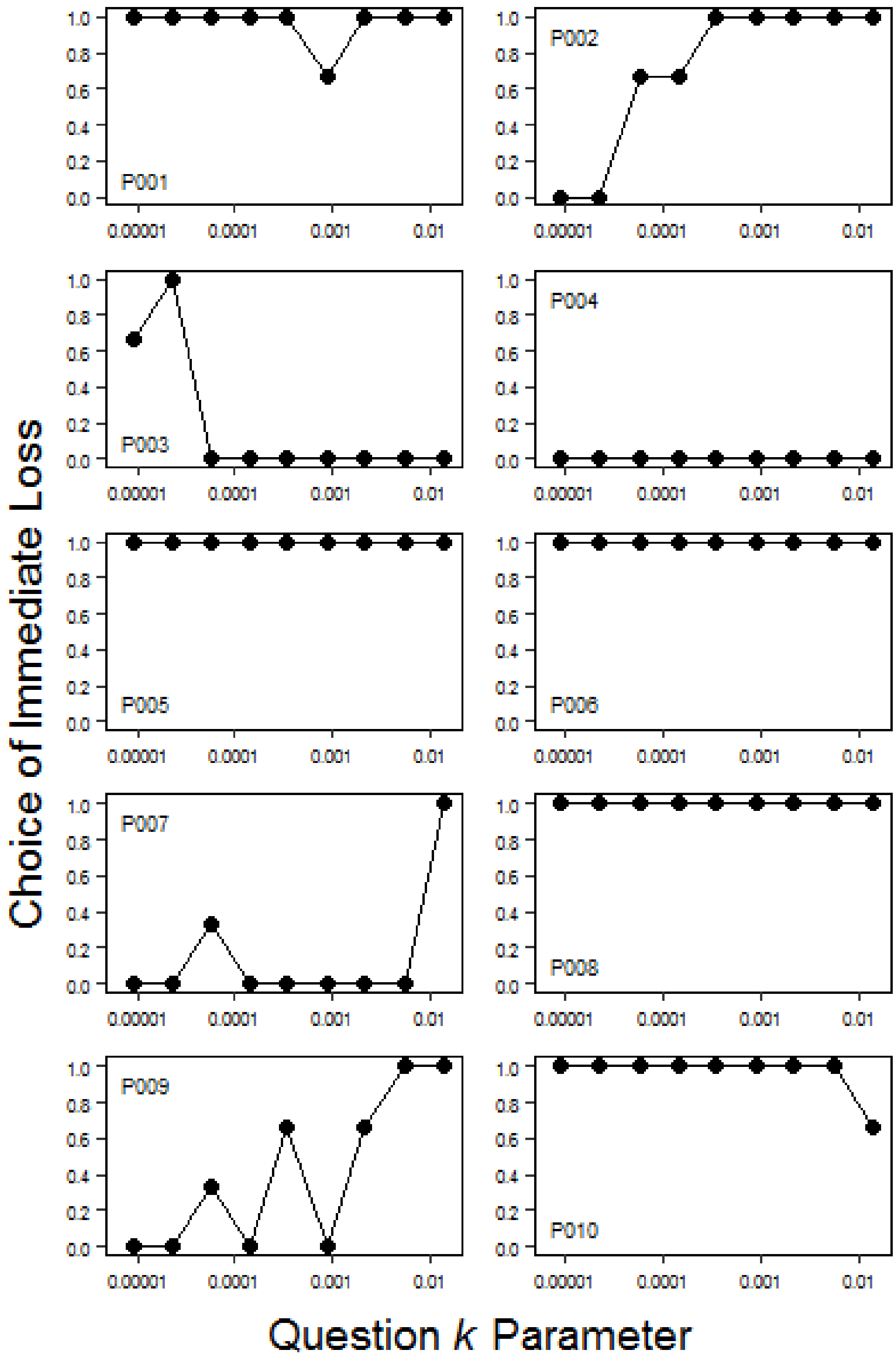

Figure 3.5 Choice responses of the first 10 participants on the delayed losses questionnaire, averaged across small, medium, and large amounts.

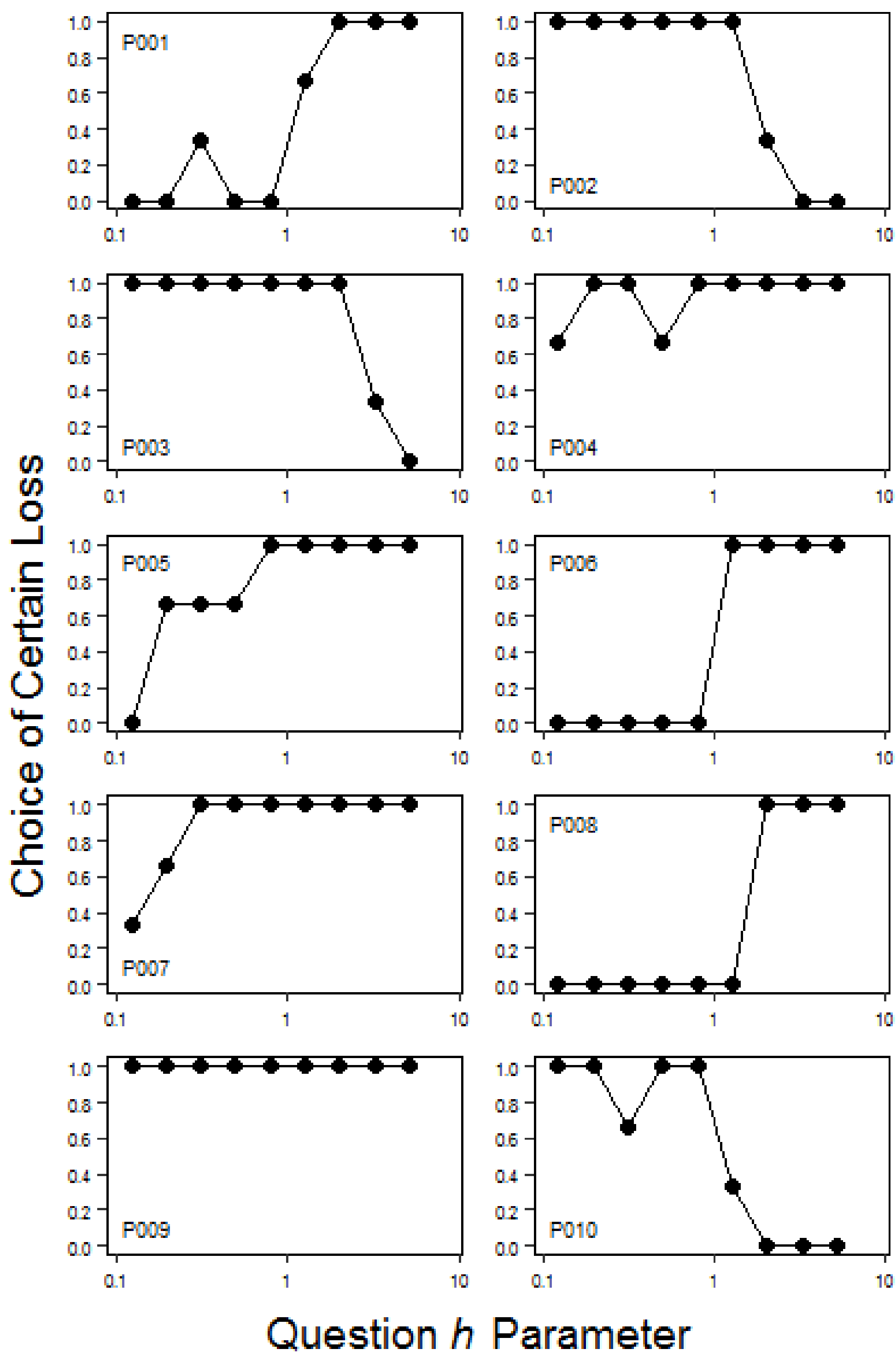

Figure 3.6 Choice responses of the first 10 participants on the probabilistic losses questionnaire, averaged across small, medium, and large amounts.

delayed losses questionnaires were mixed (see Figure 3.5). Participants P002 and P009 showed the expected pattern of discounting delayed losses on the delayed losses questionnaire (Loss Averse), whereas participants P003 and P010 showed the reverse pattern (Debt Averse). Participants P005, P006, and P008 always chose the smaller, immediate payment (Minimizer). These individuals' choice patterns on the probabilistic losses questionnaires were also mixed (see Figure 3.6). Participants P001, P005, P006, P007, and P008 showed a pattern of generally increasing choices of the certain losses as the *h*s associated with the questions increased (Risk Averse), whereas participants P002, P003, and, P010 showed the reverse pattern (Uncertainty Averse). Participant P009 always chose the smaller, certain payment (Minimaxer).

Figure 3.7 depicts the mean proportions of choices of the delayed gain, the immediate loss, and the probabilistic loss among subgroups identified above according to their pattern of choice on the delayed losses and probabilistic losses questionnaires. Because members of the Minimizer subgroup by definition always chose the immediate loss on the delayed losses questionnaire, their responses were not included in the statistical comparison on the delayed losses questionnaire. Likewise, members of the Minimaxer subgroup by definition always chose the certain loss on the probabilistic losses questionnaire, and thus their responses were not included in the statistical comparison on the probabilistic losses questionnaire.

A one-way ANOVA for the delayed gains questionnaire revealed that the Risk Averse, Uncertainty Averse, and Minimaxer subgroups differed in their choices (F [2, 412] = 3.67, $p <$ .05). Follow-up tests showed that the source of the difference was between the Risk Averse and Minimaxer subgroups (Bonferroni-corrected $p < .05$). For the delayed losses questionnaire, the Welch t-test revealed that the Loss Averse and Debt Averse subgroups differed in their choices

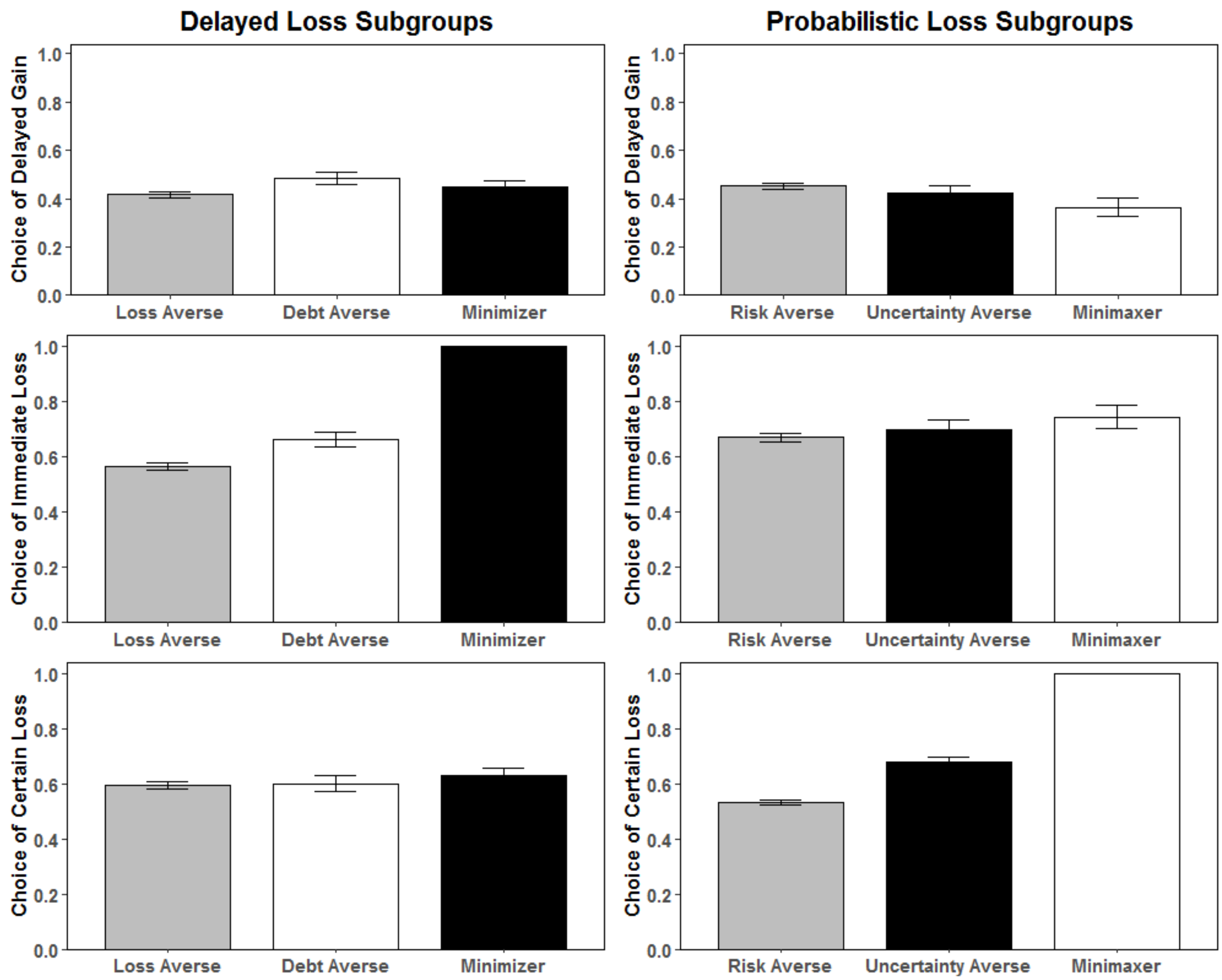

Figure 3.7 Mean proportion of choices of the delayed gains (top row), immediate losses (middle row), and certain losses (bottom row) by members of the subgroups on the delayed losses questionnaire (left column) and the probabilistic losses questionnaire (right column). Error bars represent one standard error of the mean.

(t[98.21] = -3.30, $p < .01$). Also, Risk Averse and Uncertainty Averse subgroups differed in their choices on the probabilistic losses questionnaire (t[81.68] = -6.51, $p < .001$). All remaining comparisons of the choices among subgroups failed to reach levels of statistical significance.

The subgroups also did not differ in gender, education, individual income, and household annual income. A one-way ANOVA did reveal that the Risk Averse, Uncertainty Averse, and Minimaxer subgroups differed in age (F [2, 412] = 6.70, $p < .01$). The follow-up tests revealed that the Uncertainty Averse subgroup (M = 29.68 years) was significantly younger than the Risk Averse (M = 35.71 years; $p < .001$) and Minimaxer (M = 35.85 years; $p < .05$) subgroups.

3.3 Magnitude Effects

The three panels of Figure 3.8 present the mean proportions of choices of delayed gains, immediate losses, and certain losses as a function of the amount. As may be seen in the left panel, choice of the delayed gain increased systematically with the amount, whereas choice of the immediate loss (middle panel) and the probabilistic loss (right panel) show little effect of amount on choice. Although planned contrasts showed significant linear trends for all types of discounting, the effect size was large on the delayed gains questionnaire (F [1, 418] = 316.21, $p < .001$, *partial* $\eta^2 = .43$) but near zero for the two losses questionnaires (F [1, 418] = 5.64, $p < .05$, *partial* $\eta^2 = .01$ for delayed losses; F [1, 418] = 9.68, $p < .01$, *partial* $\eta^2 = .02$ for probabilistic losses).

Two two-way mixed design ANOVAs (amount by subgroup) examined the magnitude effect within the subgroups from the delayed and probabilistic loss questionnaires separately. The linear trend for choices on the delayed gains questionnaire was highly significant for both subgroups (both ps < .001, *partial* η^2 was .35 for delayed loss subgroups and .26 for probabilistic loss subgroups). However, there was also a significant interaction in the probabilistic loss subgroups (F [2, 412] = 4.43, $p < .05$, *partial* $\eta^2 = .02$). As Figure 3.9 shows, even though the choices systematically increased with the amount of delayed gains across the subgroups, the effect was smaller in the Minimaxer than the others. The linear trend for choices on the delayed losses questionnaire was only significant in the delayed loss subgroups (F [1, 302] = 4.43, $p < .05$, *partial* $\eta^2 = .02$), and there was no significant interaction. No linear trend or interaction term reached significance for choices on the probabilistic losses questionnaires.

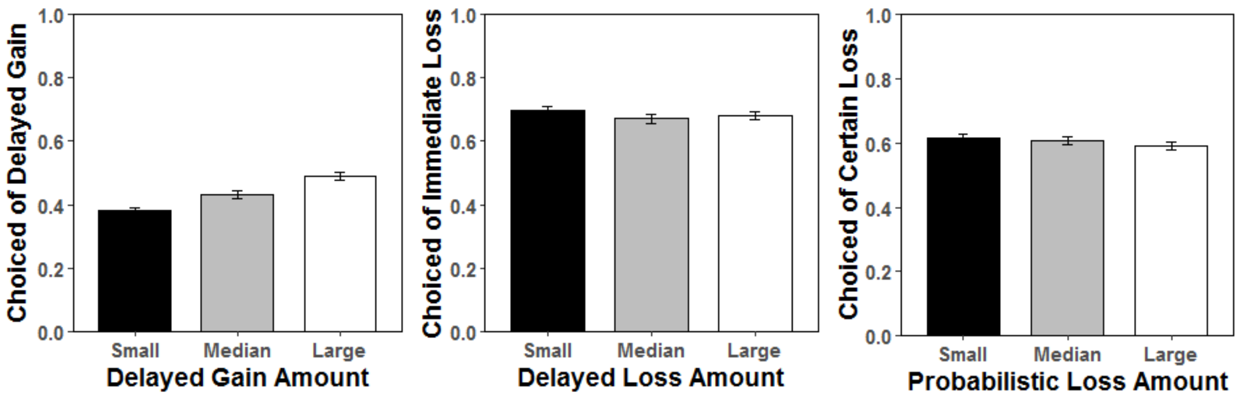

Figure 3.8 Mean proportion of choices of the delayed gains (left panel), immediate losses (middle panel), and certain losses (right panel) as a function of amount. Error bars represent one standard error of the mean.

3.4 Correlations between Different Types of Discounting

Table 3.2 shows the correlations between the proportion measures of the three discounting questionnaires. Choice of the more delayed gain was not significant correlated with either choice of the more immediate loss or choice of the more certain loss, and there was a weak positive correlation between choices on the delayed and probabilistic losses questionnaires.

When the same analysis was conducted on the subgroups, however, a very different correlation picture emerges. As Table 3.3 shows, the correlations between the delayed gains and the delayed losses questionnaires were significant in all subgroups except Loss Averse, where a negative correlation means that those who chose the delayed gain most often also tended to be the ones who chose the immediate loss less often. The correlations between the delayed gains

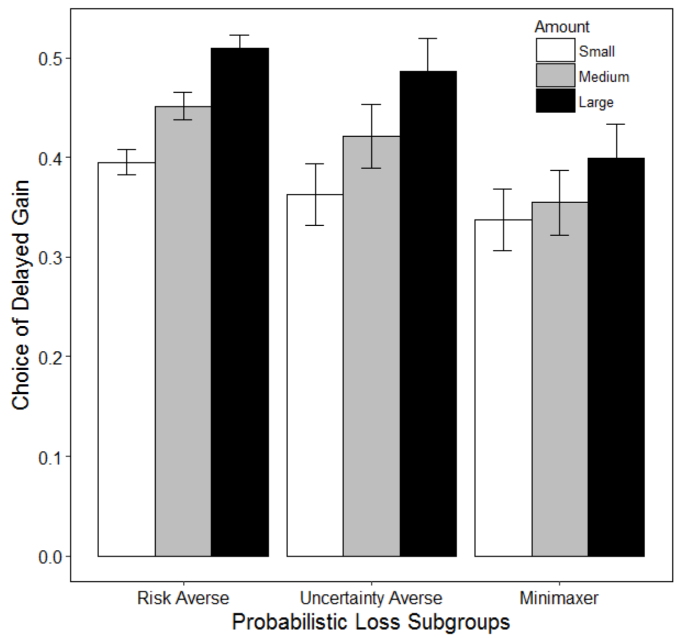

Figure 3.9 Mean proportion of choices of the delayed gains as a function of amount for the probabilistic loss subgroups.

Table 3.2 *Correlations between choice questionnaires: Means (M) of choosing delayed gains, immediate losses, and certain losses, standard deviations (SD), and correlations with confidence intervals*

Questionnaire	*M*	*SD*	Delayed Losses	Probabilistic Losses
Delayed Gains	0.44	0.22	.01 [-.09, .10]	-.09 [-.19, .00]
Delayed Losses	0.68	0.27		.13** [.03, .22]
Probabilistic Losses	0.60	0.23		

Note: * indicates $p < .05$; ** indicates $p < .01$. Values in brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014).

Table 3.3 *Correlations between choice questionnaires within subgroups: Means (M) of choosing delayed gains, immediate losses, and certain losses, standard deviations (SD), and correlations with confidence intervals*

	M	*SD*	Delayed Losses	Probabilistic Losses
Loss Averse				
Delayed Gains	0.42	0.18	.07 [-.046, .19]	-.04 [-.17, .08]
Delayed Losses	0.56	0.22		.19** [.06, .31]
Probabilistic Losses	0.59	0.22		
Debt Averse				
Delayed Gains	0.48	0.20	-.53** [-.69, -.33]	.12 [-.13, .35]
Delayed Losses	0.66	0.22		-.12 [-.35, .13]
Probabilistic Losses	0.60	0.22		
Minimizer				
Delayed Gains	0.45	0.30	--	-.31** [-.47, -.13]
Delayed Losses	1	--		--
Probabilistic Losses	0.63	0.26		
Risk Averse				
Delayed Gains	0.45	0.21	.21** [.10, .32]	-.04 [-.15, .07]
Delayed Losses	0.67	0.27		.04 [-.07, .15]
Probabilistic Losses	0.53	0.18		
Uncertainty Averse				
Delayed Gains	0.42	0.22	-.55** [-.72, -.33]	-.23 [-.47, .04]
Delayed Losses	0.70	0.25		.37* [.11, .58]
Probabilistic Losses	0.68	0.15		
Minimaxer				
Delayed Gains	0.36	0.28	-.49** [-.67, -.25]	--
Delayed Losses	0.75	0.29		--
Probabilistic Losses	1	--		

Note: * indicates $p < .05$; ** indicates $p < .01$. Values in brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014).

and the probabilistic losses questionnaire were only significant in the Minimizer subgroup for which the negative correlation means that those who were more willing to wait for a delayed gain tended to be the ones who were less willing to pay a certain payment. The positive correlations between the delayed and probabilistic losses questionnaires were significant in the Loss Averse and Uncertainty Averse subgroups, suggesting that those who choose more immediate payments tended to be the ones who chose more certain payments. It is to be noted that the individuals in the Minimizer subgroup always chose the immediate loss on the delayed losses questionnaire, thereby precluding calculation of the correlation of their choices on the delayed losses questionnaire with their choices on the other two questionnaires. Likewise, individuals in the Minimaxer subgroup always chose the certain loss on the probabilistic losses questionnaire, and so correlations of their choices on the probabilistic loss questionnaire with those on the other two types of questionnaires is not possible.

Chapter 4: Discussion

To evaluate individual differences in the discounting of probabilistic losses, we developed a 27-item questionnaire modeled on that developed by Kirby et al. (1999) for delayed gains and Myerson et al. (2017) for delayed losses. The new measure proved to be valid. It showed respectable reliability, and choices of the certain payment systematically changed as a function of the *h* parameters. The questionnaire also captured individual difference in evaluating probabilistic losses, revealing different subgroups of individuals.

The current study produced several notable findings. First, we replicated our previous finding of three subgroups in the discounting of delayed losses (Myerson et al., 2017). In that study, about 60% of participants were identified as Loss Averse, and approximately 20% were Debt Averse and 20% were Minimizers. In the current sample, 58% of participants were identified as Loss Averse, 14% as Debt Averse, and 27% percent as Minimizers. The presence of the debt averse subgroup, which shows a pattern of discounting different from the majority of individuals may explain the inconsistencies in the loss discounting literature noted by Harris (2012).

When a similar identification procedure was applied to the results from the discounting of probabilistic losses questionnaire, three subgroups again were observed. Seventy percent of participants were identified as Risk Averse, for whom the aversiveness of a loss decreased with the probability of its occurrence. For 11% of the participants, identified as Uncertainty Averse, the aversiveness of a loss increased as the likelihood of occurrence decreased. About 14% of the participants always chose the certain, smaller loss even though the expected value of the probabilistic alternative sometimes was less than that of the certain loss, and were identified as

Minimaxers. There are no other published studies that have explored individual differences in the discounting of probabilistic losses, and consequently this three-subgroup classification requires replication. However, it is to be noted that when we applied the same identification procedure to the delayed losses questionnaire, we also found three subgroups, replicating the findings of Myerson et al. (2017). Moreover, with the delayed gains questionnaire, no subgroups comprising a large percentage of participants were found. Whereas 377 participants increasingly discounted the value of gains as the delay to their receipt increased, only 12 individuals showed negative discounting (choice of the delayed monetary gain increased with time to its receipt). There were also 13 people who always chose the delayed, larger gain, and 17 people who always chose the immediate, smaller gain. Compared with their choice behavior on the delayed and probabilistic losses questionnaires, the participants performed in a far more consistent pattern, with differences among individuals being quantitative in nature, on the delayed gains questionnaire. Those observations support the conclusion that individuals differ qualitatively as well as quantitatively in their discounting of delayed and probabilistic losses.

Other differences among these subgroups also support these classifications. Myerson et al. (2017) found that the delayed loss subgroups differed with respect to their choices involving delayed gains, and therefore argued that these subgroups were not merely descriptions of people's behavior in one kind of choice situation. In that study, members of the Debt Averse subgroup chose the delayed gains significantly more than the other two subgroups. Although not significant, we, too, observed a trend in which members of the Debt Averse subgroup chose the more delayed gains. In addition, when the participants' choices on the three questionnaires were correlated, the delayed loss subgroups differed with respect to the significance and direction of the correlations, consistent with the observation of Myerson et al. (2017). Similarly, we compared the probabilistic loss subgroups and found that members of the Risk Averse subgroup chose the delayed gains significantly more than members of the Minimaxer subgroup. The Risk Averse and Uncertainty Averse subgroups also differed with respect to their correlations among the choice questionnaires.

Another notable set of findings related to the magnitude effect. At the group level, there was a clear and reliable effect of amount on the discounting of delayed gains, whereas the effect sizes for that for the discounting of the delayed and probabilistic losses were minimal. At the subgroup level, only the delayed gains discounting task produced a persistent magnitude effect either in the delayed loss subgroups or in the probabilistic loss subgroups. In contrast, although there was also a significant linear trend in discounting delayed losses across the delayed loss subgroups, the relation was in fact better described by a quadratic term. Myerson et al. (2017), using the same delayed losses questionnaire, found no magnitude effect. One might propose that their lack of a magnitude effect with losses was because the differences between the amounts were too small to be differentially effective. However, the finding of an effect of amount on the discounting of delayed gains with comparable differences between amounts has been consistently observed (Kirby et al., 1999; Myerson et al., 2017; Yoon & Chapman, 2016), whereas studies have failed to find consistent effect using amounts of loss over a wide range (Green et al., 2014). Taken together, the pattern of findings suggests that amount has little effect on the discounting of delayed or probabilistic losses.

Our results also demonstrate the value of taking individual differences into account in studying the relations among different discounting tasks. The literature shows inconsistent findings regarding the correlation between the discounting of delayed gains and delayed losses. We failed to find a significant correlation between the choice of delayed gains and the choice of immediate payments and found a significant correlation between the discounting of delayed and probabilistic losses, contrary to the observation of Mitchell and Wilson (2010). This inconsistency, however, could be easily resolved when one takes into account the subgroups. Each subgroup we identified had distinct characteristics. While a positive correlation between the discounting of delayed gains and delayed losses was found in the Risk Averse subgroup, significant negative correlations were observed in the Debt Averse, Uncertainty Averse, and Minimaxer subgroups. Different percentages of the subgroups in the sample have the effect of changing the correlations observed. For example, if the correlation between the discounting of delayed gains and delayed losses was calculated with a sample involving several more Minimizers, the correlation coefficient would inevitably be attenuated. Thus, any differences between studies may well be due to differences in the sizes of the subgroups, and other studies have not known to look for these subgroups.

Myerson et al. (2017) reported a significant negative correlation between choice of delayed gains and choice of delayed losses in their Loss Averse subgroup, and a non-significant positive correlation in the Debt Averse subgroup (They used choice of delayed losses instead of immediate losses in their analysis, which simply makes the sign the correlation different from ours). In our sample, we observed a significant negative correlation between choice of delayed gains and choice of immediate losses in the Debt Averse subgroup, but a non-significant correlation in the Loss Averse subgroup. This inconsistency is perplexing, but may be a result of the arbitrarily determined classification rule. We identified participants who always chose the immediate, smaller payment as Minimizers. However, it's unclear how much those participants differ from those who also showed strong preference for the immediate, smaller payment but choose one delayed payment on one of the 27 items. It's possible that if more extreme option were offered, some of those identified as Minimizers might choose a delayed, larger payment and then be classified as a member of the Loss Averse subgroup. Even though we argue that each subgroup had a distinct characteristic, it doesn't prevent the possibility that the Minimizer subgroup included some extreme members of the Loss Averse and Debt Averse subgroups while Loss Averse and Debt Averse subgroups might also include some members of Minimizer. In support of this suggestion it is to be noted that when we excluded the 15 participants who chose only one delayed payment in the delayed losses questionnaire from the Loss Averse subgroup, a significant positive correlation was then observed (r = .161; 95%; CI [.031, .286]). This finding, however, points out a potential issue related to the current identification procedure. Adding more extreme items to the questionnaire might help. Nevertheless, further research is needed to refine the classification method that would complement the current initial approach.

The addition of test items to directly assess zero and negative discounting could provide one avenue to improve the current subgroup identification procedure. To detect unusual discounting, Yoon and Chapman (2016) included an additional item that explicitly asked participants whether the delay to a payment would make a difference if the amount to be paid remained the same, or if they would prefer to pay more today instead of paying less after few days delay. In their study, 32 participants showed either zero or negative discounting whereas 59 participants had positive discounting rates. This method seemed to be valid, but it should be interpreted with caution when compared with our identification procedure.

In the present study, the members of the Loss Averse and Risk Averse subgroups were those who discounted losses as the delay to and the odds against paying increased, respectively. The members of the Debt Averse and Uncertainty Averse subgroups also discounted delayed and probabilistic losses but for them, there was a general trend that the aversiveness of a loss increased with the delay and unpredictability. The members of Minimizer and Minimaxer subgroups were those who chose solely based on the amount or the probability of the payment. If all participants were evaluated by the approach used by Yoon and Chapman (2016), the members of our Loss Averse and Risk Averse subgroups would be expected to show positive discounting rates. The members of the Debt Averse and Uncertainty Averse subgroups also would show positive discounting rates, but their choice patterns cannot be well described by the hyperbolic discounting model, which makes the discounting rate estimation inappropriate (see Gonçalves & Silva, 2015 for an alternative model that might be used to describe the data). The members of the Minimizer and Minimaxer subgroups show zero discounting in this study; however, because there was no test item in the delayed and probabilistic losses questionnaire that involved an alternative payment with an equal amount (e.g., pay $90 now or pay $90 in 4 months), it's unclear how they would respond to the item that directly assesses zero discounting. Some members of the Minimizer subgroup might even choose to pay more immediately rather than delay the payment and thus show negative discounting. In contrary, it's unlikely that any member of the Minimaxer subgroup would show negative discounting since a result would imply a preference for a larger loss.

Because the questions used in the current study asked about hypothetical choices, one may well raise the question as to whether the observed individual differences would be evident if the participants' choices were associated with real consequences. Previous studies, it is to be noted, have reported little difference in discounting rates between situations using real and hypothetical delayed gains (Bickel et al., 2010; Bickel, Pitcock, Yi, & Angtuaco, 2009). In addition, the discounting rate of delayed hypothetical monetary gains has been found to correlate significantly with real life behaviors, such as drug usage, sexual activity, and obesity (Kirby et al., 1999; Reimers, Maylor, Stewart, & Chater, 2009). These findings suggest that the results from discounting studies using hypothetical outcomes provide insight into real-world decision-making. We would note, however, that currently there is no study that has evaluated whether similar patterns of discounting behavior are evident when real and hypothetical losses are compared. An innovative method, one in which real losses could be involved, is needed to answer that question.

Chapter 5: Conclusion

The results from the present study show that people differ quantitatively in their discounting of delayed gains but differ qualitatively as well as quantitatively in their discounting of delayed and probabilistic losses. There was a magnitude effect in the discounting of delayed gains, but not in the discounting of delayed or probabilistic losses. Although most participants increasingly discounted the value of a gain as the delay to its receipt increased, they evaluated delayed and probabilistic losses differently. Many people increasingly discounted the value of a loss with the increase in its delay and odds against; however, for others, the aversiveness of a loss actually increased with its delay and odds against receiving it. There were also people who didn't discount the aversiveness of losses with delay or probability at all. When these differences in evaluation of delayed and probabilistic losses were taken into account, different relations between the choices of delayed gains, delayed losses, and probabilistic losses emerged, which provides a resolution to the inconsistent findings in the literature. Taken together, the current results suggest that the processes underlying the discounting of delayed gains, delayed losses, and probabilistic losses are different, and it is critical to consider individual differences in decision-making when studying loss discounting.

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