The Effect of Temporal Delay on the Interpretation of Probability

Amber N. Bloomfield (a-bloomfield@northwestern.edu)
Department of Psychology, 2029 Sheridan Road
Evanston, IL 60208 USA

Abstract

The studies reported here investigate the interaction between probability and delay. In the first study, the fits of a range of high and low probability words were calculated for numerical probabilities presented with either a short or long delay. Results show that participants in the long delay condition felt that high probability words fit small numerical probabilities better and that low probability words fit large numerical probabilities better than did participants in the short delay condition. In a second study, participants were presented with money offers that were both delayed and risky. Findings indicate that delay is given less weight at low probabilities, and probability is given less weight at large delays when probabilities are mid-range. Combined, these data suggest that a trade-off occurs between giving attention to delay and giving attention to probability in judgments. One component of this arises from long time delays "dampening down" the influence of probability level, but the complete nature of the interaction between probability and delay remains to be explored.

Introduction

In everyday decision making, individuals must determine the value that various outcomes have for them. Often, even if people have a clear idea of the value that an outcome has for them in general (such as a week in Paris), they must assess its value in terms of different types of uncertainty associated with the outcome. One type of uncertainty arises from the outcome having a less than 100% likelihood of occurring (i.e., it is probabilistic). This type of uncertainty is normatively applied by translating an outcome into its *expected value* (EV): multiplying the value of the outcome by its probability of occurring. Another type of uncertainty associated with outcomes is temporal delay. Adjustment of an outcome due to temporal delay is referred to as *temporal discounting.*

Choice involving risk (i.e., probabilistic outcomes) and intertemporal choice have several parallel anomalies (Prelec & Loewenstein, 1991). These anomalies include common difference and ratio effects, immediacy and certainty effects, magnitude effects and sign effects. Common difference effect occurs when a pair of delayed outcomes which an individual is indifferent between produce a decisive preference for him or her when a common delay is added to both. For instance, a person might be indifferent between $25 now and $40 is one week, but may express a preference for the $40 if a one-week delay is added to both options. Similarly, common ratio effect occurs when two probabilistic options which a person is indifferent between produce a solid preference when their probabilities are multiplied by a common probability. A person might be indifferent between a 5% chance of $10 and 2% chance of $15, but prefer the $15 option if both probabilities are multiplied by 50%. Immediacy and certainty effects involve the overweighting of immediate outcomes in intertemporal choice and the overweighting of certain outcomes in risky choice. Magnitude effects occur when large amounts are discounted to a lesser (temporal discounting) or greater (discounting for risk) degree than are small amounts. Sign effects involve a tendency towards risk-aversion for gains and risk-seeking for losses in risky choice, and a steeper discounting of gains than losses in intertemporal choice.

Given these parallels, it is not surprising that some researchers have suggested that discounting for risk and discounting for delay arise from the same source. For instance, Benzion, Rapoport and Yagil (1989) argue that, in addition to the time value of money (characterized as the accepted interest rate) delay introduces a *risk premium*, which arises from the implicit risk associated with delay. By this interpretation, the temporal discounting stems from implicit risk combined with the rational time value of money. Alternatively, Rachlin and Raineri (1992) argue that probability can be expressed as waiting time, by estimating the number of trials until a win (60% chance ≈ 6 out of 10 trials are wins), and adding together the amount of time between each trial preceding the first win to calculate overall waiting time. These two ideas both argue for a fundamental source of uncertainty (either risk or delay) that leads to both types of discounting.

It is likely that because of the focus on equating probability and delay little attention has been paid to how they affect each other, both in determining the value of outcomes and directly. Only a few studies have actually presented participants with outcomes that are both delayed and probabilistic. Keren and Roelofsma (1995) argue for two different types of uncertainty present in intertemporal choice: internal (involving doubts about one's ability to predict future tastes/needs) and external (concerning doubts about whether promised future payments will be honored). Internal uncertainty is the type of uncertainty typically associated with intertemporal choice. External uncertainty is probabilistic uncertainty, which they argue is also a component of any temporal delay. They found that the immediacy effect could be derailed by making the options probabilistic (the immediate option was no longer over-weighted), and that adding a delay to a certain option weakened the certainty effect (the certain option was no longer as over-weighted, and more people preferred a risky option that had a higher payoff). Keren and Roelofsma did not find a significant interaction of delay and probability, and suggested that the two factors are additive. However, they used only two levels of probability in their experiment examining the immediacy effect, and only one level of temporal delay when examining the certainty effect.

Keren and Roelofsma's (1995) description of the external uncertainty component of delay does suggest that the subjective interpretation of a given probability when a delay is introduced should be lower, because the uncertainty associated with a delay should make the relevant outcome seem even less likely to be received. While Keren and Roelofsma only used delay and probability to make qualitative departures from certainty and immediacy, respectively, a more continuous effect of delay on probability should be evident if external uncertainty increases with delay.

In the following studies, the effect of delay on the interpretation of probability is explored. In the first study, a range of probabilities are paired with one of two levels of delay for all participants, and 10 probability words are rated as to their fit of each of the numerical probabilities. In the second study, multiple levels of probability and delay are combined to examine their effects on the value of two different monetary outcomes.

Study 1

In Study 1, a direct method of examining the influence of delay on probability was employed. This design was based on past work by Budescu, Karelitz and Wallsten (2003) examining how numerical probabilities are mapped on to linguistic probability words/phrases. The method of presentation was reversed, so that participants were asked to rate degree of fit of 10 probability words for each of 10 numerical probabilities. It was predicted that, if there is an external uncertainty component of delay, this would lead to numerical probabilities presented with the longer temporal delay to elicit higher fit ratings for the low probability words and lower fit ratings for the high probability words.

Methods

Materials

Instructions Participants were asked to respond to each numerical probability item by rating each probability word for that numerical probability on a scale from 1 to 8, with 1 indicating that the word fit the numerical probability "not at all" and 8 indicating that the word "absolutely" fit the numerical probability.

Stimuli Participants were randomly assigned to receive all numerical probability statements with either a short (6 months) or long (3 years) delay. Participants were presented with 10 numerical probabilities (5% - 95% in steps of 10%) embedded in the following statement: "If someone told you 'you have a _% chance of winning $9,864 in 6 months/3 years,' to what degree do you feel each of the following words fits the probability this person stated?" For each statement, participants rated 10 probability words on the basis of their fit. The probability words, (from lowest to highest probability-mapping, according to Budescu, et al., 2003) were: Impossible, Improbable, Unlikely, Doubtful, Toss-up, Possible, Probable, Good chance, Likely and Certain. The numerical probabilities were presented in a different randomized order for each participant.

Procedure Participants received the instructions for the task and responded to the test items via computer. During the task, participants were presented with each numerical probability statement followed by the 10 probability words. Participants typed in their rating for each word on the keyboard. After responding to all 10 numerical probability statements, participants were presented with the debriefing.

Participants Participants were 32 Northwestern undergraduates who participated to fulfill partial course requirement (17 in the 6 month delay condition, 15 in the 3 year delay condition).

Results

The mean rating of each probability word for each numerical probability in the two conditions was translated into proportion of total fit (by dividing the mean score by eight). These proportions were then collapsed across the three low probability words, not including impossibility (Improbable, Unlikely, and Doubtful) and the three high probability words, not including certainty (Probable, Good chance and Likely) to create a composite Overall-Low and Overall-High fit for each numerical probability.

A regression performed on the Overall-Low composite fits revealed a significant effect of probability ($t(19) = -24.94$, $B = -.979$, $p<.001$), a marginally significant effect of condition ($t(19) = 2.05$, $B = .080$, $p = .058$) and a significant interaction between probability and condition ($t(19) = 2.51$, $B = .099$, $p<.05$). Figure 1 displays the Overall-Low fits for the 6 month and 3 year conditions across numerical probabilities.

Overall-Low fits decreased as probability increased (as

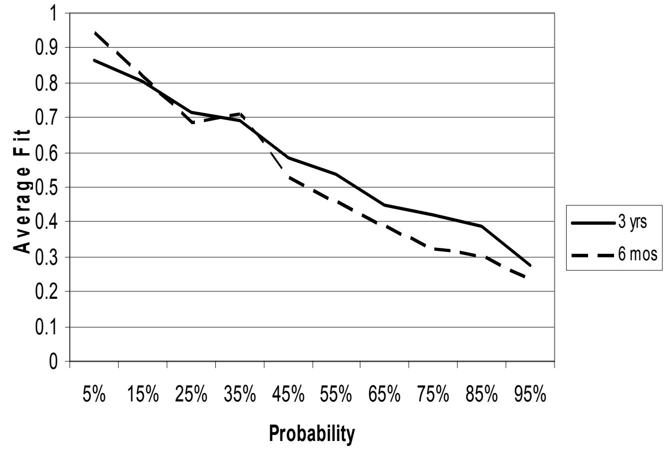

Figure 1: Overall-Low Proportions Across Probabilities

would be expected), and were higher for the 3-year delay condition (as was predicted). However, the interaction between condition and probability reveals a more complicated picture: While participants in the 3 year delay condition have higher Overall-Low fits for the higher numerical probabilities than do participants in the 6 month delay condition, there is also a tendency for these participants to rate the fit of low probability words as *lower* for the smaller numerical probabilities.

A regression performed on the Overall-High composite fits revealed a significant effect of probability ($t(19) = 25.47$, $B = .981$, $p<.001$) and a significant interaction between probability and condition ($t(19) = -2.90$, $B = -.111$, $p<.05$). Figure 2 presents the Overall-High fits across probabilities for both conditions. For the Overall-High ratings, the nature of the interaction between condition and probability is more pronounced. Participants in the 3-year condition provided lower fit ratings of the high probability words for the higher numerical probabilities *and* higher fit ratings for the lower numerical probabilities.

The findings of Study 1 suggest that delay does not have a uniform effect on the interpretation of probabilities. Rather, the effect of delay is determined by both the level of the numerical probability and the "level" of the probability word. The longer delay increases the fit of the low probability words to the numerical probabilities, as predicted, but only for those probabilities in the mid-range or higher. For smaller numerical probabilities, the longer delay *decreases* the participants' ratings of low probability words. Similarly, the longer delay decreases participants' ratings of high probability words for probabilities in the mid-range or higher, as predicted, but *increases* these ratings for the lower numerical probabilities. It seems that a longer delay decreases the "positive-ness" of the high probabilities but also the "negative-ness" of the low probabilities. At long delay, participants do not seem to uniformly interpret probabilities as lower, but do seem to uniformly interpret probabilities as less extreme.

Given the findings of Study 1, it is apparent that delay does influence how numerical probabilities are understood, and the direction of this effect depends on the level of the numerical probability. Because this interaction exists, it is important to look at how probability and delay combine in determining the value of outcomes that are both delayed and probabilistic. In Study 2, the effects of delay and probability, and the interaction between the two, on the value of monetary outcomes are investigated.

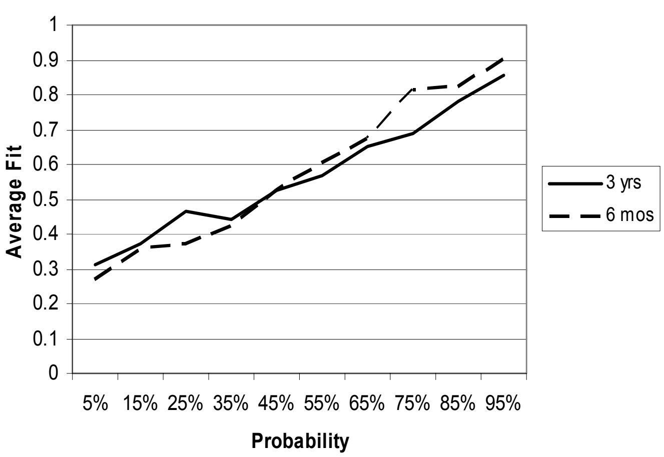

Figure 2: Overall-High Proportions Across Probabilities

Study 2

Methods

Materials

Instructions Participants were instructed to respond to each item by providing a *certainty equivalent* (CE) for the money offer. A certainty equivalent is an amount that will be received immediately and for certain, such that participants feel they would be indifferent between this amount and the presented money offer.

Stimuli Participants responded to a total of 70 money offers. For each of two payoff amounts ($10,000 and $1 million) participants responded to five gambles with one of five probabilities (5%, 30%, 55%, 80% or 95%), five delayed payments with one of five time delays (6 months, 1 year, 3 years, 5 years or 10 years) and 25 *delayed gambles*, combining each probability level with each delay level once. Gambles, delayed payments and delayed gambles for both payoffs were presented in a different random order for each participant.

Procedure Participants received the instructions for the task and responded to the test items via computer. During the task, participants were presented with each money offer and typed in a certainty equivalent using the keyboard. Participants were not given any feedback on their performance. At the end of the 70 money offers, participants were read debriefing information by the experimenter.

Participants Participants were 18 Northwestern undergraduates who participated to fulfill partial course requirement. The data from two additional participants was excluded due to a failure to follow directions (more than ¼ of their responses were greater than the payoff of the money offer or they responded "0" to one or more items).

Results

Because several participants had one or two responses that were greater than the payoff amount (errors occurring from accidentally typing an extra "0" into the computer), all analyses were performed on median responses as opposed to mean responses.

Weighting and Discounting Factors Using the responses to the delayed payments, it was possible to calculate the temporal discounting factor (k) for each participant. This factor represents the extent to which, for each day of delay, an individual devalued the payoff amount. The formula for k

is derived from the formula for temporal discounting developed by Mazur (1987): $k = (V/dv)-(1/d)$, where V is the undiscounted value of the outcome, d is the delay in days and v is the provided subjective value of the outcome. A k of 0 implies no discounting of the outcome for delay. For each participant, the median k across all delayed payments was obtained.

There was a significant effect of amount on the median k values: participants tended to have larger ks for payoffs of \$10,000 than for payoffs of \$1 million ($t(17) = 2.85$, $p < .05$). The mean k for the \$10,000 delayed payments was .0005, while that for the \$1 million delayed payments was .0002. Larger ks imply greater temporal discounting, and greater discounting of smaller payoffs is consistent with the magnitude effect discussed in Prelec and Loewenstein (1991). Although the difference between the k factors for the two amounts seems quite small, such a difference would result in an 8% decrease in value for \$10,000 delayed by 6 months compared to only a 4% decrease for \$1 million delayed by 6 months.

Using the responses to the gambles, the probability weighting factor (h) was calculated for each participant. This factor represents the extent to which an individual's weighting of probabilities in their responses corresponds to expected value (h = 1 means responses are perfectly in line with expected value). An h greater than 1 demonstrates risk-aversion (the certainty equivalent is less than the expected value of the gamble), while an h between 0 and 1 shows risk-seeking (the CE is more than the gamble's expected value). The formula used to calculate h was derived from the probability weighting formula provided by Rachlin and Raineri (1991): $h = pV/v(1-p) - p/(1-p)$. Here, p is the probability of acquiring the outcome amount V, and v is the provided subjective value of the outcome. For each participant, a median h was obtained.

There was no significant effect of amount on h, ($t(17) = 1.51$, $p > .05$). The mean h for \$10,000 gambles was 1.66, and 5.62 for the \$1 million gambles. The large difference is due to one participants' extremely risk-averse responses for the \$1 million gambles (median h for \$10,000 = 1; for \$1 million, median h = 1.11). This is consistent with Green, Myerson and Ostaszewski (1999), who found that magnitude effects in probability discounting are often small or non-existent. However, it is worth mentioning that, of the 14 participants that had different probability weighting factors for the \$10,000 and \$1 million gambles, 10 had larger h values for the \$1 million gambles, which is consistent with the discussion of Prelec and Loewenstein (1991).

Overall Analyses for Delayed Gambles Participants' certainty equivalents were transformed to proportion of payoff amount (e.g., \$5000 for a \$10,000 payoff was .50) for overall data analyses. Again, the median rather than the mean of these proportions was used for analyses to control for extreme responses. A regression with amount, probability and delay as predictors revealed significant effects of probability ($t(49) = 23.15$, $B = .95$, $p<.001$) and delay ($t(49) = -2.97$, $B = -.12$, $p<.01$), and a marginally significant interaction between probability and delay ($t(49) = -1.88$, $B = -.08$, $p = .068$), on the median proportion CE. The effect of probability on response was as expected (greater CEs provided for larger probabilities), although participants over-weighted 5% to a far greater degree than has been found in past studies. Delay also had the predicted effect, with smaller CEs provided for larger delays. Figure 3 displays the overall findings of proportion CE for the five delays and the five probabilities. Because amount had no significant influence on proportion CEs, they are collapsed across amount.

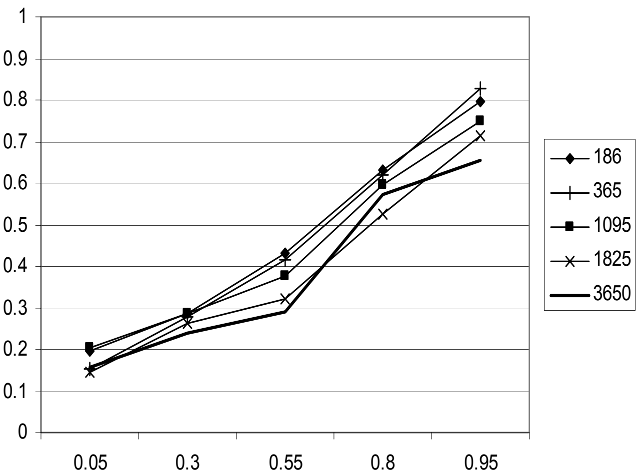

Figure 3: Proportion Certainty Equivalents by Delay and Probability

The delay by probability interaction is most apparent for the two longest delays (5 and 10 years). Participants show little increase in proportion CE with the increase from 30% to 55% probability for delayed gambles at a 5 or 10 year delay. In addition, participants show little sensitivity to delay at the two smallest probabilities.

These findings suggest an interaction between probability and delay of the type found in Study 1. Probability appears to be given less weight at longer delays. While the lines representing gambles at 5 and 10 year delays show no increase in CEs between 30% and 55%, the lines for gambles at 6 month, 1 year and 3 year delays show a relatively constant increase with probability. The influence of delay on probability is not evident until delay reaches high levels.

The findings of Study 2 are not so one-sided, however. In deciding the value of delayed and probabilistic outcomes, participants seem to be dividing their attention between probability and delay. It is not simply that probability is given less weight when longer delays are present: probability levels are given less weight at long delays when probabilities are *small*. Further, as is evident from examining the points at 5% and 30%, little attention is given to delay at the two smallest probability levels (it is not until a 55% probability of winning that participants really begin to differentiate between the delay levels in their responses). This interpretation does not necessarily require that long delays induce smaller subjective probabilities. Rather, in the influence of delay on probability, at long delays participants could simply be using probability less in determining their responses. This idea of trading off attention between option components is supported by analyses performed for the \$10,000 and \$1 million gambles separately: delay was not a significant predictor for the \$1 million gambles ($t(24) = -1.61$, $B = -.09$, $p > .10$, but was significant for the \$10,000 gambles ($t(24) = -2.67$, $B = -.15$, $p < .05$). This could indicate that, when outcome amount was large, participants devoted attention to the amount and the probability level in their figuring of a certainty equivalent, leaving no attention for delay.

The present interaction demonstrates that probability is weighted less when a long delay is associated with the gamble, and that delay is weighted less when probability of winning is low. Study 2 provides evidence that probability and delay influence each other in determining the value of payoffs.

Discussion

Study 1's findings indicate that delay influences the interpretation of probability, such that low probabilities are interpreted as less *unlikely*, *improbable* and *doubtful*, and high probabilities are interpreted as less *probable*, representative of a "*good chance*," and *likely*. A large delay seems to take attention away from probability at both high and low levels, suppressing the negative-ness of the low probabilities, and the positive-ness of the high probabilities (in effect, "dampening " the impact of probability).

Study 2's findings support the idea that delay influences the interpretation of probability: Probability (when it is mid-range) is given less weight in participants' judgments when delays are long. However, the relationship between delay and probability seems to be more complicated: delay is also given little weight when probability is very small. This suggests that what may actually be going on in the evaluation of the delayed gambles is a tradeoff between the attention given to probability and the attention given to delay. Thus, when delay is very large, and probability is mid-range, probability is given less attention than at smaller delays. Conversely, when probability is small, delay is given less attention than when probability is higher. The finding that delay is not a significant predictor for \$1 million gambles also suggests that when amount is very high, there may not be enough attention left over for delay to figure into participants' responses.

Whether or not the "dampening" effect was present in Study 2 is not completely clear. Although the interaction of delay and probability can be interpreted as less attention given to probability when delay is very long, the effect of probability level on the weight given to delay was unanticipated. Further, if the dampening effect of large delays on probability was present one would have expected to see less weight given to probability, not just for the mid-range probabilities, but for the higher probabilities as well. However, if the interaction of delay and probability arises largely from the influence of delay on probability, it would be extremely difficult to see in the data from Study 2. As was pointed out above, probability had a *much* greater impact on responses than either delay or the interaction of delay and probability. In fact, it was not unusual for participants to show no sensitivity to delay at all in responding to the delayed gambles, but rather simply respond in accordance with expected value.

Past studies have demonstrated that outcome amount and probability have a dominant/subordinate relationship, with outcome amount taking precedence (Liberman & Trope, 1998; Sagristano, Trope, & Liberman, 2002). Although Study 2 did not provide any way of looking at that particular relationship, its findings do suggest that a similar relationship may exist between probability and delay. Probability accounted for most of the variance across both outcome amounts, and was significant within both outcome amounts. Delay, on the other hand, accounted for a small amount of variance across amounts, and ceased to be a significant predictor when only the \$1 million gambles were considered. This makes sense if payoff is more important to participants than probability, which is more important than delay. The possibility of a dominant/subordinate relationship between probability and delay should be more directly examined in future studies using a method similar to that used by Liberman and Trope (1998).

If probability is indeed more important to participants making decisions about delayed gambles than is delay, techniques to highlight delay could be used. In Study 2, for all delayed gambles, participants were given the probability information first. This could have decreased the role of delay in participants' responses. Further, payoff amounts were expressed as round numbers (\$10,000 and \$1 million) for which it would be relatively easy to calculate expected value. A current study is investigating the influence between delay and probability when items are counterbalanced as to which information is presented first, and when payoffs are not round (e.g., \$10,135). It is hoped that this study will produce responses that are more sensitive to delay, and allow a clearer picture of the interaction between delay and probability.

Another question that remains unanswered is the manner in which probability level influences the interpretation of a given delay. Study 2's findings suggest that the effect of delay may be dampened by the presence of a small probability. If the external uncertainty portion of the temporal delay affects probability interpretations, perhaps the external uncertainty associated with risk changes the interpretation of delays, by highlighting the delay's external uncertainty. Although it is difficult to find a factor to pair with delay that will parallel the relationship between numerical probabilities and probability words, one could be constructed presenting linguistic descriptions of durations (e.g., "brief time" or "very long wait") to examine the influence of small and large probability levels on the interpretation of delays associated with monetary outcomes. It is possible that for a very small probability people will not differentiate as much between different levels of delays as they do with a large probability.

A final area yet to be examined is that the two uncertainty components of delay (internal and external) mentioned in Keren and Roelofsma (1995) may be able to be separately manipulated. For instance, it is easy to imagine situations where a delay could imply greater external uncertainty (e.g., a promise from an unreliable source), but not necessarily greater internal uncertainty. Conversely, while a spring vacation in Cancun might seem very valuable to me now, I have good reason to believe that it will have less value for me when I am ten years older, though I have no reason to think that I am less likely to receive that trip in ten years as opposed to a trip to Spain. Looking at how delay influences the value of different outcomes which emphasize or increase its internal or external uncertainty component is necessary to fully understand why delay decreases value.

Conclusion

The present studies demonstrate that there is an effect of delay on the interpretation of probabilities and an interaction between delay and probability on the value of monetary outcomes. When delay is longer, probabilities are interpreted as less extreme, at both higher and lower levels. Further, mid-range probabilities are weighted less at longer delays when valuing monetary outcomes, and delay is weighted very little when probabilities are small, suggesting that attention is traded off between delay and probability, depending on the levels of each. Because choices in life often involve delays and likelihoods less that 100%, it is worthwhile to explore the way people combine these two types of uncertainty and, especially for temporal delay, to gain a better understanding of the roots of delay's influence on value.

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