Management Science

Publication details, including instructions for authors and subscription information:
http://pubsonline.informs.org

Intertemporal Uncertainty Avoidance: When the Future Is Uncertain, People Prefer the Present, and When the Present Is Uncertain, People Prefer the Future

David J. Hardisty, Jeffrey Pfeffer

To cite this article:
David J. Hardisty, Jeffrey Pfeffer (2017) Intertemporal Uncertainty Avoidance: When the Future Is Uncertain, People Prefer the Present, and When the Present Is Uncertain, People Prefer the Future. Management Science 63(2):519-527. http://dx.doi.org/10.1287/mnsc.2015.2349

http://pubsonline.informs.org/journal/mnsc/

MANAGEMENT SCIENCE
Vol. 63, No. 2, February 2017, pp. 519–527
ISSN 0025-1909 (print), ISSN 1526-5501 (online)

Intertemporal Uncertainty Avoidance: When the Future Is Uncertain, People Prefer the Present, and When the Present Is Uncertain, People Prefer the Future

David J. Hardisty,[a] Jeffrey Pfeffer [b]

[a] Sauder School of Business, University of British Columbia, Vancouver, British Columbia V6T 1Z2, Canada; [b] Graduate School of Business, Stanford University, Stanford, California 94305

Contact: david.hardisty@sauder.ubc.ca (DJH); pfeff@stanford.edu (JP)

Received: March 2, 2014
Accepted: August 19, 2015
Published Online in Articles in Advance: February 29, 2016

https://doi.org/10.1287/mnsc.2015.2349

Abstract. Three studies explored the effects of uncertainty on people's time preferences for financial gains and losses. In general, individuals seek to avoid uncertainty in situations of intertemporal choice. While holding the expected value of payouts constant, participants preferred immediate gains and losses if the future was uncertain, and preferred future gains and losses if the present was uncertain. This pattern of preferences is incompatible with current models of intertemporal choice, in which people should consistently prefer to have gains now and losses later. This pattern of uncertainty avoidance is also not explained by prospect theory models, which predict risk seeking for losses. We discuss these findings in relation to previous literature.

History: Accepted by Yuval Rottenstreich, judgment and decision making.
Funding: The authors thank the Social Sciences and Humanities Research Council of Canada [Grant SSHRC 430-2014-00068] for supporting this research.
Supplemental Material: Data and the online appendices are available at https://doi.org/10.1287/mnsc.2015.2349.

Keywords: utility preference • decision analysis • economics • behavior and behavioral decision making • probability

Introduction

People must constantly decide between the present and the future. For example, should someone spend money on a nice vacation now, or save it for retirement? Pay a credit card bill now, or wait until next month? These "intertemporal choices" are often modeled with an equation that attempts to distill a person's time preferences over multiple periods into a single discount rate, such as in popular exponential and hyperbolic models (Mazur 1987, Samuelson 1937). These models generally assume a positive discount rate, implying that people consistently prefer to have good things now and put off bad things until later.

Of course, many delayed outcomes are also uncertain (e.g., a 50% chance of receiving $100 in one week). Unified treatments of risk and delay generally assume that decision makers first evaluate the risk component (50% chance of $100), subjectively transforming it into a certainty equivalent (e.g., $40), and then temporally discount this certainty equivalent (e.g., Loewenstein and Prelec 1992, Rachlin and Raineri 1992, Rachlin et al. 1991, Samuelson 1937). Thus, most formal models have treated risk and time separately, implicitly assuming that uncertainty does not change time preferences, and that the presence of delay does not influence risk preferences. However, experimental investigations have found that uncertainty does indeed influence time preferences for rewards. For example, greater future uncertainty increases the preference for immediate gains (Ahlbrecht and Weber 1997, Anderson and Stafford 2009, Mischel and Grusec 1967), adding uncertainty to all outcomes removes the premium people put on immediate rewards, and delaying outcomes removes the premium people put on certain rewards (Keren and Roelofsma 1995, Weber and Chapman 2005). Thus, the story for gains is fairly clear: people dislike delay, dislike uncertainty, and really dislike the combination of delay and uncertainty (more so than the linear combination of these two factors).

A critical moderator of time and risk preferences is whether the outcome is a gain or a loss (Estle et al. 2006, Mitchell and Wilson 2010). For time, the "sign effect" describes the fact that losses are discounted less than gains (Hardisty and Weber 2009, Thaler 1981). In other words, people want sooner gains more strongly than they want to postpone losses. For risk, prospect theory holds that people are generally risk seeking for losses but risk averse for gains (Kahneman and Tversky 1979). Loewenstein and Prelec's model of time and risk preference incorporates both of these findings in a unified framework (Loewenstein and Prelec 1992), and assumes that they do not interact (i.e., that time preference for losses is not effected by the presence of risk). Empirical research on time preferences for

Table 1. Previous Empirical Studies on the Effect of Uncertainty on Time Preferences for Gains and Losses

Reference	Sample	Procedure	Stimuli	Sign effect	Effect of risk on time preference
Mischel and Grusec (1967)	96 U.S. elementary school children	21 choices between SS and LL rewards or punishments (within subjects)	Choice between SS and LL outcomes (both financial and nonfinancial) delayed 1 day, 1 week, or 1 month, with probability = 0.1, 0.5, or 1.0. Note that LL values were constant; therefore the expected values of the probabilistic outcomes were always closer to 0.	Yes	Greater future uncertainty led to more SS reward choices and more LL punishment choices.
Shelley (1994)	30 U.S. M.B.A. students	30- to 45-min instruction and practice, then 128 ratings of investments, then a one-day break, then 128 ratings of the same investment gambles	All outcomes were mixed lotteries including a gain ($1,000, $500, $100, or $60), a loss (−$900, −$400, −$200, −$160), a risk of gain versus loss ($p = 0.6$ or $p = 0.4$), a delay (immediate, 6 months, 1 year, or 2 years), and an immediate loss of $100.	Reversed	Different levels of explicit uncertainty had no effect on time preferences for gains or for losses. However, note that there were no certain outcomes in the stimuli set.
Ahlbrecht and Weber (1997)	132 German banking and finance undergraduate students	15-min instruction and practice, then 24 matching questions, then 42 choice questions using indifference points from earlier matching. Gain versus loss between subjects	For matching questions, future outcomes were delayed 6 months or 24 months, with amounts 12, 250, or 25,000 DM, and with probability = 0.99, 0.5, 0.01, or ambiguous. In choice questions, the SS option was taken from the participant's earlier matching answer.	No	In matching data, future uncertainty led to a stronger preference for SS gains and LL losses. In choice data, there was no effect of future uncertainty on time preferences.
Blackburn and El-Deredy (2013)	103 British non-psychology, noneconomics university students	~216 choices (dynamically generated) between SS and LL financial gains or losses (within subjects)	LL outcomes were £100 (certainty), a 50% chance of £200 (outcome uncertainty), or 100% chance of £50, £100, or £150 (amount uncertainty). In large-magnitude conditions, LL amounts were 10 times larger. LL outcomes were delayed 0 days, 2 days, 30 days, 6 months, 1 year, 2 years, 5 years, or 10 years.	Yes	Future outcome uncertainty led to more SS choices for gains and more LL choices for small losses (but not large losses). Future amount uncertainty led to more LL choices for large gains (but not small gains) and had no effect on losses.

Note. SS indicates "smaller, sooner" and LL indicates "larger, later."

uncertain losses (in contrast to gains) is quite heterogeneous in methods and findings (see Table 1), with some finding that future uncertainty makes future losses more attractive, and others finding no effect. We review this work in relation to our findings in the General Discussion.

In what follows, we systematically explore the effect of explicit uncertainty on time preferences for both losses and gains. We give participants standard intertemporal choice questions, such as a choice between paying $100 today or $110 next year. We then compare this with cases where the future is uncertain ($100 today versus 50% chance of $220 next year), cases where the present is uncertain (50% chance of $200 today vs. $110 next year), and cases where both the present and future are uncertain (50% chance of $200 today vs. 50% chance of $220 next year), holding the expected value constant. As far as we are aware, this is the first investigation of losses and gains to include scenarios in which the future is more certain than the present. We test these cases in national samples of U.S. adults (rather than the student samples used in previous research).

We find that people prefer to avoid uncertainty when making intertemporal choices, and that this uncertainty avoidance holds for both gains and losses. Formally,

Finding 1: When the future is uncertain, people prefer immediate, certain gains and losses more strongly (Study 1).

Finding 2: When the present is uncertain, people prefer future, certain gains and losses more strongly (Study 2).

Finding 3: When both the present and the future are uncertain, time preferences for gains and losses are relatively unaffected (Study 3).

On the one hand, this pattern of findings cannot be explained by prospect theory-style value functions (which predict risk seeking, rather than risk aversion, for losses). On the other hand, these findings cannot be explained by positing that the presence of uncertain outcomes in a given period uniformly changes the weight placed on that period (which would predict, for example, that uncertainty makes gains less good and losses less bad). Rather, our results illustrate a nonuniformity: people's intertemporal choices imply that uncertain gains receive less weight, but uncertain losses receive more weight. More colloquially, people avoid uncertainty in intertemporal choice. When the future is uncertain, people prefer the present, and when the present is uncertain, people prefer the future.

Study 1: Immediate Certainty vs. Future Uncertainty

Method

A sample of 70 U.S. residents (mean age = 46, SD = 16) was recruited via Survey Sampling International for a study on decision making. Participants were only eligible to participate if they were at least 18 years old, passed an attention check (similar to Oppenheimer et al. 2009) on the first page of the study, and were completing the study for the first time from that IP address (i.e., no repeat participants). These eligibility criteria were used for all our studies. The design was a 2 (future uncertainty: certain versus uncertain) × 2 (sign: gain versus loss) within-subjects design.

Target sample sizes for each study were chosen based on intuition of what would be a healthy sample size given the number of conditions and the results (e.g., variance) of previous studies. All manipulations and measures for all studies can be found in Online Appendix A. Furthermore, there are no unreported ("file drawer") studies on this project: all the studies we ran are reported in this paper or in the online appendix.

All participants responded to two "certain" intertemporal choice scenarios involving certain gains or losses. In the gain scenario, participants read the instruction, "Please imagine you face a set of choices about receiving $100 from investments immediately, or another amount 1 year from now." This was followed by six intertemporal choices:

1. Receive $100 immediately OR Receive $90 in 1 year
2. Receive $100 immediately OR Receive $100 in 1 year
3. Receive $100 immediately OR Receive $110 in 1 year
4. Receive $100 immediately OR Receive $125 in 1 year
5. Receive $100 immediately OR Receive $150 in 1 year
6. Receive $100 immediately OR Receive $200 in 1 year.

The dependent variable was the proportion of immediate choices. For example, a participant who chose the immediate $100 all six times would get a score of 1.0 on this measure, whereas a participant that chose the immediate option half the time would get a score of 0.50.

In the loss scenario, participants read the instruction, "Please imagine you face a set of choices about paying a $100 bill immediately, or another amount 1 year from now." This was followed by six intertemporal choices (for the complete experimental materials, see Online Appendix A), such as "Pay $100 immediately OR Pay $110 in 1 year."

All participants also responded to two "uncertain" intertemporal choice scenarios involving certain immediate outcomes versus uncertain future outcomes. In these scenarios, the future options were twice as large but only had a 50% chance of occurring. Thus, the expected value of the options was the same in the certainty and uncertainty conditions. At the beginning of the uncertain future gain scenario, participants read the instruction, "Please imagine you face a set of choices about receiving $100 from investments immediately, or another amount 1 year from now that would be uncertain (only a 50% chance of receiving it, which would be determined randomly, 1 year from now)." There were six intertemporal choice pairs for each scenario, such as "Receive $100 immediately OR 50% chance of receiving $220 in 1 year."

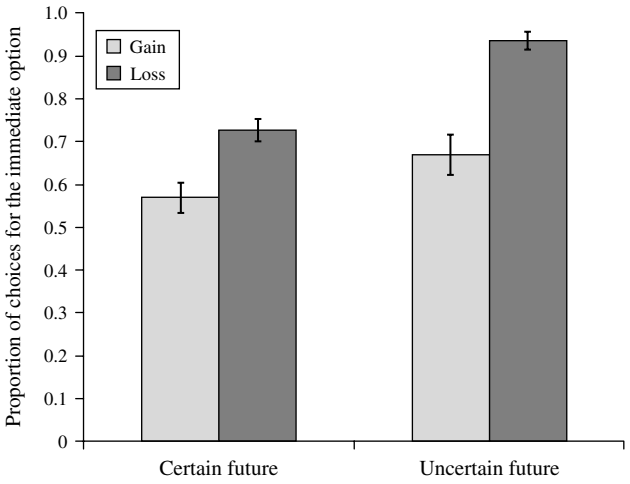
At the beginning of the uncertain future loss scenario, participants read, "Please imagine you face a set of choices about paying a $100 bill immediately, or another amount 1 year from now that would be uncertain (only a 50% chance of paying it, which would be determined randomly, 1 year from now)." There were six intertemporal choice pairs, such as "Pay $100 immediately OR 50% chance of paying $220 in 1 year."

All scenarios were presented in counterbalanced order. Finally, participants completed demographic measures.

Results

Rather than estimating exact discount rates, our goal was to explore the relative influence of uncertainty on time preferences. As such, throughout the results, we have operationalized time preference as the proportion of choices for the sooner option,[1] and risk preferences as the proportion of choices for the certain option. For

Figure 1. Mean Proportion of "Immediate" Choices When the Future Is Certain vs. Uncertain, in Study 1



Note. Error bars indicate ± one standard error.

each participant, we calculated four proportions, indicating the strength of preference for the immediate option when the future was certain versus uncertain for both gains and losses.

The order of the scenarios (intertemporal choice under certainty first or intertemporal choice with future uncertainty first) had no main effect on participants' choices, nor did it interact with uncertainty (in either the two- or three-way interactions), each $p = 0.32$ or greater. Therefore, we collapse across order in the following analyses.

As seen in Figure 1, the presence (or absence) of future uncertainty had a significant effect on participants' intertemporal choices: participants showed a stronger preference for immediate gains and losses when the future was uncertain. We ran a 2×2 repeated-measures general linear model (GLM) with future uncertainty (present versus absent) and sign (gain versus loss) predicting the proportion of choices for the immediate option. As predicted, a main effect of uncertainty, $F(1,69) = 31.4$, $p < 0.001$, $\eta^2 = 0.31$, indicated that participants chose the immediate option more often when the future was uncertain. A main effect of sign, $F(1,69) = 27.6$, $p < 0.001$, $\eta^2 = 0.29$, indicated that immediate losses were chosen more often than immediate gains, but this result was not relevant to our hypotheses.[2] The uncertainty by sign interaction was also significant, $F(1,69) = 4.0$, $p = 0.05$, $\eta^2 = 0.06$, indicating that the effect of future uncertainty on time preferences was stronger for losses than for gains. Pairwise contrasts confirmed that the effect of uncertainty on time preferences was significant for both gains, $t(69) = 2.0$, $p = 0.05$, and losses, $t(69) = 8.7$, $p < 0.001$.

On a within-subject level, 44% of participants chose immediate gains more often when the future was uncertain (compared to when all options were certain), 23% did not change their choices, and 33% chose immediate gains less often when the future was uncertain. With losses, 70% chose the immediate loss more often when the future was uncertain, 30% did not change their answers, and 6% chose immediate losses less often when the future was uncertain. Thus, although the modal participant showed the "intertemporal uncertainty avoidance" effect, there was still notable heterogeneity in the sample.

In dollar terms, participants' average choices implied being indifferent between receiving $100 today or $140 next year, and paying $100 today or $104 next year. When considering uncertain future outcomes, participants' average choices implied being indifferent between receiving $100 today or a 50% chance of $337 next year, and paying $100 today or a 50% chance of $180 next year.

Discussion

Participants avoided future uncertainty for both gains and losses. For gains, these results are consistent with previous research (Ahlbrecht and Weber 1997, Anderson and Stafford 2009, Blackburn and El-Deredy 2013, Mischel and Grusec 1967). Our findings for losses, however, seem to contradict prospect theory (Kahneman and Tversky 1979). We found that participants avoided future risk for both gains and future losses, whereas prospect theory predicts risk aversion for gains and risk seeking for losses. Risk seeking for losses would have made uncertain, future losses more attractive, but we found the opposite. Of course, prospect theory was developed with immediate outcomes and has not been thoroughly tested in intertemporal choice contexts. Likewise, our result for losses is at odds with popular formal models of time and risk (e.g., Loewenstein and Prelec 1992, Rachlin et al. 1991), which generally predict that future uncertainty should make future losses more attractive (not less).

Whereas Study 1 examined future uncertainty, in some cases the present is more uncertain than the future. For example, the payoff from a project or investment may not be clear if launched immediately (e.g., an unrefined product), but may be more certain in the future (as additional time and effort are put in). Therefore, in Study 2 we examined time preferences when choosing between immediate, uncertain outcomes and future, certain outcomes. We predicted that participants would prefer to avoid the risky gains and losses when making intertemporal choices, similar to the results of Study 1.

The Study 2 design addresses a potential confounding factor in Study 1: perhaps there is some "living with uncertainty" aversion in terms of not knowing for a year how the uncertainty will resolve, which may be a separate phenomenon from risk aversion. In other words, perhaps the participants in Study 1 who chose the immediate, certain losses just did not want the

uncertain future loss hanging over their head for a year. In Study 2, the risky options are always immediate, and the future options are always certain. Therefore, any effects of risk on intertemporal choices would not be driven by a psychological desire to have the risk resolved as early as possible.

Study 2: Immediate Uncertainty vs. Future Certainty

Method

A sample of 118 participants was recruited from a Qualtrics partner panel, using the same eligibility criteria as Study 1. Also similar to Study 1, participants answered a series of intertemporal choice questions, in a 2 (sign) × 2 (uncertainty) within-subjects design. Questions in the "certain" intertemporal choice scenarios were exactly the same as Study 1. In the "uncertain" intertemporal choice scenarios, participants made choices between immediate, uncertain outcomes and future, certain outcomes. For the gain scenario, they read the instruction, "Please imagine you face a set of choices about receiving $200 from investments immediately that would be uncertain (only a 50% chance of receiving it, which would be determined randomly), or another amount 1 year from now that would be for sure." Participants then made six intertemporal choices, such as "50% chance of receiving $200 immediately OR Receive $110 for sure in 1 year."

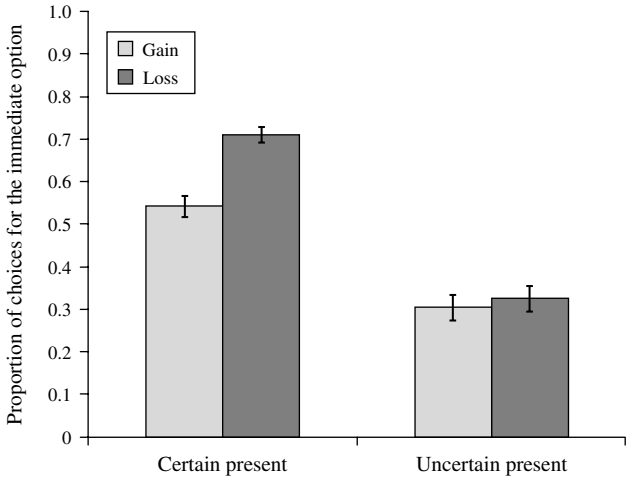
The loss scenario was similar. For the complete text of the experimental materials, see Online Appendix A.

Results

Intertemporal choices (with and without immediate uncertainty). The order of the scenarios (intertemporal choice under certainty first or intertemporal choice with present uncertainty first) had no main effect on participants' choices, nor did it interact with the effect of uncertainty on choices all $p = 0.17$ or greater. Therefore, we collapse across order in the following analyses.

As seen in Figure 2, when considering immediate uncertainty versus future certainty, participants avoided the immediate uncertainty. This led to preference for (certain) future gains and losses. Testing our primary hypothesis, a 2 × 2 GLM showed a main effect of uncertainty, $F(1, 117) = 142.0$, $p < 0.001$, $\eta^2 = 0.55$, indicating that participants chose the immediate option less often when the immediate option was uncertain. A main effect of sign, $F(1, 117) = 14.2$, $p < 0.001$, $\eta^2 = 0.10$, indicated that participants chose immediate losses more often than they chose immediate gains. This finding is not relevant to our hypotheses. A significant uncertainty by sign interaction, $F(1, 117) = 10.0$, $p < 0.01$, $\eta^2 = 0.08$, indicated that the effect of immediate uncertainty on time preferences was stronger for losses than for gains. Pairwise contrasts confirmed that the effect of uncertainty on time preferences was significant for both gains, $t(117) = 6.7$, $p < 0.001$, and losses, $t(117) = 11.3$, $p < 0.001$.

Figure 2. Mean Proportion of "Immediate" Choices When Immediate Outcomes Are Certain vs. Uncertain, in Study 2



Note. Error bars indicate ± one standard error.

On a within-subject level, 18% of participants chose immediate gains more often when the present was uncertain (compared to when all options were certain), 17% did not change their choices, and 65% chose immediate gains less often when the present was uncertain. With losses, 14% chose the immediate loss more often when the present was uncertain, 13% did not change their answers, and 74% chose immediate losses less often when the present was uncertain. Thus, although the modal participant showed the "intertemporal uncertainty avoidance" effect, there was still some heterogeneity in the sample.

In dollar terms, participants' average choices implied being indifferent between receiving $100 today or $136 next year, and paying $100 today or $105 next year. When considering uncertain immediate outcomes, participants' average choices implied being indifferent between a 50% chance of receiving $200 today or $104 for sure next year, and a 50% chance of paying $200 today or paying $160 for sure next year.

Discussion

As in Study 1, participants avoided uncertainty in the intertemporal context for both gains and losses. However, because the immediate outcomes were uncertain (rather than the future outcomes), this shifted people's choices toward future gains and losses. Our results are similar to a recent finding (reported in Baucells and Heukamp 2012) that when participants choose between a 90% chance of receiving €100 now or €100 for sure in 1 month, 81% of participants choose the certain future gain.[3] Overall, our findings for gains are

consistent with existing models (e.g., Kahneman and Tversky 1979), but our findings for losses are not.

In the real world people often cannot choose between certainty and uncertainty and, instead, confront choices that all entail some degree of uncertainty. Therefore, in Study 3, we examined the case where both immediate and future outcomes were uncertain. In this case, there would be no opportunity for participants to avoid the uncertainty, so we predicted that their choices would be similar to the condition where both outcomes are certain.

Study 3: Immediate Uncertainty vs. Future Uncertainty

Method

A sample of 53 participants was recruited from Amazon Mechanical Turk. In a 2 (sign) × 2 (uncertainty) within-subjects design, participants answered a series of intertemporal choice questions. Questions in the "certain" intertemporal choice conditions were exactly the same as Studies 1 and 2. In the "uncertain" intertemporal choice conditions, participants made choices between immediate uncertain outcomes and future uncertain outcomes. In the gain scenario, they read the instruction, "Please imagine you face a set of choices about uncertain investments, possibly receiving $200 from investments immediately, or another amount 1 year from now. In each case, there is only a 50% chance of actually receiving the money (determined randomly). If you choose the immediate option, you will find out immediately whether it pays off or not, whereas if you choose the future option, you will find out in 1 year if it pays off." Participants then made choices such as, "50% chance of receiving $200 immediately OR 50% chance of receiving $220 in 1 year."

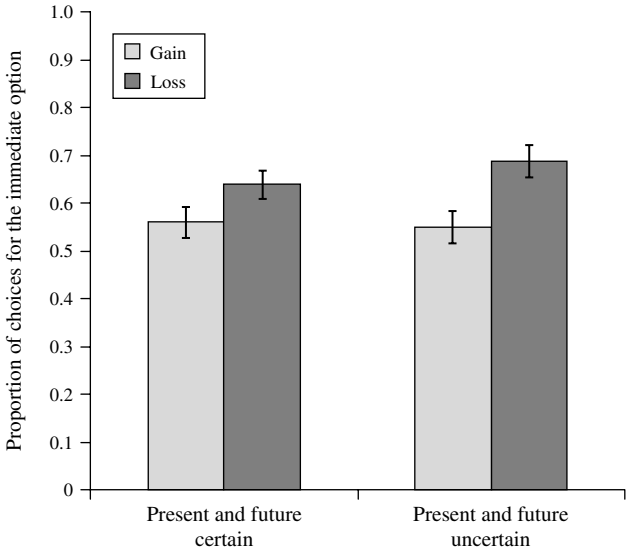
The loss choices were similar. For the full text of the choices, see Online Appendix A.

Results

The order of the scenarios (intertemporal choice under certainty first or intertemporal choice with present and future uncertainty first) had no main effect on participants' choices, nor did it interact with effect of uncertainty on choices, all $p = 0.36$ or greater. Therefore, we collapse across order in the following analyses.

When both immediate and future gains and losses were uncertain, choices were similar to those in the certainty condition, as seen in Figure 3. Differences between the certainty and uncertainty conditions were small and not significant. A 2 × 2 GLM found no main effect of uncertainty (versus certainty) on time preference, $F(1, 52) = 1.0$, $p = 0.32$, $\eta^2 = 0.02$. The main effect of sign was significant, $F(1, 52) = 6.0$, $p = 0.02$, $\eta^2 = 0.10$, indicating that participants chose immediate losses more often than they chose immediate gains. Again,

Figure 3. Mean Proportion of "Immediate" Choices When Immediate and Future Outcomes Are Certain vs. Uncertain, in Study 3



Note. Error bars indicate ± one standard error.

this difference between gains and losses was not relevant to our hypotheses. The interaction of uncertainty and sign was also not significant, $F(1, 52) = 1.7$, $p = 0.20$, $\eta^2 = 0.03$.

On a within-subject basis, 21% of participants chose the immediate gain more often when both outcomes were uncertain, 49% did not change their answer, and 30% chose the future option more often when both outcomes were uncertain. For losses with both outcomes uncertain, 21% chose the immediate option more often, 42% did not change their answer, and 38% chose the future option more often. Thus, although the modal participant did not change the time preferences when both the future and present were uncertain, there was still notable heterogeneity in the sample.

In dollar terms, participants' average choices implied being indifferent between receiving $100 today or $135 next year, and paying $100 today or $111 next year. When considering uncertain immediate outcomes, participants' average choices implied being indifferent between a 50% chance of receiving $200 today or a 50% chance of $271 next year, and a 50% chance of paying $200 today or a 50% chance of paying $216 next year.

Discussion

These null effects of unavoidable uncertainty on time preferences have at least two possible psychological process explanations. One is that because uncertainty was present in all outcomes, and therefore unavoidable, it had no effect on participants' thoughts and choices; they may have mentally edited out the uncertainty and focused on the features that were different between each choice option (Kahneman and Tversky 1979). A second interpretation is that participants *were*

strongly affected by the uncertainty (as in Study 1 and Study 2), but the two sources of uncertainty pushed them in opposite directions, cancelling each other out and resulting in a null effect. Either way, our results replicate those of Shelley (1994), who also found that when risk is unavoidable, it does not influence time preferences for gains or losses.

Additional Experiments and Conditions

In addition to the experimental conditions reported above in Studies 1–3, we ran several other experimental conditions and studies that replicated our effects and investigated possible confounding factors, mediators and moderators. These conditions and studies are reported in Online Appendices A and B.

We found that the difference between risk preference for gains and losses (i.e., prospect theory) is weaker in intertemporal choice than when all outcomes are immediate (Studies 2 and 5S in the online appendix), showing that the intertemporal risk-avoidance phenomenon is particular to the intertemporal context. Moreover, we show that intertemporal risk avoidance persists even when controlling for risk preferences for immediate outcomes (Study 4S). We also found that the intertemporal uncertainty avoidance phenomenon generally holds with both small-magnitude ($100) and large-magnitude ($10,000) outcomes, with both uncertain outcomes (50% chance of $100) and uncertain amounts (a random amount between $50 and $150), and with both the general population and MBA students (Studies 1, 2, 2S, 3, and 5S in the online appendix). Furthermore, we replicated a number of classic "anomalies" previously found in intertemporal and risky choice (Baucells and Heukamp 2012, Estle et al. 2006, Green et al. 1999, Kahneman and Tversky 1979, Prelec and Loewenstein 1991, Richards et al. 1999).

We found some evidence that the intertemporal uncertainty avoidance phenomenon is driven by complexity aversion (Study 5S in the online appendix). When risk and time are combined, the choice options become relatively complicated (as rated by participants), and participants prefer the simpler, certain gains and losses under these circumstances. Furthermore, ratings of outcome complexity predict intertemporal choices under uncertainty, but do not predict simple risky choices or intertemporal choices under certainty. In other words, when people make choices about time or choices about risk, outcome complexity does not matter, but when people make choices trading off both time and risk, people prefer simpler outcomes, which results in risk aversion. This theory explains all of the results in all of our studies.

General Discussion

When the future is uncertain, people prefer immediate gains and losses, and when the present is uncertain, people prefer future gains and losses. Our results thus diverge from prospect theory (Kahneman and Tversky 1979), which would predict that uncertain future losses and immediate uncertain losses should be quite attractive because people are risk seeking for losses. Prospect theory was developed with immediate gains and losses, and our online appendix results show that, when all outcomes are immediate, participants are indeed risk seeking for losses. Thus, it appears that the impact of risk on preferences for losses is different when people are making intertemporal choices.

Previous research (Mazur 1987) on time preference has established that animals discount future outcomes according to a hyperbolic function, $V_d = A/(1 + kD)$, where V_d is the subjective (present) value of the delayed reward (e.g., $100), A is the actual future amount (e.g., $110), D is the delay (e.g., 1 year), and k is the discount rate (e.g., 0.1). Rachlin et al. (1991) found that people also discount immediate probabilistic gains according to a similar hyperbolic function, $V_p = A/(1 + h\theta)$, where V_p is the subjective value of the reward, A is the actual amount, θ is $(1/p) - 1$ or "odds against" (p is the probability of receiving the reward), and h is the discount rate. Thus, with positive k and h greater than 1 (as is generally assumed), people discount both future rewards and probabilistic rewards hyperbolically (Estle et al. 2006; Green and Myerson 2004; Rachlin et al. 2000, 1991; Richards et al. 1999; Shead and Hodgins 2009). When a reward is both delayed and probabilistic, total discounting is the product of the individual probability and delay discount functions (Rachlin and Raineri 1992). This model does not differentiate between gains and losses and therefore applies a uniform down-weighting to risky outcomes, making risky gains less attractive and risky losses more attractive.

Loewenstein and Prelec's (1992) popular descriptive model of risk and time combines hyperbolic discounting of future outcomes with prospect theory-style weighting of uncertain gains and losses. The value of a prospect x at time t is $v(x)\varphi(t)$, where $v(x)$ is a value function and $\varphi(t)$ is a temporal discount function. The discount function is a generalized hyperbola, $\varphi(t) = (1 + \alpha t)^{-\beta/\alpha}$, where α and β are fitted temporal discounting parameters and are greater than 0. The value function $v(x)$ is concave for gains (i.e., risk averse) and convex for losses (i.e., risk seeking), as in prospect theory. Furthermore, the value function for losses is steeper than the value function for gains, the value function for losses is more elastic than the value function for gains (i.e., it "bends over" faster for gains than for losses), and the value function is more elastic for outcomes that are larger in absolute magnitude (i.e., it "bends over" faster at smaller magnitudes and is straighter at larger magnitudes). This model predicts a range of intertemporal choice "anomalies" including

the common difference effect, the magnitude effect, the sign effect, and the delay–speedup asymmetry.

The models of Rachlin et al. (1991), Kahneman and Tversky (1979), and Loewenstein and Prelec (1992) predict our key results for gains but not our results for losses in Studies 1 and 2. In Study 1, hyperbolic discounting of future uncertainty (or risk aversion for gains) should make future uncertain gains less attractive, leading to a stronger preference for immediate gains, which is what we found. However, hyperbolic discounting of future uncertainty (or risk seeking for losses) should make future uncertain losses more attractive; therefore, people should choose future losses more often when they are uncertain, which is the opposite of what we found. Likewise, in Study 2, hyperbolic discounting of uncertainty (or risk aversion for gains) should make immediate uncertain rewards less attractive and push people toward certain future rewards, which is what we found. However, these models predict that the opposite should happen with losses, which is not what we found. In Study 3, all three models match our findings. Outcomes are equally uncertain, which should lead to equal change in weights on all outcomes and no change in choices, which is what we found. Finally, none of these models predict different risk preferences for immediate choices as opposed to intertemporal choices (i.e., an interaction of risk and time), which we demonstrate in the supplemental materials.

Our findings for losses—that greater future uncertainty leads to more choices for the immediate, certain option—diverge from previous empirical literature, which either found no effect or the opposite, as summarized in Table 1. The fact that Mischel and Grusec (1967) found greater future uncertainty made future losses more attractive is not particularly surprising, given that they did not control expected value (i.e., a 50% chance of losing $100 next month is clearly more attractive than losing $100 for sure next month). One theory that explains the difference between our findings and the other previous studies is task familiarity. Participants in our study came from the general population, received minimal instruction, and only answered a modest number of questions. We have some evidence (in online appendix Study 4S) that participants found these (novel) intertemporal uncertainty questions to be complex and opted for the simpler, certain options where possible. In contrast, participants in previous studies were students (often in business or finance), often received extensive instruction and practice, and answered a much larger number of questions. For these participants, the task was likely more familiar and routine and therefore (subjectively) less complicated. As such, they either employed classic risk and time heuristics or relied on mathematical calculations (as reportedly occurred somewhat in Shelley 1994). In real life, both situations are common. We would expect our results to generalize in novel situations involving constructed preference, such as a one-time banking or loan decision, and previous literature to generalize in situations involving experienced actors and repeated choice, such as day trading.

All the studies in this paper examined explicit uncertainty (e.g., a 50% chance that a future outcome will occur). A growing literature has documented that people implicitly associate future gains with uncertainty, even when it is not mentioned in the experimental procedure (and all outcomes are supposedly certain). After all, the future is inherently uncertain, because one might die before receiving a promised future $100. Indeed, reaction time data show that delay primes the processing of uncertainty (Bixter and Luhmann 2015), but not vice versa. Likewise, delayed rewards are rated as increasingly uncertain at progressively longer delays (Patak and Reynolds 2007, Reynolds et al. 2007, Takahashi et al. 2007), and ratings of uncertainty are correlated with time preferences ($r = 0.55$ in Patak and Reynolds 2007, $r = 0.37$ in Reynolds et al. 2007, and $\rho = 0.47$ in Takahashi et al. 2007). Similarly, individual difference measures of risk aversion and time preferences for rewards are often correlated (Anderhub et al. 2001, Jones and Rachlin 2009), such that participants preferring certain gains also tend to prefer immediate gains. A recent axiomatic model formalizes this idea that time acts as probability and probability acts as time (Baucells and Heukamp 2012).

Taken together, these results suggest that perceptions of uncertainty (and preferences for uncertainty) may influence intertemporal choices, with perceived future uncertainty (even if only implicit) leading people to choose immediate, certain rewards (Epper et al. 2011). Extending this line of research to losses, our results suggest an important hypothesis: implicit future uncertainty could increase the preference for immediate, certain losses as well. For example, if you have a $100 bill to pay either now or in the future, one might prefer to pay it immediately because "who knows what might happen if you wait?," and many people find this implicit future uncertainty aversive. This would provide an explanation for the "sign effect" (Thaler 1981) in intertemporal choice: implicit future uncertainty leads to stronger preferences for immediate gains and losses, thereby increasing discount rates for gains and decreasing discount rates for losses, producing the observed difference in discount rates between gains and losses.

Acknowledgments

The authors thank Steven Schechter for his comments on an earlier draft of this paper, as well as the anonymous reviewers and editorial team at *Management Science* for helpful suggestions.

Endnotes

[1] Throughout our results, we employ a simple definition of time preference: the preference for things to happen now versus in the future. Note that a greater preference for immediate outcomes implies greater discount rates for gains and lower discount rates for losses.

[2] A test of the "sign effect" in discounting (Estle et al. 2007, Mitchell and Wilson 2010, Thaler 1981) should compare the proportion of "sooner" choices for gains to the proportion of "later" choices for losses. For the interested reader, we did indeed reverse score the losses and run this comparison. Across all studies and conditions (including those reported in the online appendix material), the sign effect was significant and in the predicted direction in 49 of 60 cases, with an average effect size of $d = 0.52$. The cases where the sign effect was eliminated or reversed was often when there was a choice between immediate uncertainty and future certainty (such as in Study 2), which pushed people toward future gains and losses, lowering discount rates for gains and increasing discount rates for losses, thus eliminating or reversing the sign effect.

[3] Notably, when choosing between smaller amounts (90% chance of €5 now or €5 for sure in one month), only 43% choose the certain future €5. The preference for the immediate, uncertain gain in this case could be driven by the magnitude effect, with temporal discount rates for gains being extremely high at such small magnitudes. In addition, this result could be driven by the peanuts effect (Hershey and Schoemaker 1980), where people are risk seeking for small-magnitude gains.

References

Ahlbrecht M, Weber M (1997) An empirical study on intertemporal decision making under risk. *Management Sci.* 43(6):813–826.

Anderhub V, Guth W, Gneezy U, Sonsino D (2001) On the interaction of risk and time preferences: An experimental study. *German Econom. Rev.* 2(3):239–253.

Anderson LR, Stafford SL (2009) Individual decision-making experiments with risk and intertemporal choice. *J. Risk Uncertainty* 38(1):51–72.

Baucells M, Heukamp FH (2012) Probability and time trade-off. *Management Sci.* 58(4):831–842.

Bixter MT, Luhmann CC (2015) Evidence for implicit risk: Delay facilitates the processing of uncertainty information. *J. Behav. Decision Making* 28(4):347–359.

Blackburn M, El-Deredy W (2013) The future is risky: Discounting of delayed and uncertain outcomes. *Behav. Processes* 94:9–18.

Epper T, Fehr-Duda H, Bruhin A (2011) Viewing the future through a warped lens: Why uncertainty generates hyperbolic discounting. *J. Risk Uncertainty* 43(3):169–203.

Estle SJ, Green L, Myerson J, Holt DD (2006) Differential effects of amount on temporal and probability discounting of gains and losses. *Memory Cognition* 34(4):914–928.

Estle SJ, Green L, Myerson J, Holt DD (2007) Discounting of monetary and directly consumable rewards. *Psych. Sci.* 18(1):58–63.

Green L, Myerson J (2004) A discounting framework for choice with delayed and probabilistic rewards. *Psych. Bull.* 130(5):769–792.

Green L, Myerson J, Ostaszewski P (1999) Amount of reward has opposite effects on the discounting of delayed and probabilistic outcomes. *J. Experiment. Psych.: Learn., Memory, Cognition* 25(2): 418–427.

Hardisty DJ, Weber EU (2009) Discounting future green: Money versus the environment. *J. Experiment. Psych. General* 138(3): 329–340.

Hershey JC, Schoemaker PJ (1980) Prospect theory's reflection hypothesis: A critical examination. *Organ. Behav. Human Performance* 25(3):395–418.

Jones BA, Rachlin H (2009) Delay, probability, and social discounting in a public goods game. *J. Experiment. Anal. Behav.* 91(1):61–73.

Kahneman D, Tversky A (1979) Prospect theory: An analysis of decision under risk. *Econometrica* 47(2):263–291.

Keren G, Roelofsma P (1995) Immediacy and certainty in intertemporal choice. *Organ. Behav. Human Decision Processes* 63(3):287–297.

Loewenstein G, Prelec D (1992) Anomalies in intertemporal choice: Evidence and interpretation. *Quart. J. Econom.* 107(2):573–597.

Mazur JE (1987) An adjusting procedure for studying delayed reinforcement. Commons ML, Mazure JE, Nevin JA, Rachlin H, eds. *Quantitative Analyses of Behavior*, Vol. 5, The effect of delay and intervening events on reinforcement value (Erlbaum, Hillsdale, NJ), 55–73.

Mischel W, Grusec J (1967) Waiting for rewards and punishments: Effects of time and probability on choice. *J. Personality Soc. Psych.* 5(1):24–31.

Mitchell SH, Wilson VB (2010) The subjective value of delayed and probabilistic outcomes: Outcome size matters for gains but not for losses. *Behav. Processes* 83(1):36–40.

Oppenheimer DM, Meyvis T, Davidenko N (2009) Instructional manipulation checks: Detecting satisficing to increase statistical power. *J. Experiment. Soc. Psych.* 45(4):867–872.

Patak M, Reynolds B (2007) Question-based assessments of delay discounting: Do respondents spontaneously incorporate uncertainty into their valuations for delayed rewards? *Addictive Behav.* 32(2):351–357.

Prelec D, Loewenstein G (1991) Decision-making over time and under uncertainty: A common approach. *Management Sci.* 37(7): 770–786.

Rachlin H, Raineri A (1992) Irrationality, impulsiveness, and selfishness as discount reversal effects. Loewenstein G, Elster J, eds. *Choice Over Time* (Russell Sage Foundation, New York), 93–118.

Rachlin H, Brown J, Cross D (2000) Discounting in judgments of delay and probability. *J. Behav. Decision Making* 13(2):145–159.

Rachlin H, Raineri A, Cross D (1991) Subjective probability and delay. *J. Experiment. Anal. Behav.* 55(2):233–244.

Reynolds B, Patak M, Shroff P (2007) Adolescent smokers rate delayed rewards as less certain than adolescent nonsmokers. *Drug Alcohol Dependence* 90(2–3):301–303.

Richards JB, Zhang L, Mitchell SH, Wit H (1999) Delay or probability discounting in a model of impulsive behavior: Effect of alcohol. *J. Experiment. Anal. Behav.* 71(2):121–143.

Samuelson P (1937) A note on measurement of utility. *Rev. Econom. Stud.* 4:155–161.

Shead NW, Hodgins DC (2009) Probability discounting of gains and losses: Implications for risk attitudes and impulsivity. *J. Experiment. Anal. Behav.* 92(1):1–16.

Shelley MK (1994) Gain/loss asymmetry in risky intertemporal choice. *Organ. Behav. Human Decision Processes* 59(1):124–159.

Takahashi T, Ikeda K, Hasegawa T (2007) A hyperbolic decay of subjective probability of obtaining delayed rewards. *Behav. Brain Functions* 3:52.

Thaler R (1981) Some empirical evidence on dynamic inconsistency. *Econom. Lett.* 8:201–207.

Weber BJ, Chapman GB (2005) The combined effects of risk and time on choice: Does uncertainty eliminate the immediacy effect? Does delay eliminate the certainty effect? *Organ. Behav. Human Decision Processes* 96(2):104–118.