Immediacy and Certainty in Intertemporal Choice

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Time delay and uncertainty are deeply interrelated though the nature of the interaction between these two constructs remains equivocal. The immediacy and the certainty effects provide an easy access to study the relationship between time delay and uncertainty. Three experiments are described which examine the effect of uncertainty on the immediacy effect and the effect of time delay on the certainty effect. We also present analytical arguments that lead to the tentative conclusion that immediacy is more likely to be a derivative of certainty than the reverse. It is further proposed that laboratory experiments may undermine the importance of uncertainty underlying time delays as demonstrated in experiment 4. Theoretical and methodological intricacies associated with separating uncertainty and time delay are discussed. © 1995 Academic Press, Inc.

The psychology underlying intertemporal choice has recently received substantial attention in the literature of behavioral decision making. Traditionally, intertemporal choices have been analyzed by the concept of discounting (e.g., Ainslie & Haslam, 1992; Loewenstein, 1988) and the corresponding discounted utility model (Prelec & Loewenstein, 1991). According to this model, the choice between two or more alternative outcomes expected to be realized at different points in time is determined by comparing their present values discounted by a fixed (discount) rate. Recent research, however, has identified several anomalies within the discounting framework (e.g., Ainslie, 1991; Loewenstein & Thaler, 1989; Loewenstein & Prelec, 1992; Tha-

ler, 1981), thus casting doubt on the model's adequacy at least from a descriptive viewpoint.

There are close interrelationships and a high level of similarity between intertemporal and risky decisions (e.g., Prelec & Loewenstein, 1991; Rachlin, Logue, Gibbon, & Frankel, 1986; Rachlin & Siegel, 1994). This is reflected in the resemblance between the theories that attempt to capture these phenomena, as well as in the behavioral expressions associated with these theories. For example, the discounted utility model (intertemporal choice) and the subjective expected utility model (risky choice) have a similar structure enabling an easy access to the interconnected domains of time and uncertainty (Prelec & Loewenstein, 1991). Both models are originally normative and share several common basic assumptions, specifically that choice between alternatives is based on a comparison of weighted sums of utilities: In the discounting models utilities are weighted by discount rates, while in the subjective expected utility model they are weighted by probabilities.

Whereas both models were originally conceived as normative ones, both have also been applied as descriptive models. Recent research, however, casts doubts on the descriptive adequacy of both the discounted and the subjective expected utility models. Moreover, in an elegant and lucid paper, Prelec and Loewenstein (1991) show that the (behavioral) empirical violations (or anomalies) of the two models have a similar structure.

The similarity between the two models is best illustrated in the so-called *immediacy* and *certainty* effects. The immediacy effect refers to the tendency of decision makers to amplify the significance of immediately (relative to delayed) experienced outcomes. The certainty effect refers to the observation that "people overweigh outcomes that are considered certain, relative to outcomes which are merely probable" (Kahneman & Tversky, 1979, p. 265).

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The immediacy and the certainty effects are instances of violations of the stationarity and proportionality principles (Prelec & Loewenstein, 1991), and as such are extensions (or extreme examples) of broader effects. The immediacy effect is a special case of what Loewenstein and Prelec (1992) termed the *common difference effect:* The discounting utility model entails stationarity, namely, that preference between two temporal prospects should depend on the absolute time interval between the occurrence of the two outcomes. Casual observations and empirical evidence (e.g., Thaler, 1981; Benzion, Rapoport, & Yagil, 1989), however, suggest that the impact of a constant time delay diminishes as the corresponding outcomes are more remote, thus violating the stationarity principle. The certainty effect is a special case of the so-called *common ratio effect* in the domain of risky choice. According to the subjective expected utility model, preferences between risky prospects should remain unaltered by multiplying of (non-zero) outcomes by a common factor (a property implied by the substitution axiom of utility theory). Both the certainty and the possibility effects (Kahneman & Tversky, 1979) provide empirical evidence for the violation of this requirement.

The affinity between the common difference and common ratio effects (and correspondingly between the immediacy and certainty effects[2]) is also reflected in the similarity in the explanations that were offered to account for these phenomena. For instance, one possible account of the common difference effect, mainly psychophysical in nature, is based on Weber's law: Accordingly, the subjective duration of an (objective) identical time delay will be perceived as shorter the more distant it is from the present. Consequently time differences in the far future will be perceived as shorter than imminent time differences.[3] For example, consider the following two choice problems:

Problem 1: (a) $150 today   or
           (b) $200 in 9 months.
Problem 2: (a') $150 in 10 years   or
           (b') $200 in 10 years and 9 months.

The only difference between the two choice problems is that a delay of 10 years has been added to both options in problem 2. Following the immediacy effect, many people may prefer option (a) over (b) yet favor option (b') over (a'). According to the psychophysical account the time difference (of 9 months) in problem 1 between today and 9 months ahead is perceived as sufficiently large to overcome the monetary advantage of option (b). In contrast, in the second problem, the same time advantage when associated with option (a') is assessed as relatively small (because it is perceived as so far ahead) and may thus be dominated by the difference in value (of $50) between the two options consequently resulting in a preference for (b').

A similar psychophysical explication can be applied to the common ratio effect. For instance, consider the following two choice problems:

Problem 1: (a) $150 with probability .95   or
           (b) $200 with probability .75.
Problem 2: (a') $150 with probability .19   or
           (b') $200 with probability .15.

The only difference between the two choice problems is that the probabilities in problem 1 have been multiplied by a constant of .2 to obtain those of problem 2. Following the common ratio effect many people may prefer (a) over (b) and reverse their preference in the second problem by favoring (b') over (a'). The psychophysical account applied here follows similar lines to the previous example. Supposedly, in the first choice problem the difference between a probability of .95 (which is almost certain) and .75 is perceived as large enough as to loom over the monetary advantage of option (b). On the other hand, in the second choice problem, the difference in probabilities between .19 and .15 is perceived as relatively small and insufficient to overcome the monetary advantage of option (b').

A second, and different, account of the common difference effect is based on empirical studies suggesting that time discounting in animal as well as in human behavior is frequently incompatible with the traditional *exponential* function. Instead, several authors proposed that these findings are best described by *hyperbolic* functions (e.g., Ainslie & Haslam, 1992). Such functions often cross each other as a function of time thus being able to account for a possible switch in preferences like those that occur under the common difference effect (as in the above example). As noted by Mazur (1987), however, the reasons that give rise to such hyperbolic functions are not entirely clear. For instance, Gibbon's (1977) scalar expectancy theory assumes that "expectancy" of reinforcement grows at an accelerating rate as the reinforcer gets closer in time, thus resulting in a hyperbolic discount-rate function.

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[2] The immediacy and certainty effects are extreme instances of the broader common difference and common ratio effects, respectively. They may be considered as fundamentally different, since both the immediacy and the certainty effect are associated with *qualitative* changes (i.e., the transition from immediate to delayed outcome and from certain to uncertain outcomes), whereas the common ratio and common difference phenomena are associated with quantitative differences (e.g., two outcomes with different delay times or with different levels of uncertainty).

[3] It is important to note, however, that the empirical evidence for supporting the psychophysical assumption is not unequivocal (Allan, 1979; Fraise, 1984), and most of the relevant research on time perception is based on relatively short durations.

The hyperbolic nature of discounting is also embedded in Herrnstein's (1990) "matching law," which assumes that preferences are proportional to reward rate and amount, and inversely proportional to delay.

A similar approach to account for the common ratio effect in risky choices has been proposed by Kahneman and Tversky (1979). Developing prospect theory as an alternative to subjective expected utility theory, these authors postulated a weighing function π that relates decision weights to probabilities. Decision weights supposedly measure the sensitivity of preferences to changes in probability (as the discount function measures the sensitivity of preferences to changes in delay of prospects). Kahneman and Tversky employed a hypothetical weighing function and applied it to account for Allais' paradox (which is an instance of the certainty effect).

A third interpretation of the common difference effect provides a direct link between time delay and uncertainty, and accordingly between the common difference and ratio effects. Underlying this interpretation is the assumption that delayed consequences are associated with an implicit risk value: The larger the delay, the larger the associated risk.[4] For instance, Benzion *et al.* (1989) assessed discount rates from responses of a sample of 282 subjects. Their data also suggest that discount rates as a function of time delay approximate a hyperbolic function. They propose that uncertainty and the ensuing risk associated with delayed consequences may be a major factor in determining the shape of the discount-rate function.

While there can be little doubt that time delay and uncertainty are deeply interrelated, the nature of the interaction between the two remains controversial (Rachlin & Siegel, 1994). Specifically, whereas Benzion *et al.* (1989) argue that uncertainty is the fundamental process underlying time delay (a stand also supported by the work of Mischel & Grusec, 1967, and Rotter, 1954), others (e.g., Rachlin *et al.*, 1986; Rachlin, Raineri, & Cross, 1991; Rachlin & Siegel, 1994) have argued that delay discounting is the more elemental process underlying uncertainty.

The purpose of the present paper is to shed some additional light on the intricate relationship between time delay and uncertainty, specifically between the immediacy and the certainty effects. In experiments 1 and 2 we explore the effects of uncertainty on the immediacy effect. Experiment 3 examines the effect of time delay on the certainty effect. The implications of the results of these three experiments for the issues raised above are then discussed. Finally, experiment 4 provides another example of the relationship between

time delay and uncertainty and carries a specific methodological point to be discussed later.

Subjects in all our experiments were undergraduate students from the Free University of Amsterdam who responded to a campus advertisement. They were paid 12 Dutch guilders (approximately $7) for completing the task required in the experiment as part of a 45-min session that included some other unrelated tasks on decision making. No subject participated in more than one of the following studies.

As mentioned above, recent studies suggest that an exponential declining discount function cannot account for some empirical findings of inconsistent time preferences as a function of elapsed time (e.g., Ainslie, 1991; Herrnstein, 1990; Prelec & Loewenstein, 1991). An illuminating example is offered by Herrnstein (1990): Based on informal observations he suggests that most people when asked to choose between (A) $100 tomorrow or (B) $115 a week from tomorrow, prefer option A; yet, when required to choose between (C) $100 52 weeks from now or (D) $115 53 weeks from now, prefer option D. Note that options C and D are derived by adding a constant of 52 weeks to options A and B, respectively, and thus the choice of options A and D implies a reversal which constitutes the immediacy effect and is incompatible with the standard discounting model (i.e., the constant difference effect) and cannot be accounted for by an exponential discount function (Ainslie, 1991).

A possible weakness of Herrnstein's informal study concerns an underlying assumption regarding the uncertainty associated with the delayed prospects. Specifically, Herrnstein's choice problems could be easily interpreted as a choice between two *sure* outcomes for which considerations of uncertainty seem to be irrelevant. The certainty associated with monetary awards is further emphasized by Herrnstein (1990), who says that "Whichever the person chooses, the money is said to be kept in escrow by a Federal Reserve bank, then delivered by bonded courier" (p. 358). By excluding potential uncertainty a central element associated with time delays is impoverished. In experiment 1 uncertainty was explicitly introduced in order to assess its impact on the immediacy effect. Whether the preference reversal observed by Herrnstein would also be maintained when uncertainties are introduced was the focus of experiment 1.

EXPERIMENT 1

Method and Design

Subjects in this experiment were allocated to one of six (between subjects) groups. The first two groups were used as a replication of Herrnstein's observations.

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[4] This explanation borrows from Mischel and Grusec (1967), who applied Rotter's theory of expectancy value to delayed consequences.

Subjects in the first group were presented with the choice between (A) receive Fl. 100 now and (B) receive Fl. 110 4 weeks from now. We label this condition the *imminent future* choice problem. Subjects in the second group were asked to choose between (C) receive Fl. 100 26 weeks from now and (D) receive Fl. 110 30 weeks from now. We refer to this condition as the *remote future* choice problem. The remaining groups had problems identical to those presented to groups 1 and 2 except that the outcomes were probabilistic. For instance, subjects in group 3 (imminent future) were asked to choose between (A) receive Fl. 100 with a probability of .9 now and (B) receive Fl. 110 with a probability of .9 4 weeks from now. The choice problem for group 4 was identical to the problem of group 2 (remote future) except that outcomes were associated with a probability of .90. Finally, groups 5 and 6 received the same choice problems as groups 3 and 4 except that the probability of the monetary rewards was set at .50.

Results

The results are presented in Table 1. As can be seen in the first column ($p = 1.0$), Herrnstein's observations have been replicated: a large majority of subjects in the imminent future condition prefer the immediate award of Fl. 100 over the 4 weeks delayed award of Fl. 110, yet most subjects in the remote future condition prefer the more delayed award of Fl. 110 in 30 weeks over the more proximate award of Fl. 100 in 26 weeks. When uncertainty is excluded ($p = 1.0$), there is a difference between the imminent and the remote future conditions of 45% in the percentage of subjects who prefer the immediate over the more delayed outcome. This pattern of results is not maintained, however, when uncertainty is introduced, as can be seen from the last two columns of Table 1. The difference between the imminent and remote conditions in percentage of sub-

TABLE 1
Proportion (Actual Numbers in Parentheses) of Subjects Preferring the More Immediate Outcome of Fl. 100 for Three Different Levels of Uncertainty

	Probability of monetary reward		
	$p = 1.0$	$p = .9$	$p = .5$
Imminent future			
A. Fl. 100 now	82% (49)	54% (38)	39% (39)
B. Fl. 110 in 4 weeks	18% (11)	46% (32)	61% (61)
Remote future			
C. Fl. 100 in 26 weeks	37% (22)	25% (20)	33% (33)
D. Fl. 110 in 30 weeks	63% (38)	75% (59)	67% (67)
Difference[a]	45%	29%	6%

[a] The difference between the imminent and remote conditions in proportion of subjects who prefer the more immediate outcome.

jects who prefer the more immediate outcome drops to 29% for uncertain outcomes with $p = .9$, and further to 6% for uncertain outcomes with $p = .5$.

To examine the effect of the uncertainty manipulation, tests for linear trends in proportions and frequencies (Marascuilo & McSweeney, 1977) were conducted separately for the imminent and remote future conditions. There was a significant trend for the imminent ($p < .001$) but not for the remote future condition ($p > .3$). Evidently, the uncertainty manipulation affects imminent future choices: As certainty is reduced, the proportion of subjects choosing the more delayed but higher award is increased.

Discussion

The results of experiment 1 support Herrnstein's informal observations, yet suggest that the reversal in preferences is greatly reduced (for $p = .9$) or completely eliminated (for $p = .5$) when uncertainty is introduced. How does uncertainty affect subjects' choice?

Consider first Herrnstein's original observations and our corresponding replication, that is, under the condition where $p = 1.0$. Both options (A) and (B), under the imminent future condition, are represented as sure in the sense that the responsible agent (e.g., the experimenter) is completely trustworthy. Notwithstanding, an award promised in the future is always less certain[5] than an immediate award given here and now that cannot be altered. Indeed, the central claim of the present paper is that uncertainty is encapsulated in any future outcome. The option of Fl. 110 in 4 weeks is supposedly perceived as highly likely yet, due to the time delay, its probability is assessed as less than 1. The difference in probability between the two options under the imminent future conditions, as small as it may be, is not just a quantitative but also a qualitative one. Evidently, the change of an option from an immediate (and thus sure) gain to a delayed (and probable) one greatly reduces its desirability.

In contrast to the imminent future condition, both options (C) and (D) under the remote future condition are delayed and are thus considered uncertain. Supposedly, both options are perceived as being associated with probabilities where the relative difference is so small that it is being overwhelmed by the monetary difference between the two options. Consequently, under the remote future condition, the majority of the subjects choose the option that carries the higher valued but more delayed reward. The reversal of choices

[5] This uncertainty may for instance reflect the individual's inability to predict the utility of the delayed outcome when it is due or alternatively represent doubts regarding the ability to collect the reward on the scheduled time (e.g., due to possible sickness or, in the extreme case, death).

between the imminent and remote future conditions constitutes the immediacy effect.

Let us now examine the two other conditions with probabilistic outcomes. Consider first the condition in which $p = .9$ (second column in Table 1). There is still a reversal in preferences between the imminent and remote conditions, but the effect is much smaller compared with the condition of $p = 1.0$. Finally, for the condition in which $p = .5$ there is no difference between the imminent and remote conditions: In both cases there is a preference for the higher monetary outcome, exactly as in the remote future condition with $p = 1.0$. Apparently, introducing external uncertainty (i.e., introducing probabilistic outcomes) has the same effect as increasing the uncertainty encapsulated in the expansion of time delay. In particular, 61% of the subjects under the imminent and uncertain condition where $p = .5$ prefer the higher and delayed outcome B, almost the same as the proportion (63%) of subjects who prefer the higher and delayed outcome D under the remote certain ($p = 1.0$) condition.

It is important to note that, as implied by our analysis, introducing uncertainty affects mainly the imminent future but not the remote future conditions. In other words, the manipulation of uncertainty has little effect in altering preferences for the delayed rewards (which already contain an element of uncertainty), but has a profound influence on immediate preferences.

Underlying the immediacy effect is the reasoning that delaying an immediate reward by a fixed amount of time x is qualitatively different from delaying an already delayed reward by an additional time x. An almost identical kind of reasoning is applicable to the

certainty effect in risky choices. The essence of the certainty effect is that multiplying probabilities by a constant leads not just to a quantitative difference (which according to utility theory should not affect choices), but also to a qualitative difference. Specifically "this change produces a greater reduction in desirability when it alters the character of the prospect from a sure gain to a probable one, than when both the original and the reduced prospects are uncertain" (Kahneman & Tversky, 1979, p. 266).[6] In experiment 1 we demonstrated that the change in preferences associated with the immediacy effect can also be obtained by manipulation of uncertainty (i.e., probabilities). In experiment 2 we test whether the changes in preferences associated with the certainly effect can also be obtained by manipulations of time delay.

EXPERIMENT 2

Method and Design

Subjects in this experiment were divided into four groups. Group 1 ($N = 86$) was asked to make the choice among

A. Win Fl. 3000 with probability .33
   Win Fl. 2700 with probability .66
   Win nothing with probability .01

B. Win Fl. 2700 with certainty

The problem for group 2 ($N = 76$) was obtained by subtracting a .66 chance to win Fl. 2700 from both options. It was thus reduced to:

C. Win Fl. 3000 with probability .33
   Win nothing with probability .67

D. Win Fl. 2700 with probability .34
   Win nothing with probability .66

The choice problems for the first two groups are identical to those used by Kahneman and Tversky (1979) except that the payoffs are slightly changed and expressed in Dutch currency ($1.00 is approximately Fl. 2.00). Note that the expected value of gambles A and C is higher than the expected value of gambles B and D, respectively.

Groups 3 and 4 were presented with problems similar to those presented to groups 1 and 2, respectively, except that uncertainty was further manipulated by adding a time delay. Specifically, group 3 ($N = 86$) was presented with choice options E and F that were iden-

[6] The certainty effect is not necessarily restricted to a probability of 1.0 and is also obtained with probabilities close to 1.0 (e.g., .99) which are interpreted by subjects, for all practical purposes, to imply certainty. For an empirical demonstration see Keren and Wagenaar (1987).

TABLE 2
Subjects' Preferences (in Percentages) for the Four Choice Problems in Experiment 2

		N
(A) 3000 with $p = .33$ 2700 with $p = .66$ 0 with $p = .01$ 22%	(B) 2700 for certain 78%	(86)
(C) 3000 with $p = .33$ 0 with $p = .67$ 75%	(D) 2700 with $p = .34$ 0 with $p = .66$ 25%	(76)
(E) 3000 in 1 year with $p = .33$ 2700 in 2 year with $p = .66$ 0 with $p = .01$ 43%	(F) 2700 in 1 year for certain 57%	(86)
(G) 3000 in 1 year with $p = .33$ 0 in 1 year with $p = $ .67 92%	(H) 2700 in 1 year with $p = .34$ 0 in 1 year with $p = $ .66 8%	(86)

tical to options A and B, respectively, except for adding that *all payoffs will take place in a year from now.* Similarly, group 4 ($N = 75$) was presented with choice options G and H that were identical to options C and D with the addition of a 1-year delay.

Results and Discussion

The results are presented in Table 2. There is a significant effect ($p < .001$) of the probability manipulation (i.e., the certainty effect): The gamble with the lower expected value is preferred more frequently when the outcome is certain than when it is uncertain. This is true for both the immediate (78% > 25%) and the delayed (57% > 8%) conditions. There is also a significant effect ($p < .001$) of the time manipulation (the immediacy effect): The gamble with the lower expected value is preferred more frequently when outcomes are immediate rather than delayed. This preference holds for both the condition in which the outcome is certain (78% > 57%) and for which it is not (25% > 8%). The interaction between the probability and time manipulation is not significant ($z = .043; p > .3$). Apparently, the two effects are additive.

The results of groups 1 and 2 afford a reliable replication of Kahneman and Tversky's certainty effect. The choice pattern of group 1 suggests that absolute certainty (i.e., a probability of 1.0) is highly valued and, following Kahneman and Tversky (1979), is overweighed compared with probabilities less than 1.0.[7] When uncertainty is introduced in both options (as in group 2), the overweighing of the probability factor is reduced and other considerations, specifically size of payoff, become more important and dominant.

The certainty effect is also obtained when comparing the pattern of preferences of groups 3 and 4, except that the initial proportion of subjects (i.e., group 3) who opt for the higher and probable (rather than the certain) outcome is increased. Specifically, the proportion of subjects in group 3 who prefer the certain outcome (57%) is reduced from the initial proportion of 78% in group 1. This later result is a simple manifestation of the immediacy effect. Thus, altering time delays leads to uncertainty and to corresponding consequences similar to those obtained by an explicit manipulation of numerical probabilities. Apparently, at least in the present experiment, the immediacy and certainty effects are additive, a point which is further addressed in the general discussion.

If changes in the time course imply corresponding changes in degree of uncertainty, then manipulating uncertainty or manipulating the time course should lead to similar consequences, as demonstrated in experiment 2. To further corroborate this conjecture and test its generality, a manipulation similar to the one used in experiment 2 was applied to the *possibility effect* (Kahneman & Tversky, 1979), except that in this experiment time delay (rather than uncertainty) was directly manipulated.

EXPERIMENT 3

A phenomenon that highly resembles the certainty effect is the so-called possibility effect (Kahneman & Tversky, 1979). It suggests that when winning probabilities are substantial, there is a tendency to overweight (and choose) the prospect for which winning is more probable, whereas when winning is possible but not probable (i.e., extremely small probabilities) there is a tendency to overweight the prospect with the higher gain. For example, Kahneman and Tversky report that most people (86%) prefer the prospect of $3000 with probability .90 over $6000 with probability .45, yet the majority (73%) prefer $6000 with probability .001 over $3000 with probability .002.

The purpose of the present experiment was to test whether the possibility effect can be obtained by manipulating time delays rather than uncertainty. Specifically, one group of subjects ($N = 75$) was asked to choose between (A) Fl. 7000 in 1 month and (B) Fl. 7500 in 7 months. A second group ($N = 75$) was asked to choose between (A') Fl. 7000 in 6½ years and (B') Fl. 7500 in 7 years. Following the possibility effect, we predicted that most subjects in group 1 will choose prospect (A), whereas most subjects in group 2 will choose option (B').

Results and Discussion

Fifty-one subjects (68%) in group 1 expressed their preference for option B. In group 2, with a few exceptions, a large majority of 68 (91%) subjects chose option (B). The proportion of subjects choosing option (B) in group 2 was significantly larger than the comparable proportion in group 1 ($p < .001$). Although we expected that more subjects in group 1 would opt for option (A), apparently the uncertainty associated with a 1-month delay was sufficiently large so that the majority has chosen option (B). Notwithstanding, the prediction implied by the possibility principle was confirmed: The large delays of 6½ and 7 years made both options so remote, and thus quite improbable, that with only a few exceptions most subjects' preference was dominated by the highest possible gain.

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[7] In terms of Prospect theory, the weighing function is such that "preferences are generally less sensitive to variation of probability than the expectation principle would dictate" (Kahneman & Tversky, 1979, p. 282) except in the extremes.

General Discussion

The three experiments presented above demonstrate that uncertainty plays a crucial role in intertemporal choice. We propose that uncertainty is an inherent component of intertemporal choice and have shown that it can account for some recently observed inconsistencies in intertemporal choice. In this section, we briefly discuss some theoretical implications of our results.

Any time delay of gratification, be it monetary or of any other form, has two implications: One concerns the detainment of the potential pleasure involved and the other is associated with the uncertainty encapsulated in any future outcome. For example, the interest on a given loan may be conceived as a compensation to the loaner for (a) preventing the loaner from using the sum of the loan for a specified period and (b) as an insurance premium for the uncertainty that the loan will lose part of its value (e.g., in the case of a high rate of inflation) or be lost completely. Indeed, a major consideration in determining the interest rate for a given loan is the estimated risk associated with this loan. A major problem, further discussed below, concerns the difficulties in separating the uncertainty component from other considerations.

It may be instructive to distinguish between two sources of uncertainty: One type, termed *external*, is attributed to the outside world and hence is external to the individual. In our specific context, the probability that the payments specified in each of the options in experiment 1 will indeed be honored (by the responsible agent, e.g., the experimenter) is external. Herrnstein, in his original informal experiment attempted to control for such external uncertainty by using specific instructions that would convince his subjects that delayed promised payments will indeed be honored (whether such instructions are effective, specifically in real life conditions, remains questionable). Likewise, the uncertainty regarding the rate of inflation during a specified period of a loan should also be viewed as external.

The other type, termed *internal*, reflects factors that are exclusively associated with the individual's own state. This internal uncertainty stems from the fact that the individual may not be certain to be able to collect the reward, for instance because of sickness or, in the extreme case, death. Also, an individual may not be able to predict for certain the utility of an outcome at the time it is due in the future. For instance, a person who considers whether to buy a current model of a PC may decide to wait for a new version that will only be available after some period of time, yet find at the end that waiting for the new model offered only a limited improvement not being worth it. While external

uncertainty may sometimes be reduced or completely resolved by institutional warranties, internal uncertainty can only be resolved by immediate consumption.[8]

In experiment 1 the probability manipulation is external, yet internal uncertainty cannot be ruled out. Consider first condition 1 (first column in Table 1) that served as an exact replication of Herrnstein's experiment. In this condition we assumed that subjects took for granted that there is no external uncertainty associated with either option (A) or (B) in the imminent future case (which is why we identified the first column of Table 1 with $p = 1$). However, only in option (A) which offers an immediate reward (and *not* in option (B)) is internal uncertainty completely eliminated. Option (A) is preferred by the majority of the subjects because both external and internal uncertainties have been entirely removed. In contrast, under the remote future case, both options (C) and (D) are afflicted by internal uncertainty, in which case the monetary advantage of (D) over (C) dominates subjects' choice.

Now consider the second and third conditions of experiment 1 (columns 2 and 3 in Table 1): Here the experimental manipulation is based on introducing external uncertainty that had a marked effect on the imminent future condition: Option (A), which is still characterized by immediacy, hence implying no internal uncertainty, is now associated with external uncertainty and thus has lost its relative appeal compared with option (B). On the other hand, introducing external uncertainty did not alter the remote future conditions, since internal uncertainty was present already and subjects choice was dominated by monetary payoffs.

In sum, the only case where a large majority of subjects (82%) prefer the smaller but more immediate monetary outcome[9] is under conditions of complete certainty—both internal and external. When either internal or external certainty are removed, subjects' preference is changed accordingly. This change of preferences is analogous to Kahneman and Tversky's (1979) certainty effect, except that they manipulated only external uncertainty. The similarity with the certainty effect is further demonstrated in experiment 2 where the time manipulation lead to effects similar to those obtained by manipulating uncertainty.

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[8] Kahneman and Tversky (1982) distinguished between uncertainty related to the *external* world (e.g., uncertainty associated with tossing a coin) and *internal* uncertainty attributed to one's state of knowledge (e.g., how certain am I that France has a larger population than Italy). Howell and Burnett (1978) use internal and external uncertainty to separate between events that are controllable or uncontrollable, respectively. Our distinction is similar yet not identical to either of the above two interpretations.

[9] Implying that they give up a yearly interest in excess of 120%.

Despite the high similarity between the effects of immediacy and certainty, the relations between them remains an open question. Rachlin, Castrogiovanni, and Cross (1987) proposed that the two effects are virtually the same and further that probability is a derivative of time delay. Their claim is based, among other things, on an empirical demonstration that a probability discount function is derivable from that of a delay discount function. Whether such a demonstration is sufficient to warrant the generalization that the certainty effect is a derivative of the immediacy effect (or that risk aversiveness is a special case of time discounting) is highly questionable.

A different (third) account of the relationship between certainty and immediacy has been offered by Prelec and Loewenstein (1991). They suggest the plausible assumption that neither effect is derivative of the other. Rather, both effects are a reflection of a psychophysical observation (as described earlier in this paper) that people tend to be sensitive to both differences (i.e., the common difference effect) and ratios (i.e., the common ratio effect). Indeed, the fact that both the certainty and immediacy effects share a common similar psychophysics does not necessarily imply that one is a deriviative of the other. Notwithstanding, for a better understanding of the relationship between time delay and uncertainty, additional empirical research would be desired aimed at separating between the two aversive components of time delay: The deferral of hedonic experience and the raise in uncertainty associated with increments in time delay.

Regardless of whether these two aversive components can be empirically separated, it is our opinion that the question of whether uncertainty is a derivative of time delay or vice versa cannot be resolved by empirical demonstrations that varying time delay (as an independent variable) leads to variations in uncertainty (as a dependent variable) or vice versa. Specifically, the issue can also be examined from an analytical viewpoint. Suppose I promised you a prize of $100 for *certain*. Taken literally, it can only be certain if the prize is delivered immediately. Any time delay (regardless of its aversiveness) implies some uncertainty because (if to take the extreme case) you, or I, or both can drop dead before the deadline date of payment. In this respect, uncertainty may be viewed as a derivative of time delay. But now suppose that I promise you an *immediate* reward of $100 depending on the outcome of a coin toss to take place immediately. Obviously, the gain of $100 is uncertain (in fact the probability is .50) yet it cannot be accounted for in terms of time delay (which is zero). Those claiming that probability discounting depends on its relation to delay (e.g., Rachlin *et al.*, 1987, 1991) may argue that the reaction to uncertainty is a learned response associated with the fact that in general, things that are uncertain are also delayed. We believe that such a pure operant perspective is too narrow and does not provide a satisfactory account for many situations. The entire uncertainty in the above example is encapsulated in the outcome of the coin toss, and it is this event which people confronted with such a situation will focus on. Any delayed rewards in this example are simply irrelevant and will not capture the attention of the person involved.

Some Methodological Considerations

The role of uncertainty inherent in any intertemporal choice has important methodological implications. One problem concerns the extent to which the uncertainty underlying intertemporal choice is also reflected in controlled experiments. Real life is characterized by both internal and external uncertainty. In contrast, controlled experiments that attempt to elicit subjects intertemporal preferences often (if not always) lack an important source of external uncertainty. In almost all experiments, independent of whether rewards associated with different choice options are hypothetical or to be handed in real, there is an implicit assumption that these rewards are certain regardless of the specified time delay. As in any other experiment, subjects and experimenter rely on a set of tacit assumptions that govern their interaction (e.g., Schwartz, 1994). One common supposition is that the experimenter's instructions should be taken for granted and their reliability not be questioned. That applies equally to any promised reward, be it imaginary or real. It is for this reason that we have questioned the generalizability of Herrnstein's original experiment. His instructions were formulated such that any possible source of external uncertainty was eliminated. Indeed, as shown in experiment 1, introducing external uncertainty has altered subjects preferences. Another example of the possible effect of undermining external uncertainty in laboratory experiments is provided in experiment 4.

EXPERIMENT 4

A well-documented empirical finding is the disposition, of both humans and animals, to prefer immediate outcomes and downgrade delayed rewards or consumption (e.g., Loewenstein, 1988; Mischel, Grusec, & Masters, 1969). This phenomenon, referred to as *positive time preference* (or positive time discounting), is the basic mechanism underlying the traditional discount model (Bjorkman, 1984). In an insightful paper, Loewenstein and Prelec (1993) proposed that positive time preferences are mainly observed when elicited preferences concern single outcomes. They suggested, however, that positive time preferences may disappear when outcomes are presented as sequences rather than

as separate prospects. They reasoned that intertemporal choices are influenced by two factors (in addition to time discounting): A tendency to spread gratification (i.e., scatter pleasure over time) and an inclination to favor sequences that improve over time. Following these authors the preference for improvement depends, among other things, on whether the choice options are framed (and consequently perceived) as single separate outcomes or as sequences. Following their theoretical framework, the choice between sequences is heavily influenced by the need for spreading gratification and the aspiration for improvement over time, and these may override positive time preferences. To support their hypothesis, Loewenstein and Prelec (1993) report the following empirical study (p. 93). Ninety-five subjects were asked the following:

1. Which would you prefer if both were free?
   A. Dinner at a fancy French restaurant. (86%)
   B. Dinner at local Greek restaurant. (14%)

For those who prefer French:

2. Which would you prefer?
   C. Dinner at the French restaurant of Friday in 1 month. (80%)
   D. Dinner at the French restaurant on Friday in 2 months. (20%)

3. Which would you prefer?
   E. Dinner at the French restaurant on Friday in 1 month and dinner at the Greek restaurant on Friday in 2 months. (43%)
   F. Dinner at the Greek restaurant on Friday in 1 month and dinner at the French restaurant on Friday in 2 months. (57%)

The pattern of results (percentages in parentheses) reported by Loewenstein and Prelec was congruent with their predictions. Of the 86% of subjects who preferred the fancy French dinner (question 1), 80% preferred the more immediate French dinner (option C) over the delayed alternative (option D) when the question was formulated as a choice between two *single* prospects (question 2). When, however, the same options were presented in a *sequence* as in question 3, the majority preferred option (F) where the favorable French dinner was delayed over the more immediate option (E). Note that this pattern of choices is incompatible with any discounted utility model.

One issue encapsulated in the study by Loewenstein and Prelec concerns the possible interpretation adopted by subjects when responding to the above questions. Specifically, subjects are likely to interpret the questions under the assumption that the promised dinner is *certain* regardless of size of delay. Under this perspective the only issue entailed by the questions concerns preferences regarding the spread of outcomes

over time. For example, a plausible interpretation of option (F) is a *sure* Greek meal in 1 month and a *sure* French meal in 2 months. The fact that in reality the more remote an outcome the higher the uncertainty of its realization is not reflected in the option.

Two problems arise in this context. First, the questions may be ambiguous in that some subjects may indeed embrace the assumption of certainty with regard to outcomes while others may not. Second, it is our claim that the assumption of certainty regarding future events may often be unrealistic and thus not representative of the real world. This should not necessarily be interpreted as a criticism on the study by Loewenstein and Prelec, whose interest was to study the desire for spreading gratification across time and the need for improvement of future outcomes. If, as we suggest, subjects regarded the outcomes as certain, then the effects demonstrated by Loewenstein and Prelec are indeed real and are not confounded with uncertainty. Our main thesis, however, is that the uncertainty encapsulated in intertemporal choices is a prominent factor that may often loom over other considerations such as spreading preferences and the desire for improvement.

Method and Design

Two conditions were employed in this experiment. One condition was aimed at replicating as close as possible the experiment of Loewenstein and Prelec (1993) as described above. Subjects ($N = 87$) were presented with exactly the same three questions used by Loewenstein and Prelec, the only difference being that the "local Greek restaurant" was replaced by a "local Italian Pizza Hut," and the short and long delays were 4 and 13 weeks (instead of 1 and 2 months), respectively. Subjects in the other condition ($N = 88$) were presented with exactly the same questions except that all the outcomes were stated probabilistically with a chance of $p = .60$. For example, option (F) for the replication group was "Dinner at a local Italian Pizza Hut (including a salad and drinks) on Friday in 4 weeks and an elaborate dinner at a French restaurant (including drinks) on Friday in 13 weeks"; for the other (probabilistic) group the same option was phrased as "A 60% chance for a dinner at a local Italian Pizza Hut (including a salad and drinks) on Friday in 4 weeks and a 60% chance of an elaborate dinner at a French restaurant (including drinks) on Friday in 13 weeks". It was also added that "the outcome will be determined by use of a lottery."

Results

Table 3 presents the results of experiment 4 along with those reported by Loewenstein and Prelec (1993).

TABLE 3

Subjects' Preferences (in Percentages) in the Three Choice Problems for Loewenstein and Prelec's (1993) Study, for the Replication in Experiment 4, and for the Probabilistic Replication

	Loewenstein and Prelec (1993)	Replication	Probabilistic replication
Question 1			
A	86%	89%	85%
B	14%	11%	15%
Question 2			
C	80%	92%	84%
D	20%	8%	16%
Question 3			
E	43%	41%	75%
F	57%	59%	25%

Comparison of the first two columns show that the results reported by Loewenstein and Prelec (1993) and our replication are highly similar. Specifically, like Loewenstein and Prelec we obtained a clear reversal in choices to questions 2 and 3 ($X_1^2 = 44.4$; $p < .001$). The pattern of results for the probabilistic condition, however, suggests that subjects' choices in questions 2 and 3 were not different ($X_1^2 < 1$). Evidently, under probabilistic conditions, subjects have a clear preference in both question 2 and question 3 to receive the French dinner sooner rather than later.

Discussion

As in Loewenstein and Prelec, the results of our replication (condition 1) clearly demonstrate that the time positivity inclination can be eliminated if the options are framed in terms of sequences. Yet, as is evident from the choice pattern of subjects in condition 2, when the sequential prospects are explicitly associated with uncertainty positive time preferences reemerge, again dominating subjects' choice.

The observation that subjects' preferences in Loewenstein and Prelec's study are incompatible with positive time preferences and violate rational prescriptions can thus be due to the lack of uncertainty embodied in their experimental setting. According to this argument, the main factor underlying positive time preference is uncertainty that increases as the outcome (or reward) is more remote. Given that most people are risk averse, uncertainty looms over other potential considerations that leads to positive time preferences.[10] Positive time preferences in this view are mainly a result of risk aversion since the sooner the reward the smaller the corresponding uncertainty. Once uncer-

tainty is removed, other considerations such as spreading positive outcomes and the aspiration for sequences that improve over time (e.g., Loewenstein & Prelec, 1993) may dominate subjects' choice.

In sum, subjects in both the Loewenstein and Prelec study and in the first condition of our experiment may have interpreted the outcomes as certain (regardless of the size of delay) and consequently made their choice on considerations other than risk. In contrast, subjects in our second (probabilistic) condition were explicitly confronted with an uncertain situation. Under this condition uncertainty considerations dominated their choice resulting in positive time preferences.[11] Evidently, the study of intertemporal choice is intricate from both a theoretical and methodological viewpoint. In order to derive valid theoretical conclusions, future research should ensure that the component of uncertainty inherent in any time delay is also incorporated in the experimental design.

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[10] The argument is based on risk aversiveness in the positive domain. When negative outcomes are involved, the same line of reasoning would yield negative time preferences.

[11] Another explanation (offered to us by George Loewenstein), albeit one which is consistent with ours, is that the introduction of uncertainty eliminated subjects' abilities to savor the delayed dinner due to the introduction of anxiety.

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