An Investigation of Time-Inconsistency

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Abstract

Preference between two future outcomes may change over time -- a phenomenon labeled as time-inconsistency. The term "time-inconsistency" is usually used to refer to cases in which a larger-later outcome is preferred over a smaller-sooner one when both are delayed by some time, but then with the passage of time preference switches to the smaller-sooner outcome. The current paper presents four empirical studies showing that time-inconsistency in the other direction is also possible: A person may prefer the smaller-sooner outcome when both options are in the future, but decide to wait for the larger-later one when the smaller option becomes immediately available. We find that such "reverse time-inconsistency" is more likely to be observed when the delays *to* and *between* the two outcomes are short (up to a week). We propose that reverse time-inconsistency may be associated with a reversed-S shape discount function, and provide evidence that such a discount function captures part of the variation in intertemporal preferences.

Keywords: time-inconsistency, reverse time-inconsistency, time preference, intertemporal preferences

1. Introduction

An individual's preference for a particular future outcome over another one may change with the passage of time. Usually, the term "time-inconsistency" (or dynamic inconsistency) is used to refer to the change in the following direction: a larger-later outcome is preferred over a smaller-sooner one when both are delayed, but when the smaller-sooner outcome becomes imminent, there is a switch to this option (e.g. Hoch and Loewenstein 1991). There is a large body of behavioral literature examining such preference reversals (see Frederick *et al*. 2002 for a review). Yet, except for a few studies, most experimental work on dynamic inconsistency looks at preference reversals only for long delays (delays to and between outcomes ranging from one month to 50 years).

Recent research suggests that that individuals have an extended notion of the present, where the present may prolong into the immediate future, and the "real" future begins only after a certain delay (Coller *et al*. 2005, Takeuchi 2007). Thus, for shorter delays the nature of intertemporal preference reversals may be different from the time-inconsistency as we know it. This is the main motivation of the current paper. Our empirical studies focus mainly on delays shorter than several weeks. In addition, we use both longitudinal and cross-sectional designs, whereas most prior studies involve cross-sectional designs. Considering the link between temporal preference reversals and time discounting, our paper also elicits individual discount factors for short delays.

We conducted four studies in our analysis of dynamic inconsistency. Study 1 is a longitudinal experiment with real monetary payments. Our findings from this study reveal that, for short delays (up to one week) individuals exhibit what could be called *reverse time-inconsistency*: They prefer a smaller-sooner future outcome to a larger-later one but decide to wait for the larger outcome when the smaller option becomes immediate. In Study 2, using similar delays and outcomes in a cross-sectional design with hypothetical payments, we again find evidence for reverse time-inconsistency. Findings from these two studies indicate that reverse time-inconsistency is more likely to be observed when the delays to and between the two outcomes are up to one week. In Study 3, we extend the range of delays to cover longer periods, and we find that regular time-inconsistency is more prevalent. Study 4 examines the extent of discounting patterns which can accommodate regular and reverse preference reversals. In essence, the current paper shows that intertemporal preferences are richer than previously recognized: Reverse time-inconsistency is more frequently observed for short delays but regular time-inconsistency becomes more prevalent for longer periods. We also find that many individuals exhibit lower discounting for intervals closer to the present than for distant ones, in contrast to hyperbolic discounting.

The paper proceeds as follows. Section 2 reviews existing literature on time-inconsistent preferences and places our paper in context. We present the findings from our four studies in Section 3. After a general discussion in Section 4, we conclude in Section 5.

2. Background

According to the discounted utility theory (DUT), the standard economic model of choice over time, preferences between two temporal outcomes do not depend on when the evaluation is made (Samuelson 1937, Koopmans 1960, Fishburn and Rubinstein 1982). In other words, if the outcomes are moved forward by the same amount of time, the preference ordering should stay the same. Stationarity, taken together with other DUT axioms, implies exponential discounting where the discount rate does not change with delay. However, both the stationarity axiom and the corresponding exponential discount function have been challenged in terms of descriptive validity (e.g. Thaler 1981, Benzion *et al*. 1989, etc.). Time-inconsistency (or dynamic-inconsistency), a concept first analyzed by Strotz (1955), refers to non-stationarity of preferences. For example, an individual may prefer to receive $10 today rather than $12 tomorrow, even though she prefers to receive $12 in 31 days to $10 in 30 days.

In this section, we will examine the experimental research regarding time-inconsistency under two headings. A number of studies provide evidence for the time-inconsistency phenomenon itself; others examine the discounting behavior, such as hyperbolic discounting, which is used to explain this preference reversal. The main design difference between time-inconsistency and discounting studies is that to demonstrate time-inconsistency, one needs to compare preferences between two future outcomes from two different time viewpoints -- one closer to the present than the other. Discounting studies, on the other hand, look at the pattern of valuation of future outcomes vis-à-vis the present. As will be discussed later, this pattern can be obtained through valuations for a number of delays to the present (*delay*-discount function); or examining discount rates in intervals that start at consecutive periods, including the present period (*interval*-discount function).

Most of the previous work on temporal preference reversals focuses on (regular) time-inconsistency. The term reverse time-inconsistency was used previously by Loewenstein (1987), although he used it to apply to situations different than what we study. He proposed that, for vivid and fleeting consumption (such as Halloween candies, an expensive wine, etc.), positive utility from anticipation may lead one to prefer later consumption, rather than immediate. That is, the devaluation of future consumption can take a “hump” shape pattern (Loewenstein 1987, p. 668). The implication of this model is that, even in the presence of self-control techniques, individuals may defer consumption repeatedly. Loewenstein (1987) calls this phenomenon reverse time-inconsistency. Our paper empirically shows that individuals may exhibit reverse time-inconsistency in the context of two monetary outcomes.

2.1. Time-Inconsistency

Table 1 summarizes a number of experimental studies on time-inconsistency.[1] The table reports several aspects of the experimental design, including cross-sectional versus longitudinal designs, delay levels, and the nature of outcomes (monetary or non-monetary outcomes such as snacks, etc.). Overall, time consistency (TC) is the most common finding and time-inconsistency (TI) is more prevalent than reverse time-inconsistency (RTI).

---- Insert Table 1 about here ----

[1] TI is also reported in animal studies (e.g. Rachlin and Green 1972, Ainslie 1974, Green *et al*. 1981), even though the delays to and between the smaller-sooner (SS) and larger-later (LL) outcomes are obviously much smaller than in human experiments. For instance, Green *et al.* (1981) had four pigeons as subjects. Keeping the interval between SS and LL at 4 seconds, the authors found that as the delay to SS was increased from 2 to 28 seconds, all four pigeons switched to LL.

There are two noteworthy observations from the table. First, most of these studies involve cross-sectional designs (e.g. Green *et al*. 1994, Keren and Roelofsma 1995, Kirby and Herrnstein 1995, Coller and Williams 1999). In such a design, subjects are asked to state preferences between two temporal outcomes in the following scenarios:

- Scenario A: choice between (x, t_1) and $(y, t_1 + t_2)$
- Scenario B: choice between $(x, 0)$ and (y, t_2)

where (x, t) refers to outcome x receivable in time period $t \geq 0$. In both scenarios A and B, choices are made from the present standpoint where subjects are asked to choose between two temporal outcomes (a smaller-sooner one versus a larger-later one), and their vantage point is manipulated by stipulating the front-end delay *to* the smaller outcome (immediate versus delayed), keeping the delay *between* the outcomes constant.[2] The implicit assumption for Scenario B is that it is equivalent to the case where t_1 periods have passed since Scenario A, even though it is not really the case in the experimental setting. In other words, in Scenario B the choice is made from the vantage point of $t = 0$, but it is interpreted as if the choice is made at time period t_1. This cross-sectional design can be implemented in within- or between-subjects experiments.

In contrast, a longitudinal study compares scenarios A and C, where Scenario C involves the actual passage of time, and the design is within-subjects:[3]

- Scenario C: choice between $(x, 0)$ and (y, t_2) at time period $t = t_1$

Although most of the experimental research on time-inconsistency is based on cross-sectional designs, cross-sectional inconsistency does not necessarily entail longitudinal inconsistency (Read 2004). Experiments with a longitudinal design are quite scarce -- to our knowledge, there are only three studies

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[2] The distinction can be made using other terms. For instance, Read (2001) designates the time to the later outcome as the *delay* and the time between the two outcomes as the *interval*.

[3] In principle, this manipulation does not have to be within-subjects nor involve an actual passage of time. Subjects may be instructed to answer from the standpoint of time t_1. For instance, Baron (2000) elicited preferences regarding the number of species saved today, in 25 years, and in 50 years, with one condition stating "if the decision were made in 25 years". Nevertheless, credibility of scenarios with "imaginary passage of time" may be questioned.

reported in the literature. Two of these involve choices between non-monetary outcomes. In the first study, Read and van Leeuwen (1998) asked subjects to indicate their choices between healthy and unhealthy snacks one week before consumption and again on the consumption date. On average, subjects preferred the unhealthy snack more frequently when both snacks were immediately available than when available in a week.[4] The second longitudinal study with non-monetary outcomes is reported by Read *et al*. (1999) in which subjects were asked to choose between "highbrow" versus "lowbrow" movies at different points in time. The results show that the percentage of highbrow movies chosen was higher in the distant condition than in the immediate one. Experiment 2 in Ainslie and Haendel (1983) is the only longitudinal study which used monetary outcomes: 18 substance abuse patients indicated their choices between smaller-sooner (SS) and larger-later (LL) options a week before the SS outcome was realized and again, a week later, when SS was due. The results show that more subjects exhibited TI than RTI. In short, these three longitudinal studies either use a particular outcome structure (healthy versus unhealthy snacks, highbrow versus lowbrow movies) or a specific subject pool (substance abuse patients). In contrast, in the current paper we examine longitudinal inconsistencies by using monetary outcomes and by recruiting students as the subject pool.

The second observation from Table 1 concerns the delays levels. The delays used in most studies are long, ranging from one month to 50 years. In the few studies which look at shorter delays, a substantial number of subjects exhibit RTI. The most striking result is by Holcomb and Nelson (1992). In their study, 101 subjects indicated choices between \$5 versus \$5(1+*r*) where *r* is a daily interest rate of 1.5% or 3% (and between \$17 versus \$17(1+*r*)). The delay to the smaller outcome was 0, 1, or 7 days and the delay between the outcomes was 1, 7, or 14 days. Although significance levels are not reported, the aggregate results suggest RTI in many conditions, particularly when the delay to the smaller outcome is one day. This means that in these conditions subjects actually preferred LL more frequently when SS was

[4] Incidentally, in this case the two options are available at the same time but we could still categorize the preference reversal as TI, rather than RTI: The option that is "better" from a long-term or rational perspective (a "virtue" such as healthy snacks) becomes less attractive when both options are immediately available.

immediate.[5] The findings by Scholten and Read (2006), another study covering short delays, also reveal some RTI behavior. However, none of these studies acknowledge RTI explicitly as a behavioral phenomenon. Our paper provides evidence that when the delays to and between the outcomes are small, RTI is more prevalent than TI.

2.2 Explanations for Time-Inconsistency

Researchers have proposed and examined different explanations for TI. Of these, hyperbolic discounting (or declining impatience) has received the most attention (e.g. Ainslie 1975, Mazur 1987, Loewenstein and Prelec 1992). It should be noted that TI is also interpreted as evidence for hyperbolic discounting (cf. Frederick *et al*. 2002). Under hyperbolic discounting, the discount rate for a given time interval is smaller if the interval is temporally remote. Consider the earlier example where $12 in 31 days is preferred over $10 in 30 days, but $10 today is preferred over $12 tomorrow. Hyperbolic discounting can account for the shift in preferences because the per-period discount rate moving from 30 days to 31 days is smaller than the per-period discount rate moving from today to tomorrow.

Although hyperbolic discounting can account for TI, there are two issues. First, evidence for hyperbolic discounting is not evidence for TI per se. TI should be inferred based on a comparison of preferences between two future outcomes from two different time viewpoints (keeping the delay between these outcomes fixed). However, hyperbolic discounting can be inferred from valuations of an outcome for a number of delays to the present (simply by using a few choice or matching tasks as in the previous section). Secondly, and more importantly, a higher per-period discounting over a short delay than a longer one (*delay*-discount function) does not necessarily mean that the discounting in an interval starting at the present period is higher than the discounting starting at a later period (*interval*-discount function) (Read 2001). Assume that the discount rate is the same for 0-1 month and for 1-2 months intervals, but it is larger than the per-month discount rate over 0-2 months. If the discount rate in the 0-1 interval is

[5] Holcomb and Nelson (1992) ran a logit model to examine the impact of delay and magnitude on choice. They found no significant effect of "delay to the smaller outcome" which is a continuous variable encompassing 0, 1, and 7 days. Comparing the "0 (today)" case with "1 day" and "7 days" cases separately might lead to a different result.

compared with the per-month discount rate in 0-2 months, then subadditive time-discounting might be interpreted as hyperbolic discounting. Therefore, confounding the delay between the outcomes and the delay to the larger outcome would be misleading. By eliciting the discount rate over different partitions of the delay, Read (2001) found support for subadditive discounting but not hyperbolic discounting. Read and Roelofsma (2003) show that this finding holds for both choice and matching tasks of elicitation: Hyperbolic discounting is not evident in either task, although there is some evidence for declining discounting in matching. Even without taking subadditivity into account, inferred discount rates may still depend on the elicitation method chosen. Ahlbrecht and Weber (1997) report that for most subjects in a matching task, the discount rate is higher over the short delay than over the long delay (evidence for hyperbolic discounting); however, in the choice task part, preferences were mostly consistent over time. Moreover, their results from the choice task indicate that RTI is as common as TI. All these experimental findings suggest that evidence for hyperbolic discounting is not unequivocal.

Previous literature does not provide an explanation for RTI behavior, except for Loewenstein (1987) where the focus is on a single future consumption. He proposes a discounted utility model with two components: utility from consumption and utility from anticipation. In the model, due to positive utility from anticipation and savoring, the net present value of a vivid and fleeting consumption against time has a hump-shaped pattern, reproduced in the left panel of Figure 1. In the top curve, devaluation is initially negative, even though the discount function is exponential. Loewenstein makes the distinction between *discounting* and *devaluing* by referring to devaluing as “a decrease in the outcome’s value as a function of delay” (p. 671). As a result of this negative devaluation, when consumption becomes imminent, the individual would have an incentive to defer it again. Loewenstein (1987) names this behavior as RTI. He argues that as consumption becomes more lasting, the “hump” will become flatter, resulting in a reversed-S shape (middle curve in the left panel of Figure 1). This implies that the utility from anticipation still plays a role but it does not cause negative devaluation.

---- Insert Figure 1 about here ----

In our paper, we argue and present evidence that, in the context of two temporal monetary outcomes, RTI is possible without negative devaluation. Assume that the delay to SS is one period and the delay to LL is two periods, and that the individual prefers SS over LL. As time passes and SS becomes immediate (and delay to LL becomes one period), if the increase in the value of LL is sufficiently larger than the increase in the value of SS, she will switch to LL. In other words, the discount rate in the interval 1-2 period must be higher than the discount rate in the interval 0-1 period. Therefore, a discount function that is flatter initially and steeper later on can accommodate RTI. The reversed-S shape in the right panel of Figure 1 illustrates such a discount function. We will discuss this point further in Section 4. We note that the *reversed 'S' devaluation* of Loewenstein (1987) is conceptually different -- in his case reversed-S shape is due to savoring or utility from anticipation.

To conclude this section, since intertemporal preferences may be different for short delays, studies involving short delays would contribute to our knowledge regarding dynamic inconsistency. Furthermore, employing both cross-sectional and longitudinal designs would enrich our knowledge because cross-sectional inconsistency is not necessarily the same as longitudinal behavior. In the following section we present four empirical studies. Study 1 involves a longitudinal design and incentive compatibility through real outcomes. Study 2 has two parts, both of which use cross-sectional designs: Study 2a is based on within-subjects measures and Study 2b is between-subjects. Study 3, which involves a cross-sectional design, uses an extended range of delays. In Study 4, we examine discounting behavior using a matching task and analyze the data at the individual level to see the extent of different discounting patterns that can accommodate RTI and TI.

3. Empirical Studies

3.1. Study 1

The purpose of our first study is to explore the nature of temporal preference reversals when the delays are short. Study 1 differs from most published studies not only in terms of delay levels but also with respect to the experimental design. The study is based on a real-time experiment, i.e., we compare scenarios A and C mentioned above. Participants state their preferences between temporal payoffs first when SS is in the future and then again when it becomes immediate with the passage of time.

Method. In Study 1, we employed a within-subjects longitudinal design with real monetary payments. We presume that real payments are essential for a longitudinal study. The experiment was conducted at INSEAD, Paris. 38 participants stated their preferences between different pairs of temporal monetary outcomes. When SS became imminent, they were asked to state their choices again. Delays and outcomes are similar to those used in Holcomb and Nelson (1992).

Design and Stimuli. Subjects were students in a negotiations analysis course at INSEAD. The first phase of the longitudinal study was conducted in a class meeting. The introduction to the survey stated that the questions were intended to measure individual preferences for outcomes over time. Subjects were told that there were no right or wrong answers, and that each question should be considered independently.

Participants answered six choice questions (vignettes) with monetary outcomes, presented in Table 2. They were told that one outcome level (€7–€10 or €20–€25) would be chosen randomly, and each of the three delay scenarios for that outcome level would be honored. In subsequent sessions, when the SS option in each delay scenario was due, subjects were asked again to indicate their preference between SS and LL (done for all three delay scenarios on the respective days). In order to minimize any concerns about consistency on the part of the subjects, they were told that earlier records would not be taken into consideration. After the subjects indicated their choices, payments were made accordingly.

---- Insert Table 2 about here ----

Results and Discussion. The results are presented in Table 2. We use McNemar's χ^2-test in comparing the percentages because the respective measurements are from the same set of subjects. At the aggregate level, there is evidence for RTI rather than TI for smaller delays, particularly for the outcome level €7–€10. For example, for the first outcome-delay scenario, 29% of the subjects initially preferred LL (€10, 3 days) over SS (€7, 1 day), but when €7 became immediate and €10 due in two days, 71% chose the latter.

For the outcome pair €20–€25, there is evidence for RTI when the delay to SS is one day, even though it is not strongly significant. For longer delays, there is no evidence of inconsistency in either direction. Individual level results are presented on the last columns of Table 2. For the first scenario, 19 out of 38 subjects exhibited RTI, 3 exhibited TI, and the remaining 16 made consistent choices. RTI is more prevalent than TI when the delay (to and between the outcomes) is short. For longer delays, we observe some RTI and TI cases at the individual level, while aggregate level analysis does not detect either type of inconsistency. Overall, from 228 choice pairs (38 subjects, two outcome levels, three delays), 29% are in the direction of RTI, 13% are TI, and the remaining are consistent.

These results indicate evidence for RTI in a longitudinal setting, using delays and outcomes similar to those in Holcomb and Nelson (1992). Since the previous studies in which we can trace RTI (Holcomb and Nelson 1992, Ahlbrecht and Weber 1997, and Scholten and Read 2006) employ cross-sectional designs, in the next study we will employ a cross-sectional design using similar experimental parameters as in Study 1.

3.2. Study 2

Study 1 employed a longitudinal method in which subjects were asked to revisit their choices over time (as in scenarios A and C in Section 2). Study 2 has two parts both of which employ a cross-sectional design (comparing scenarios A and B). Study 2a is a within-subject experiment in which subjects received both scenarios A and B. Study 2b is a between-subject version of the same experiment. Even though a within-subjects design enables us to study behavior at the individual level, subjects may try to be consistent in their answers. A between-subjects design provides further insight in that respect. Payoff sizes and delay levels in Study 2 are similar to the ones in Study 1.

Method. Study 2a was conducted at Koç University in Istanbul with 72 students. Participants answered choice questions regarding hypothetical monetary outcomes. In addition to the delay levels used in Study 1, we used a fourth delay (2 weeks–4 weeks). Participants were offered a chance to win $50 in addition to course credit. The delays and outcomes in Study 2b were identical to those used in Study 2a. Study 2b was conducted at Koç University with 117 students.

Design and Stimuli. In Study 2a, participants answered sixteen choice questions, eight of them comparing two future outcomes (“distant” questions) and the other eight comparing a present outcome with a future one (“immediate” questions). A complete list of the choice pairs is presented in Table 3. Half of the subjects answered the eight “distant” questions first, and the other half answered the eight “immediate” questions first. The corresponding first and second parts were applied separately, with filler questions between the two parts.

---- Insert Table 3 about here ----

Study 2b is a between-subject version of the same experiment. Subjects in the “distant” condition were asked to indicate their preference between two outcomes, both in the future. Subjects in the “immediate” condition were asked to choose between an immediate SS and a future LL. The choice pairs are presented in Table 4. For instance, subjects in distant condition chose between receiving $7 in one day or $10 in three days, whereas subjects in the corresponding immediate case chose between receiving $7 today or $10 in two days. There were 56 subjects in the distant outcomes condition and 61 subjects in the immediate condition. In both Studies 2a and 2b, subjects answered one of the four survey versions with different randomized order of questions.

---- Insert Table 4 about here ----

Results and Discussion. As in Study 1, comparisons in Study 2a involve McNemar’s χ^2-test. Aggregate-level findings from Study 2a show evidence for RTI for short delays and no inconsistency for longer ones. This pattern is clearer for the outcome pair $20-$25 than for $7-$10. Looking at the individual level behavior (the rightmost two columns), we observe relatively more RTI than TI for short delays. From 576 choice pairs (72 subjects, two outcome levels, four delays), 13% are in the direction of RTI, 6% are in the direction of TI, and the remaining are time-consistent. The percentages in Study 2b (Table 4) are similar to those in Study 2a (Table 3). For the last scenario (the last two rows on Table 4), the percentages are in the TI direction but the difference is not statistically significant ($p = 0.11$). Generally speaking, subjects' concern for consistency in Study 2a, if any, does not play a role in their choices across the distant and immediate conditions.

Our findings from Studies 1 and 2 suggest that RTI is the prevailing form of inconsistency for short delays in both cross-sectional and longitudinal designs. If we combine individual level findings from Study 1 and Study 2a (only the first three delay scenarios), 21% of the choice pairs are in the direction of RTI and 9% indicate TI. As the delay gets longer, TI and RTI both become less extensive. However, we note that in our studies a longer delay to SS comes with a longer delay between SS and LL. With longer delays between the two options, SS becomes more attractive in both the distant and immediate conditions and hence there is less room for either type of inconsistency.

Table 5 provides an overview of the range of delays used in the current paper as well as in other papers employing similar delays and procedures.[6] In the table, a particular data point is marked as TI (RTI) if the percentage of the subjects choosing SS (LL) is higher in the corresponding immediate condition. Even though the pattern is not precise, RTI seems to be more likely in the upper left portion of the table -- where the delays to and between the outcomes are short. The delay levels in the lower part of the table, where TI may be more relevant, are rarely studied in previous research. Study 3 is motivated by this observation and it examines the delays in the shaded cells (as the "distant" conditions) of Table 5.

---- Insert Table 5 about here ----

3.3. Study 3

In Study 3, we use a wider range of delays than those used in the earlier two studies in order to examine the extent and the nature of dynamic inconsistency from a broader perspective. The range of the

[6] Studies that use a delay titration procedure, e.g. Kirby and Herrnstein (1995), are not included. Scholten and Read (2006) is not included because their comparisons do not involve immediate outcomes.

delay *between* SS and LL includes and goes beyond the respective range in our first two studies. The delay *to* the SS is longer than used in our studies up to this point. The study is based on a cross-sectional design.

Method. Study 3 employs a between-subjects design. 145 students were recruited at Koç University to participate in the experiment. Subjects answered choice questions regarding hypothetical monetary outcomes. They were offered a chance to win $50, in addition to course credit. Delays and monetary amounts are presented in Table 6. The design is similar to the earlier experiments except that it only covers the $7-$10 case. Another difference is that a factorial design is used, with three delays to SS (immediate, 2 weeks, 8 weeks) and six delays between SS and LL (2, 4 days; 1, 2, 4, 8 weeks).

Design and Stimuli. The design was the same as the one in Study 2b, except for the delay and outcome levels. Subjects in the immediate condition were asked to choose between an immediate SS and a future LL. They answered a total of six questions. Subjects in the distant condition indicated preferences between SS and LL, both in the future. These subjects answered a total of 12 questions -- six questions for "2 weeks" and six questions for "8 weeks" delays. In both distant and immediate conditions, subjects were given one of the four survey versions with different randomized order of questions.

---- Insert Table 6 about here ----

Results and Discussion. In almost all the cases in Table 6, the percentage of subjects choosing LL over SS is larger in the distant condition than in the immediate condition, implying TI. For example, although 80% of the subjects preferred LL when comparing SS ($7, 8 weeks) with LL ($10, 9 weeks), only 42% preferred LL ($10, 1 week) when SS was immediate.[7] Out of the 12 possible comparisons with the immediate case, five of them involve statistically significant differences, and these pertain to the "8

[7] A few of the delay levels are used in Studies 1 and/or 2 as well. A comparison of the percentages for these cases indicate that the number of subjects choosing LL in Study 3 are slightly higher than those in Studies 1 and 2 -- which is noteworthy because it leaves even less room for TI.

weeks" distant condition. This pattern suggests that TI is more likely to be observed when the delay to SS is longer. Combining the results from the three studies, we can conclude that RTI is more likely to be observed when the delays to and between the outcomes are up to a week; and RTI is more common than TI in that range of delays. As the delay to SS gets longer, TI is more likely to be observed. These are consistent, to a large extent, with the findings from prior studies using monetary outcomes and similar procedures.

3.4. Study 4

We noted in §2 that TI can be linked to hyperbolic discounting (even though the evidence is not unequivocal) which indicates higher discounting for closer delay intervals than for distant ones. In contrast, RTI can be associated with lower discounting for closer intervals than for distant ones. The reasoning is as follows: Keeping the delay between SS and LL constant, when SS becomes immediate, the increase in the present value of LL would be higher compared to SS; hence, the preference may switch from SS to LL. In that case, the discount function would be flatter for close intervals and steeper for later intervals (which should level off later on). In Study 4, we examine subjects' discount factors in order to check if this is the case. Basically we compare the discount rate for a temporally close interval with the rate for a more distant one. To the best of our knowledge, such a comparison at the individual level using small delay levels has not been reported elsewhere.

Method and Design. Our findings above regarding RTI, consistent with lower discounting for closer delay intervals, are obtained from choice experiments. Study 4 examines discounting behavior via a matching / valuation task and compares the discount factors in close versus distant intervals. We used a web-based interface, and collected data in a single session from 60 participants at Koç University. Subjects were asked to provide the smallest amount they would accept in the future, against a given present amount. There were 14 valuation questions using combinations of two present outcomes ($6 and $21) and seven delays (1, 2, 3, 4 days; 1, 2, 4 weeks). In order to obtain more truthful measures, we used an incentive-compatibility scheme adapted from Kirby and Marakovic (1995). In this scheme, participants' stated future valuations for one of the questions (chosen randomly) are taken as bids in an auction. The participant who states the smallest future amount receives that amount in due time, and the other participants receive the present amount.

Analysis and Discussion. We examine whether the discount factor over a temporally close delay interval is higher (lower discount rate) than the discount factor over the corresponding distant one. For instance, we compared the discount factor for the interval 0-1 day with the factor for 2-3 days. This corresponds to the case where SS advances from one day to now and LL advances from three days to two days. The discount factor for 0-1 day is the ratio of the present amount to the subject's stated future amount for one day. The discount factor for 2-3 days is found by dividing the corresponding future amounts. Since equal values are improbable, we used ±2.5% as the cutoff points to decide whether one discount factor is equal to the other. In other words, if the discount factor over 0-1 day is larger than 102.5% of the discount factor over 2-3 days, the former is considered as larger and the case is labeled as RTI. If the first factor is less than 97.5% of the second factor, it is considered as smaller -- this is consistent with TI. If the first factor is within 97.5% and 102.5% of the second factor they are considered as "equal" -- this corresponds to time-consistency.[8] We note that if either of the two discount factors is larger than 1, we did not classify the case (last column in Table 7). In addition, for the $6 outcome level, data from seven subjects, and for the $21 outcome level, data from nine subjects were excluded due to inconsistent responses (e.g. reporting future valuations of {$6, $6, $10, $6, $6, $6, $6} for the seven consecutive delays).

---- Insert Table 7 about here ----

As shown on Table 7, in 18% of the comparisons the discount factor is larger (i.e. a lower discount rate) for the closer delay interval (i.e., $\delta_1 > \delta_2$), which is consistent with RTI. Another observation is that the aggregate tendency is in the direction of $\delta_1 < \delta_2$ which implies hyperbolic discounting and can be

[8] We replicated the analysis with ±%1 as the cutoff points; the number of cases classified as "equal" decreases, but the qualitative nature of the findings does not change.

associated with TI. This suggests that aggregate measures of discounting may conceal the variety at the individual level. Looking at the "$\delta_1 > \delta_2$" column, there is no clear pattern with regards to delay in either of the $6 and $21 conditions; "$\delta_1 > \delta_2$" can be observed for any delay level. This contrasts with Studies 1-2 which suggest that RTI is less prevalent for longer delays. The "$\delta_1 < \delta_2$" column shows that hyperbolic discounting is more frequently observed for longer delays; again, this pattern does not fit squarely with the findings from Studies 1-2. Yet, if we look at the extent of RTI relative to TI (as implied by the discount factors), RTI is more likely for smaller delays, as in Studies 1-2.

For face validity purposes, we also plotted the discount factors against delays for each subject and examined the shape visually.[9] We considered data from 53 and 51 subjects, for the $6 and $21 outcome levels respectively: Overall, 16% of the curves resembled a reversed-S shape discount function, 32% resembled hyperbolic, and 16% resembled exponential curves; the remaining 36% of the curves could not be categorized. This eyeball examination confirms the formal analysis. As in the above analysis, if we pool data across subjects, the resulting curve looks like hyperbolic discounting for both outcomes.

4. General Discussion

Studies 1-3 indicate that RTI is more likely to be observed when the delays to and between the outcomes are up to a week. TI, on the other hand, is more common as the delay to SS gets longer. The first contribution of the paper is to give an insight to the extent of RTI and TI with regards to different delay levels. Our results are based on both longitudinal and cross-sectional data, and both individual level and aggregate data. Aggregate level comparisons provide a stricter test of such behavioral inconsistency, but individual level results can offer a richer picture -- RTI and TI observed at the individual level may not be evident at the aggregate level.

How do our findings from Studies 1-3 compare with previous work on time-inconsistency? It is difficult to reach a definite conclusion from the past findings summarized in Table 1; nevertheless, our

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[9] Because we have only 7 data points for a given outcome, we do not compare the goodness-of-fit results for alternative functional forms -- a functional form for reversed-S shape would need to have several parameters.

results are not contradictory to what has been reported before. There is evidence of RTI in Holcomb and Nelson (1992) and to a lesser degree in Scholten and Read (2006). Delays used in these two papers are similar to the delays in our Studies 1 and 2 -- and shorter than those used by most of the other studies. Ahlbrecht and Weber (1997), on the other hand, observe RTI for longer delays, but they use risky prospects as options, not sure amounts. For delays ranging from one week to several months, Kirby and Herrnstein (1995) find strong evidence for TI. However, we should note that the delay-titration they use is not conducive for RTI.[10] Future research examining RTI / TI over the delays in Table 5, and beyond, would extend our understanding of dynamic inconsistency.

The second contribution of the current paper is to propose that RTI is associated with reversed-S-like discounting, as seen in Figure 1 and Figure 2 (note that in Figure 2 the time axis indicates the progress of time -- the graph is the horizontal flip of the reversed-S discount function). In the top panel of Figure 2, delays to and between the outcomes are both short, and the decision maker prefers SS at the outset. As time progresses, the value of SS increases less rapidly than the value of LL (i.e. the corresponding region of the curve for SS is less steep), and LL becomes the preferred option. Reversed-S discounting can also accommodate TI. In the lower panel of Figure 2, delay to SS is much longer, and delay between SS and LL is slightly longer compared to the top panel. At the outset, the individual prefers LL, but, over time SS becomes more attractive since the relevant range in the curve is steeper compared to LL.[11] In terms of functions that can accommodate such a shape, Mazur's (1987) exponentiated hyperbolic function resembles a reversed-S shaped form.

---- Insert Figure 2 about here ----

[10] The delay-titration procedure first determines the minimum delay *between* SS (which is immediate) and LL so that the subject always prefers SS, and then the delay *to* SS is increased until the preference is switched to LL. This procedure is not conducive for RTI because SS is always preferred when it is immediate (the first stage).

[11] If TI and RTI are considered as reversals when SS is immediate, they exclude each other. On the other hand, when the delay between SS and LL is small, it is possible that preference may switch from LL to SS and then to LL again as time progresses. If the curves in the upper panel of Figure 2 are extended to the left, they would re-intersect which means two reversals along the way. Percentages reported in Holcomb and Nelson (1992) are consistent with such a case, at least for a subset of participants. Future research may examine this issue.

In Study 4 we find evidence that many individuals exhibit lower discounting for closer intervals than for distant ones -- consistent with the concave region of the reversed-S discounting. A number of conclusions can be drawn from the experimental findings: First of all, a variety of discounting forms exists at the individual level, but this richness in behavior is disguised at the aggregate level. Secondly, the imminent future where the reversed-S shape is relatively flat spans a short interval. Such a pattern would be approximated as hyperbolic if only longer delays are taken into consideration (even at the individual level). To the best of our knowledge, individual level analysis using small delay levels has not been reported previously. Thirdly, some recent studies, in addition to Read (2001), challenge hyperbolic discounting.[12] Using time-tradeoff sequences as a new method to measure intertemporal preferences, Attema *et al*. (2006) observe increasing impatience for near future (implying a concave discount function) and constant impatience in the far future. In other words, individuals “did not mind a delay at first, but after a long wait they extra disliked further delays” (Attema *et al*. 2006, p. 27). In a recent study, Takeuchi (2007) finds that about two thirds of the subjects have an expanded notion of the present; their discount function takes an “inverse-S” shape and it is concave for about 3 weeks.

What process or psychology may account for a reversed-S shape discount function, particularly the relatively flat part over the immediate future or the “expanded present”? Takeuchi (2007) argues that future does not start immediately. This could be linked to Irving Fisher’s (1930) argument that discounting is about the ability to imagine future wants: It might be easy to imagine future up to a point, hence discounting would be low until then but higher beyond it. A second explanation could be based on the argument that discounting is a reflection of the (perceived) uncertainty of future (see e.g. Green and Myerson 1996, Stevenson 1986, Frederick *et al*. 2002, Gerber and Rohde 2007). In that case, it is feasible that immediate future is almost as certain as present, but uncertainty increases rapidly beyond a certain

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[12] Read (2001) uses larger delays than used in our Study 4 when measuring the *interval-discount* function and finds sub-additive discounting (or non-decreasing discount functions). Our measurement corresponds to the *delay-discount* function, and we observe reversed-S-like discounting for some individuals. It is possible that if we measured interval-discount functions, reversed-S-like discounting might have been more extensive.

point -- and hence, discounting becomes hyperbolic. A third account could be that perception of time may be non-linear (see Read 2001). This is similar to the subjective probability weighting function in the Prospect Theory (Kahneman and Tversky 1979, Tversky and Kahneman 1992) where the probability weighting function has an inverse-S shape. Even though the analogy between risk and time is a matter of dispute among researchers (see Green and Myerson 2004), a similar perception for time may apply. Future research could shed light into this issue.

Heterogeneity across individuals aside, reversed-S discount function and the notion of expanded present could certainly be situation-dependent. Time preferences may reflect multiple motives and behavior may change across different domains; a single discount function may not even exist (Frederick *et al*. 2002). For instance, in the generalized version of Harris and Laibson's (2004) model, "present" lasts for an arbitrary (random) length of time. We suggest that future research could examine how the inferred shape of the discount function (e.g. the length of the immediate interval where discounting is low) depends on the context, the nature of the outcomes, the salience of the outcomes, and the elicitation procedure.

5. Conclusion

Although a few previous studies report RTI, only Loewenstein (1987) brought up the issue in the context of consumption associated with utility from anticipation. By providing empirical evidence that RTI may apply also for temporal monetary outcomes, we suggest that RTI is indeed a robust phenomenon, rather than a one-off experimental artifact. We also propose that a discount function with lower discounting for temporally close intervals (such as a reversed-S shape) is consistent with RTI. We find evidence that some individuals may exhibit such discounting behavior as opposed to hyperbolic or exponential discounting.

Our findings have potential implications for decision makers. For instance, one relevant setting may be loyalty programs with multiple reward levels: Some members may forego the redemption of the smaller reward when qualified for it, and aim for the later reward, even though they prefer the smaller reward at the outset. Such preference reversals have implications for planning the reward redemption process or program profitability. In terms of reversed-S shape discounting, relevant parties may consider the fact that some individuals have a smaller discount rate for close / imminent outcomes (as also suggested by other recent studies) when making or receiving a payment. It would be worthwhile for future research to study time preferences for these specific contexts.

Table 1 Previous Findings on Time-Inconsistency

Study	Experimental Design	Delays	Outcomes	Findings
Ahlbrecht & Weber (1997)	Cross-sectional Within-subjects Hypothetical goods	D=0, 6 months [a] Δ=18 months [a]	DM 120 to DM 2500 lotteries	64% TC [b] 16% RTI 20% TI
Ainslie & Haendel (1983) [c] *Experiment 2*	Cross-sectional Within-subjects Hypothetical goods	D=0 to 4 years Δ=1 month to 4 years	\$50-\$100; \$10-\$20; \$250-\$500	% subjects switching from LL to SS: 55% and 57% (indicating TI)
Ainslie & Haendel (1983) [c] *Experiment 3*	Longitudinal Within-subjects Real goods	D=0, 1 week Δ=3 days	\$2 to \$10	62% TC 4% RTI 33% TI
Baron (2000)	Cross-sectional Within-subjects Hypothetical goods	D=0 to 50 years Δ=25 to 50 years	Saving lives/species	Two conditions: 1 TC 1 TI [d]
Coller and Williams (1999)	Cross-sectional Between-subjects Real goods	D=0, 1 month Δ=2 months	\$500 vs. \$500+\$*x* where *x* corresponds to indifference	Median response indicates TI
Green, *et al.* (1994)	Cross-sectional Within-subjects Hypothetical goods	D=0 to 20 years Δ=1 week to 20 years	\$20-\$50; \$100-\$250; \$500-\$1250	For Δ=1 week, TC; For Δ>1 week, most subjects exhibited TI
Holcomb & Nelson (1992)	Cross-sectional Within-subjects Real goods	D=0, 1 day, 1 week Δ=1 day, 1 week, 2 weeks	\$5 vs. \$5(1+*r*); \$17 vs. \$17(1+*r*) where *r*=1.5% or 3% per day	24 conditions: [e] 1 TC 14 RTI 9 TI
Keren & Roelofsma (1995)	Cross-sectional Between-subjects Hypothetical goods	D=0, 26 weeks Δ=4 weeks	Fl 100 vs. Fl 110	Difference between % preferring SS: 26.7% (indicating TI)
Kirby & Herrnstein (1995)	Cross-sectional Within-subjects Real goods	Median D=6-34.5 days Median Δ= 5.5-138 days	\$12-\$16; \$21-\$25; \$30-\$34; \$45-\$52; Non-monetary outcomes	6% TC 94% TI
Read, *et al*. (1999)	Longitudinal Between-subjects Real goods	D=0, >2 days Δ=0	Rental movies (highbrow vs. lowbrow)	Difference between % preferring SS: 16% and 27% (indicating TI)
Read & van Leeuwen (1998)	Longitudinal Within-subjects Real goods	D=0, 1 week Δ=0	Healthy vs. unhealthy snacks	58% TC 7.5% RTI 34.5% TI
Scholten & Read (2006)	Cross-sectional Within-subjects Hypothetical goods	D=1 to 3 weeks Δ=1 to 3 weeks	£500 to £575	81% TC 11% RTI 8% TI

[a] D: front-end delay to outcomes, Δ: delay between outcomes
[b] TC: time consistent
[c] Subject pool in Experiment 2: 28 substance abuse patients and 42 students; in Experiment 3: 18 substance abuse patients
[d] Results based on directional changes; no individual analysis is reported.
[e] We consider the comparisons that involve the "today" condition, i.e. 24 out 36 cases.

Table 2 Results from Study 1 (*n* = 38)

Choice Options SS		LL	% subjects choosing LL	Test for difference	Number of subjects RTI	TI
€7 in 1 day	vs.	€10 in 3 days	29%	$\chi^2 = 10.23$; $p = 0.00$	19	3
€7 today	vs.	€10 in 2 days	71%			
€7 in 3 days	vs.	€10 in 1 week	29%	$\chi^2 = 5.26$; $p = 0.02$	15	4
€7 today	vs.	€10 in 4 days	58%			
€7 in 1 week	vs.	€10 in 2 weeks	29%	$\chi^2 = 0.31$; $p = 0.58$	8	5
€7 today	vs.	€10 in 1 week	37%			
€20 in 1 day	vs.	€25 in 3 days	34%	$\chi^2 = 3.05$; $p = 0.08$	15	6
€20 today	vs.	€25 in 2 days	58%			
€20 in 3 days	vs.	€25 in 1 week	32%	$\chi^2 = 0.08$; $p = 0.77$	6	6
€20 today	vs.	€25 in 4 days	32%			
€20 in 1 week	vs.	€25 in 2 weeks	29%	$\chi^2 = 0.13$; $p = 0.72$	3	5
€20 today	vs.	€25 in 1 week	24%			

NOTE: χ^2 statistics are corrected for continuity (being conservative).

Table 3 Results from Study 2a (*n* = 72)

Choice Options SS		LL	% subjects choosing LL	Test for difference	Number of subjects RTI	TI
$7 in 1 day	vs.	$10 in 3 days	65%	$\chi^2 = 8.47$; $p = 0.03$	15	2
$7 today	vs.	$10 in 2 days	83%			
$7 in 3 days	vs.	$10 in 1 week	46%	$\chi^2 = 0.00$; $p = 1.00$	11	12
$7 today	vs.	$10 in 4 days	44%			
$7 in 1 week	vs.	$10 in 2 weeks	13%	$\chi^2 = 3.50$; $p = 0.06$	11	3
$7 today	vs.	$10 in 1 week	24%			
$7 in 2 weeks	vs.	$10 in 4 weeks	10%	$\chi^2 = 0.00$; $p = 1.00$	2	2
$7 today	vs.	$10 in 2 weeks	10%			
$20 in 1 day	vs.	$25 in 3 days	76%	$\chi^2 = 3.50$; $p = 0.06$	11	3
$20 today	vs.	$25 in 2 days	88%			
$20 in 3 days	vs.	$25 in 1 week	49%	$\chi^2 = 5.06$; $p = 0.02$	13	3
$20 today	vs.	$25 in 4 days	63%			
$20 in 1 week	vs.	$25 in 2 weeks	28%	$\chi^2 = 0.06$; $p = 0.80$	9	7
$20 today	vs.	$25 in 1 week	31%			
$20 in 2 weeks	vs.	$25 in 4 weeks	10%	$\chi^2 = 0.00$; $p = 1.00$	3	2
$20 today	vs.	$25 in 2 weeks	11%			

NOTE: χ^2 statistics are corrected for continuity.

Table 4 Results from Study 2b

Choice Options SS		LL	% subjects choosing LL	Test for difference
\$7 in 1 day	vs.	\$10 in 3 days	64%	$\chi^2 = 5.72$; $p = 0.02$
\$7 today	vs.	\$10 in 2 days	84%	
\$7 in 3 days	vs.	\$10 in 1 week	54%	$\chi^2 = 0.00$; $p = 0.96$
\$7 today	vs.	\$10 in 4 days	54%	
\$7 in 1 week	vs.	\$10 in 2 weeks	38%	$\chi^2 = 0.12$; $p = 0.73$
\$7 today	vs.	\$10 in 1 week	34%	
\$7 in 2 weeks	vs.	\$10 in 4 weeks	20%	$\chi^2 = 0.00$; $p = 0.99$
\$7 today	vs.	\$10 in 2 weeks	20%	
\$20 in 1 day	vs.	\$25 in 3 days	71%	$\chi^2 = 3.32$; $p = 0.07$
\$20 today	vs.	\$25 in 2 days	85%	
\$20 in 3 days	vs.	\$25 in 1 week	48%	$\chi^2 = 6.03$; $p = 0.01$
\$20 today	vs.	\$25 in 4 days	70%	
\$20 in 1 week	vs.	\$25 in 2 weeks	43%	$\chi^2 = 0.00$; $p = 0.99$
\$20 today	vs.	\$25 in 1 week	43%	
\$20 in 2 weeks	vs.	\$25 in 4 weeks	27%	$\chi^2 = 2.59$; $p = 0.11$
\$20 today	vs.	\$25 in 2 weeks	15%	

NOTE: $n = 56$ in the distant condition (first scenario in each delay level), and $n = 61$ in the immediate case.

Table 5 Delay Levels and Time Inconsistency

	Delay *between* SS and LL							
Delay *to* SS	1 day	2 days	3 days	4 days	1 week	2 weeks	4 weeks	8 weeks
1 day	▲▲ ▲▲	▲▲▲ ▲▲▲			▲▲ ▲▽	▲▲ ▽○		
3 days				▲▲▲ ▽○○				
1 week	▲▽ ▽▽		▽		▲▲▲▽▽ ○▽▽▽▽	▲▲ ▲▲		
2 weeks						▲▽ ○○		
8 weeks								▽
26 weeks							▽▽▽▽	

NOTES:

1. Each symbol represents one outcome pair (one data point) used for the corresponding delay levels. Symbols indicate the direction of time inconsistency (significances are not considered):
   ▽: TI
   ▲: RTI
   ○: Neither TI / RTI
2. Papers included: Current paper (Studies 1 & 2); Ainslie and Haendel (1983); Holcomb and Nelson (1992); Keren and Roelofsma (1995); Coller and Williams (1999).
3. Shaded cells refer to the delays used in Study 3 of the current paper.

Table 6 Results from Study 3

Choice Options SS		LL	% subjects choosing LL	Test for difference
$7 in 8 weeks	vs.	$10 in 8 weeks + 2 days	97%	$\chi^2 = 4.51$; $p = 0.03$
$7 in 2 weeks	vs.	$10 in 2 weeks + 2 days	92%	$\chi^2 = 0.54$; $p = 0.46$
$7 today	vs.	$10 in 2 days	88%	
$7 in 8 weeks	vs.	$10 in 8 weeks + 4 days	90%	$\chi^2 = 9.94$; $p = 0.00$
$7 in 2 weeks	vs.	$10 in 2 weeks + 4 days	80%	$\chi^2 = 2.46$; $p = 0.12$
$7 today	vs.	$10 in 4 days	69%	
$7 in 8 weeks	vs.	$10 in 9 weeks	80%	$\chi^2 = 22.38$; $p = 0.00$
$7 in 2 weeks	vs.	$10 in 3 weeks	41%	$\chi^2 = 0.02$; $p = 0.90$
$7 today	vs.	$10 in 1 week	42%	
$7 in 8 weeks	vs.	$10 in 10 weeks	47%	$\chi^2 = 9.27$; $p = 0.00$
$7 in 2 weeks	vs.	$10 in 4 weeks	32%	$\chi^2 = 1.61$; $p = 0.20$
$7 today	vs.	$10 in 2 weeks	23%	
$7 in 8 weeks	vs.	$10 in 12 weeks	17%	$\chi^2 = 6.45$; $p = 0.01$
$7 in 2 weeks	vs.	$10 in 6 weeks	7%	$\chi^2 = 0.62$; $p = 0.43$
$7 today	vs.	$10 in 4 weeks	4%	
$7 in 8 weeks	vs.	$10 in 16 weeks	7%	$\chi^2 = 1.53$; $p = 0.22$
$7 in 2 weeks	vs.	$10 in 10 weeks	6%	$\chi^2 = 0.82$; $p = 0.37$
$7 today	vs.	$10 in 8 weeks	5%	

NOTES:

1. $n = 71$ in the distant conditions (first two scenarios in each delay level), and $n = 74$ in the immediate case.
2. χ^2 and p values relate to the comparison with the immediate case. i.e., $\chi^2 = 4.51$ in the first row corresponds to 97% versus 88%.

Table 7 Individual Discount Factors from Study 4

Present $	Delay Interval Close (1)		Distant (2)	Number of cases $\delta_1 > \delta_2$ (RTI)	$\delta_1 < \delta_2$ (TI)	$\delta_1 = \delta_2$ (TC)	not classified
$6	0-1 day	vs.	2-3 days	14	11	13	15
	0-3 days	vs.	4-7 days	6	24	7	16
	0-7 days	vs.	7-14 days	10	25	12	6
	0-14 days	vs.	14-28 days	8	34	3	8
$21	0-1 day	vs.	2-3 days	10	10	23	8
	0-3 days	vs.	4-7 days	7	12	13	19
	0-7 days	vs.	7-14 days	7	18	15	11
	0-14 days	vs.	14-28 days	12	15	11	13

NOTE: For $6, data from 60 − 7 = 53 subjects are used; for $21, data from 60 − 9 = 51 subjects are used.

Figure 1 Devaluation Patterns in Loewenstein (1987) and Reversed-S Discounting

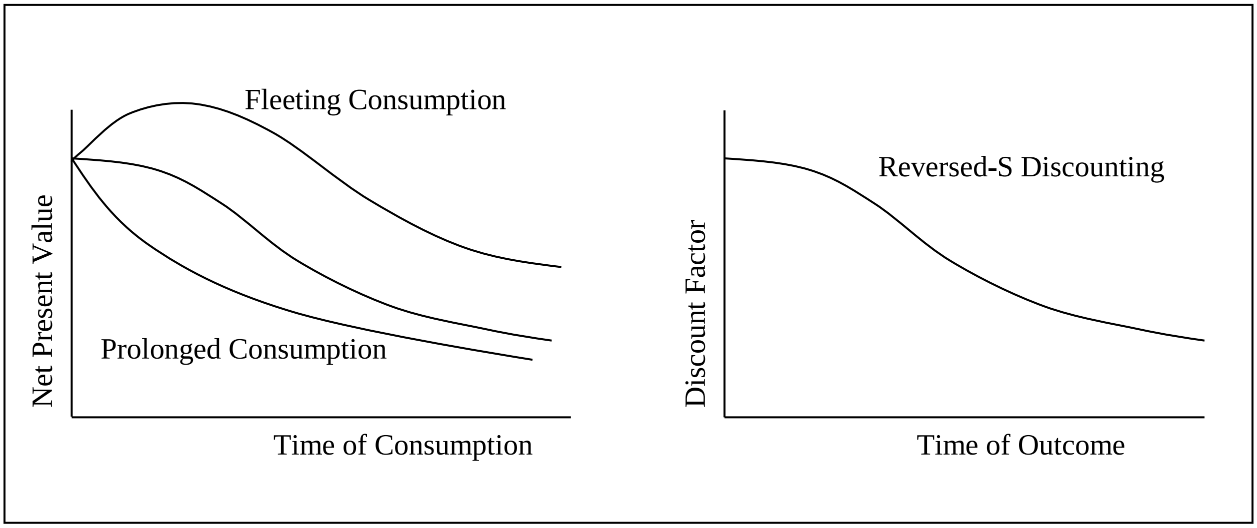
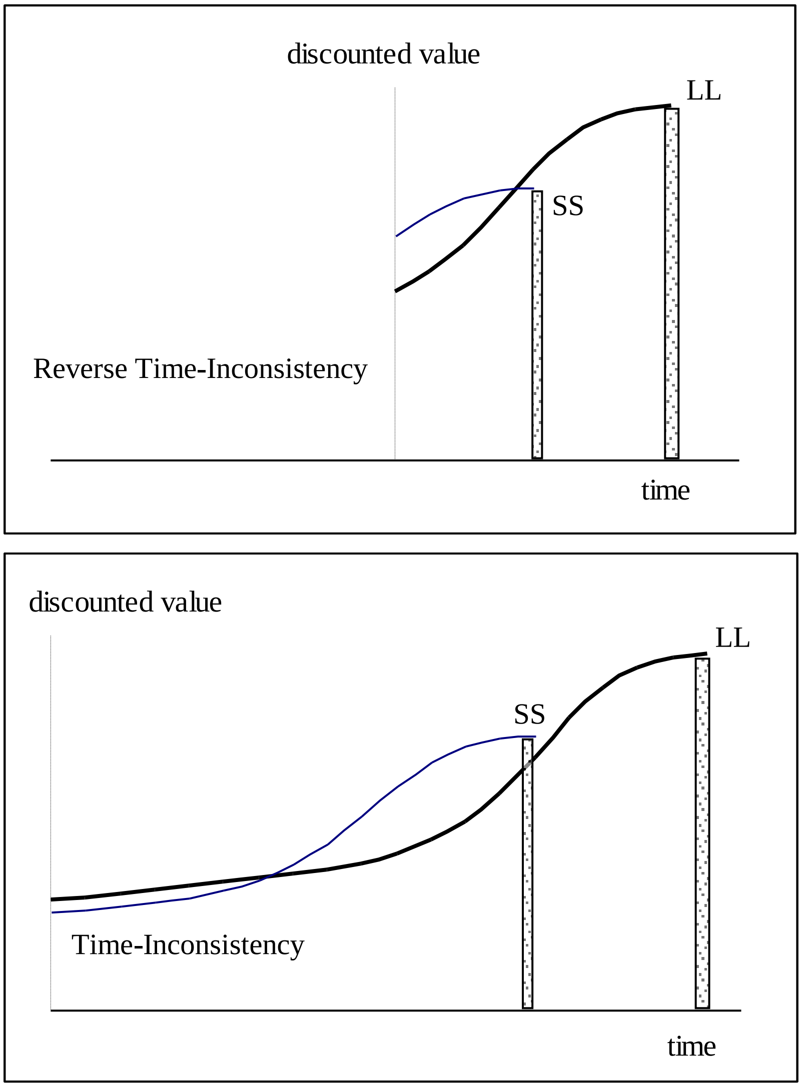


Figure 2 Reversed-S Discounting and Inconsistency



NOTE: Horizontal axis indicates the progress of time.

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