Discounting over Subjective Time:
Subjective Time Perception Helps Explain Multiple Discounted Utility Anomalies

Yitong Wang
yitong.wang@uts.edu.au
University of Technology Sydney
Sydney NSW Australia

Liangyan Wang
wly@sjtu.edu.cn
Antai College of Economics & Management
Shanghai Jiaotong University, Shanghai, China

L. Robin Keller
LRKeller@uci.edu
The Paul Merage School of Business
University of California, Irvine, CA 92697-3125

Correspondence concerning this article should be addressed to L. Robin Keller (LRKeller@uci.edu), The Paul Merage School of Business, University of California, Irvine, CA 92697-3125; Tel: +1 949 824 6348.

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Abstract

Consumers often face choices involving intertemporal tradeoffs. Existing research suggests that, in general, decision makers do not obey discounted utility theory because their discount rates are context dependent. Recent literature incorporates decision makers' subjective perception of time into the classic discounted utility model and finds relatively constant discount rates over subjective time. In the current study, we investigated the magnitude effect with subjective time, provided a holistic view via a more comprehensive experiment including multiple anomalies, and found that subjective time perception was able to explain most of the anomalies simultaneously in a single scenario.

Keywords: subjective time perception, intertemporal choice, discount rate, discounted utility anomalies

1. Introduction

Discounted utility theory is widely accepted in marketing and many other fields (Samuelson, 1937). It employs a single discount rate to model a consumer's preferences over time. However, researchers have found that consumers' behaviors often are inconsistent with this theory (Frederick et al., 2002; LeBoeuf, 2006; Read et al., 2005; Thaler, 1981). Important anomalies include the magnitude effect, long term/short term asymmetry (or hyperbolic discounting), gain/loss asymmetry, and delay/date asymmetry.

Earlier literature has proposed several mechanisms to understand the observed anomalies (Loewenstein & Prelec, 1992), most of which attributed the anomalies to changes of discount rates caused by variations of contextual factors, but left time objectively defined. More recently, subjective time perception has been investigated and used to explain intertemporal preferences (Zauberman et al., 2009). For example, researchers have found that consumers are not sufficiently sensitive to changes in objective time, which could help in explaining hyperbolic discounting (Zauberman et al., 2009); time intervals described by dates seem shorter than those described by the delay in time units, which could help in explaining delay/date asymmetry (LeBoeuf, 2006; Read et al., 2005); and consumers perceived temporal durations before losses as shorter than those before gains (Bilgin & LeBoeuf, 2010), which potentially could help explain gain/loss asymmetry, although in the original paper the authors didn't test the asymmetry explicitly using standard discounting scenarios with monetary outcomes. However, to the best of our knowledge, there is little research on perceived temporal distance on the magnitude effect, nor on bringing multiple anomalies together in a single monetary discounting scenario and testing them simultaneously (see table 1 for a brief summary of existing research on this topic). In this paper, we fill these gaps in the literature. Testing multiple anomalies in one study with a single discounting scenario will provide a

comprehensive test of the ability to explain anomalies using the perceived time length, and potentially will provide empirical support for the discounting over subjective time model for future theoretical developments.

 Insert Table 1 here

2. Experiment 1: Outcome Sizes and Perceived Temporal Distance

2.1. Procedure

Seventy four undergraduate students (mean age = 20.2; 73% female) at a university in the U.S. completed the study online for course credit. We employed a between-subjects design with two randomly assigned groups. Participants were first asked to imagine that they had just won \$4,000 (vs. \$20) in a lottery, and the winnings would be paid to them in 3 months. They were then asked, “How long does this time period until you get the winnings seem to you?” Participants indicated their responses on a seven-point scale from 1 to 7, ranging from “seems very short” to “seems very long” (LeBoeuf, 2006).

2.2. Results

An independent samples t-test revealed that the mean subjective time perception in the \$4,000 condition ($M_{\$4,000} = 4.41$, $SD_{\$4,000} = 1.79$) was significantly shorter than in the \$20 condition ($M_{\$20} = 5.78$, $SD_{\$20} = 1.40$, $t(72) = 3.70$, $p < .001$, $\eta^2 = .16$). The results show that the participants’ perception of temporal durations is not independent of the magnitudes of the outcomes, with larger monetary outcomes leading to shorter subjective time perceptions.

Prior literature suggests perception is a constructive process that can be influenced by attention (Brown, 1985). Larger outcomes may attract higher attention from consumers and thus lead to shorter subjective

time perception of the same objective temporal distance. Furthermore, the contrast between the monetary outcome and the objective temporal distance may also lead people to perceive the larger outcomes as less distant (Hsee, 1998).

3. Experiment 2: Magnitude Effect and Perceived Temporal Distance

3.1. Procedure

Forty four undergraduate students (mean age = 20.8; 58% female) at a university in the U.S. completed the study as a section of a series of unrelated tasks for course credit. This experiment employed a between-subjects design with two randomly assigned groups. Participants were told that they had just won \$20,000 (vs. \$20) in a lottery, and told they could take the money now or wait until 3 months from now. They were then asked to state the minimum amount they would need to be paid to wait before receiving their winnings. Finally, participants were then given a 140-millimeter line with endpoints labeled “very short” on the left end and “very long” on the right end (similar to Zauberman et al., 2009), and were asked to place a mark on the line indicating their response to the following question: “If you wait, how long does this time period until you get the money seem to you?” The length from the left end to the participant’s mark was measured as an indicator of subjective time perception.

3.2. Results

Subjective time perception. An independent sample t-test revealed that the mean marked length in the \$20,000 payment condition was significantly shorter than the marked length in the \$20 payment condition ($M_{\$20,000} = 68.74$ mm, $SD_{\$20,000} = 38.05$ mm, $M_{\$20} = 87.90$ mm, $SD_{\$20} = 24.99$ mm, $t(42) = 1.95$, $p = .03$, $\eta^2 = .083$). This confirmed our findings in experiment 1.

The magnitude effect. An independent samples t-test of the mean implicit annual discount rate over the *objective* time horizon showed results corresponding with the magnitude effect ($M_{\$20,000} = 134.07\%$, $SD_{\$20,000} = 100.92\%$, $M_{\$20} = 227.99\%$, $SD_{\$20} = 193.67\%$; $t(42) = 2.04$, $p = .02$, $\eta^2 = .09$).¹

Discount over subjective time. An independent samples t-test on the discount rate over the *subjective* time revealed no reliable differences between conditions ($M_{\$20,000} = 381.17\%$, $SD_{\$20,000} = 877.67\%$, $M_{\$20} = 210.87\%$, $SD_{\$20} = 162.59\%$, $t(42) = 0.88$, $p = 0.19$).² In other words, when subjective time was used to compute the discount rate, the magnitude effect disappeared.

In this experiment, we replicated the magnitude effect when calculating the discount rate according to objective time. However, the data showed no statistically reliable difference and thus did not provide evidence of the magnitude effect when we adjusted the discount rate according to the subjective time.

4. Experiment 3: Multiple Anomalies and Perceived Temporal Distance

4.1. Procedure

One hundred and forty four students recruited in a library from a university in China (mean age = 22.8; 42.2% female) completed the study with a small gift as an incentive. As we wanted to manipulate the magnitudes of the monetary outcomes, lengths of the time horizons, signs of the monetary outcomes, and presentation formats of the time delay, we employed a between-subjects design with 5 conditions, shown in Table 2. We do not intend to examine interactions among anomalies, so pair-wise comparisons are enough to test the effects we are examining. The translated scenarios are given below:

Scenarios with gains: Imagine that you just won 20 RMB/2,000 RMB in a lottery. You can take the money now or wait for (3 months/2 years/to August 26th, 2013) to get it with some additional

premium. 1) If you choose to wait, what is the lowest amount of a premium that you would need to be paid? 2) If you choose to wait, how long does this time period until you get the money seem to you?

Scenarios with losses: Imagine that you just lost 2,000 RMB in a game of chance. You can pay the money now or wait for 3 months to pay it with some additional penalty. 1) If you choose to wait, how much additional penalty at most would you want to pay? 2) If you choose to wait, how long does this time period until you pay the money seem to you?

Note that we used 20 RMB as the “small” payment, which was roughly equal to the daily on-campus dining costs for a student, and we used 2,000 RMB as the “large” payment, which was roughly equal to the monthly on-campus living costs for a student. In the second question participants were asked to place an “x” mark on a 120-millimeter line indicating their perceived temporal distance.

4.2. Results

The results are summarized in Table 2.

 Insert Table 2 here

In this study, we tested if the subjective perception of time was able to explain the magnitude effect, long term/short term asymmetry, delay/date asymmetry, and gain/loss asymmetry simultaneously in a single intertemporal choice scenario. We found that incorporating subjective time perception was able to mitigate most of the anomalies except gain/loss asymmetry. The magnitude effect, long term/short term asymmetry, and delay/date asymmetry were observed when calculated using objective time, but disappeared when calculated using the subjective time measure. Interestingly, subjective time perception was not able to fully explain gain/loss asymmetry. We suspect that gain/loss asymmetry is mostly caused by

loss aversion (as proposed and tested in experiment 3 of Bilgin & LeBoeuf (2010)) rather than differences in subjective time perception as proposed in the current paper. Just as experiments on preferences for non-temporal gambles show opposite choice patterns for gains and losses, the persistence of gain/loss asymmetry after correcting for subjective time preference suggests that participants were facing gains with a quite different thinking process than they used with losses.

5. Discussion

When explaining the discounted utility anomalies, more recent literature proposed that a behaviorally descriptive model of discounted utility should involve the perception of time rather than a varying discount rate. In addition to replicating previous work, we investigated the missing component of the magnitude effect with subjective time, provided a holistic view via a more comprehensive experiment including multiple anomalies, and found that subjective time perception was able to explain most of the anomalies simultaneously in a single scenario, except gain/loss asymmetry. Taken together, our perspective provides a unified alternative explanation of multiple discounted utility anomalies and contributes to theory on subjective time perception and consumer choices over time.

Footnotes

¹The familiar time value of money formula with annual compounding with annual discount rate δ and the change in objective time Δt uses the discount function $D(\Delta t, \delta) = 1/(1 + \delta)^{\Delta t}$. Then for continuous compounding the corresponding discount function is $D(\Delta t, \delta) = e^{-\delta \Delta t}$. Assuming utility is linear in the monetary amount, we get $x_{t_0} = e^{-\delta \Delta t} x_{t_0 + \Delta t}$. Rearranging the formula, we get $x_{t_0} / x_{t_0 + \Delta t} = e^{-\delta \Delta t}$. Taking the natural logarithm of both sides of the equation and rearranging it yields the annual discount rates for each response $\delta = \ln(x_{t_0 + \Delta t} / x_{t_0}) / \Delta t$, where x_{t_0} is the given amount at the initial period and Δt is the given length of time delay expressed in terms of years (Thaler, 1981; Zauberman et al., 2009). The magnitudes of discount rates in our results are similar to Thaler (1981) and Zauberman et al. (2009).

²Consistent with the calculation method in Zauberman et al. (2009), the discount rate over subjective time for each response is calculated by using the formula: $\delta' = \ln(x_{t_0 + \Delta t} / x_{t_0}) / \Delta t'$, where $\Delta t'$ represents the subjective time length of the time delay. We set the overall mean marked length L across the two conditions equivalent to the objective temporal distance, then the subjective time perception for a specific participant should be $\Delta t' = (l / L) \Delta t$, where l is the length marked by the participant and Δt is the objective time.

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Table 1. Summary of current and existing studies

Paper	Focus	Time perception measured?	Discounting over monetary values	Discount rates calculated?	Multiple anomalies in a single framework?
Thaler, 1981	Time discounting anomalies	No	Yes	Yes	Yes
Read et al., 2005	Date/delay asymmetry	No	Yes	Yes	No
LeBoeuf, 2006	Date/delay asymmetry	Yes	Yes	No	No
Zauberman et al., 2009	Long term/short term asymmetry	Yes	Yes	Yes	No
Bilgin & LeBoeuf, 2010	Gain/loss asymmetry	Yes	No	No	No
Current research	Date/delay asymmetry, Long term/short term asymmetry, Gain/loss asymmetry, Magnitude effect	Yes	Yes	Yes	Yes

Table 2. Study design and results of experiment 3

Comparison Presented				Objective Time		Subjective Time		
Base Condition	Compared Condition	Time Delay in months (Short or LONG)	Outcome in RMB (Large or SMALL; Positive or NEGATIVE)	Mean Discount Rates in % Calculated Over Objective Time	Result Using Discount Rates Over Objective Time	Mean Subjective Time in mm	Mean Adjusted Discount Rates in % Calculated Over Subjective Time	Result Using Adjusted Discount Rates Over Subjective Time
Short-large-positive-delay (n = 29)	LONG-large-positive-delay (n = 28)	3 vs. 24	2,000 vs. 2,000	127.04 vs. 27.83***	Long term/short term asymmetry	59.79 vs. 76.11**	224.51 vs. 355.81 ^{ns}	Long term/short term asymmetry disappears
	Short-SMALL-positive-delay (n = 29)	3 vs. 3	2,000 vs. 20	127.04 vs. 382.56***	Magnitude effect	59.79 vs. 73.62*	224.51 vs. 310.31 ^{ns}	Magnitude effect disappears
	Short-large-NEGATIVE-delay (n = 28)	3 vs. 3	2,000 vs. -2,000	127.04 vs. 17.87***	Gain/loss asymmetry	59.79 vs. 48.29*	224.51 vs. 23.76**	Gain/loss asymmetry remains
	Short-large-positive-DATE (n = 30)	3 vs. 3 [#]	2,000 vs. 2,000	127.04 vs. 81.60**	Date/delay asymmetry	59.79 vs. 44.83**	224.51 vs. 204.37 ^{ns}	Date/delay asymmetry disappears

Notes:

In one-sided t-tests: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.001$, and ^{ns} indicates not significant.[#]Experiment 3 was conducted on May 26th, 2013, and the Short-large-positive-DATE condition used “on August 26th, 2013” to represent the 3-month delay.