Journal of Marketing Research
Article Postprint
Volume XLV

Discounting Time and Time Discounting:

Subjective Time Perception and Intertemporal Preferences

GAL ZAUBERMAN

B. KYU KIM

SELIN A. MALKOC

JAMES R. BETTMAN *

March 2008

* Gal Zauberman (zauberman@wharton.upenn.edu) is Associate Professor of Marketing at the Wharton School, University of Pennsylvania, Philadelphia, PA 19104. B. Kyu Kim (bkyu@wharton.upenn.edu) is a doctoral student at the Wharton School, University of Pennsylvania, Philadelphia, PA 19104. Selin A. Malkoc (MALKOC@olin.wustl.edu) is an Assistant Professor of Marketing at the Olin Business School, Washington University in St. Louis, MO 63130. James R. Bettman (jrb12@duke.edu) is Burlington Industries Professor of Business Administration at the Fuqua School of Business, Duke University, Durham, NC 27708.
The authors thank Kristin Diehl, Jonathan Levav, John Lynch, Drazen Prelec, and Daniel Read for helpful comments. We also thank Raghu Iyengar and Christophe Van den Bulte for valuable help with the analysis of Experiment 2.

Discounting Time and Time Discounting:

Subjective Time Perception and Intertemporal Preferences

Consumers often make decisions about outcomes and events that occur over time. Our research examines consumers' sensitivity to the prospective duration relevant to their decisions and the implications of such sensitivity for intertemporal tradeoffs, especially the degree of present-bias (i.e., hyperbolic discounting). We show that participants' subjective perceptions of prospective duration are not sufficiently sensitive to changes in objective duration and are nonlinear and concave in objective time, consistent with psychophysical principles. More importantly, we show that this lack of sensitivity can explain hyperbolic discounting. Our results replicate standard hyperbolic discounting effects with respect to objective time but show a relatively constant rate of discounting with respect to subjective time perceptions. Our results replicate between (Experiment 1) and within subjects (Experiments 2), with multiple time horizons and multiple descriptors, and with different measurement orders. Furthermore, we show that when duration is primed, subjective time perception is altered (Experiment 4) and hyperbolic discounting is reduced (Experiment 3).

Keywords: hyperbolic discounting, present bias, time perception, Weber-Fechner law

Many consumer decisions involve trading off costs and benefits over time. For instance, during an online purchase, consumers frequently trade off delivery time and the costs of expedited delivery. Consumers also may decide between a smaller instant refund versus a larger one that requires some wait. Both instances require consideration of prospective duration (e.g., the length of delivery time and refund wait period). Examining consumers' sensitivity to prospective duration and its implication for their decisions is thus critical.

Research on intertemporal decisions has shown that people are heavily biased towards the present (e.g., O'Donoghue and Rabin 1999; Thaler 1981; Zauberman 2003). One of the most important and robust findings, hyperbolic discounting (present bias), is that the rate at which an outcome is discounted over time (delay discounting) decreases as the time horizon gets longer. For example, in evaluating a lottery, people required $30 instead of $15 in order to wait for 3 months (a discount rate of 277%); however, the same people only required $60 to wait for 1 year (a discount rate of 139%) and $100 to wait for 3 years (a discount rate of 63%; Thaler 1981).

Such intertemporal preferences have been attributed to impulsivity (Ainslie 1975; Loewenstein 1996), to differences in cognitive representations between near and future events (Malkoc and Zauberman 2006; Trope and Liberman 2003; Zauberman and Lynch 2005) or to individual differences in time orientation (Carstensen, Isaacowitz, and Charles 1999; Zimbardo and Boyd 1999). However, all of these research streams attribute hyperbolic discounting to changes in the perception or valuation of *outcomes* at different points in time. In this paper, we offer an alternative perspective, focusing on the effect of people's perceptions of *duration* itself (i.e., the time horizon over which a decision takes place) on intertemporal preferences.

We propose that how consumers map objective future time onto subjective perceptions of time is an important driver of intertemporal preferences, and in particular, hyperbolic discounting. We argue that when forming intertemporal preferences, consumers' subjective estimates of duration do not accurately map onto objective time. In particular, we show that consumers' mapping of objective duration onto subjective time is non-linear and characterized by insufficient sensitivity to changes in duration and that such discrepancy between objective duration and subjective time estimates can help explain preferences consistent with hyperbolic discounting. We support our theory in several studies that directly map changes in subjective time estimates onto the extent of hyperbolic discounting.

THEORETICAL DEVELOPMENT

Hyperbolic Discounting and Present-Biased Preferences

Much research on intertemporal choice has modeled present-biased preferences using hyperbolic discounting models (e.g., Ainslie 1975; Ainslie and Haslam 1992; Kirby 1997),[1] which state (e.g., Mazur 1984) that:

$$U(c_0,...,c_T) = \sum_{t=0}^{T} D(t)u(c_t),\ where\ D(t) = \frac{1}{1+\alpha t}$$

In this model, utility from a stream of outcomes is the sum of all consumption periods ($c_0, \ldots\ c_T$), weighted by the discount function *D(t)*. t is the delay and α is a constant determining the degree of discounting. The functional form of $D(t)$ imposes declining discount rates with delay (k). Although there are some important differences across models, generally they show that individuals' discount rates of future outcomes decrease with time. As noted above, different psychological mechanisms for hyperbolic discounting have been proposed, including visceral factors and impulsivity (e.g., Ainslie 1975; Loewenstein 1996) and differences in cognitive representations between near and future events (e.g., Malkoc and Zauberman 2006; Zauberman and Lynch 2005). These different explanations share the notion that the reason for the observed patterns of declining discount rates with time horizon is differential valuation of the *outcome* at different points in time. Instead, we argue that subjective perception of the time horizon *per se* also plays an important role.

Recent research on subadditive discounting (Read 2001; Scholten and Read 2006) has argued that the degree of delay discounting is related to how that time interval is divided. Read (2001) argued that declining impatience could arise due to total discounting being greater when the overall time horizon is partitioned into sub-intervals and suggested two possible explanations. One is that the result is a statistical artifact, similar to a regression-to-the-mean effect. The second posits that one reason people show subadditivity is that partitioned components draw more attention, increasing their salience (see Tversky and Koehler 1994 for subadditivity in probability judgment). Ebert and Prelec (2007) manipulated participants' attention to time and found that increased attention decreases discounting for near future outcomes and increases discounting for far future outcomes (see also Wittmann and Paulus 2007). Such an attention-based approach suggests that one reason for hyperbolic discounting is that people do not pay enough attention to time horizon, which relates to the time perception explanation in this paper.

However, no empirical research to date has directly examined consumers' perception of time independent of the valuation of outcomes and shown the impact of such subjective time perceptions on present biased preferences. We explicitly examine this relationship, providing a theoretical framework and empirical evidence demonstrating (1) the contracted nature of subjective time perception, (2) the causal link from contracted time perception to hyperbolic patterns of discounting, and (3) possible mechanisms that would moderate such biased subjective perceptions.

The Psychology of Time

The notion that subjective perception of time is more contracted than objective time has deep roots in western philosophy and the psychology of time (Sherover 1975; Fraisse 1984; Fredrickson and Kahneman 1993; Read and Loewenstein 1995; Turetzky 1998). People have difficulty thinking about time as an independent dimension and often misjudge the duration of events, although much of the evidence concerns retrospective evaluations of duration rather than prospective evaluation of time. Decision researchers have found that people generally are not sensitive to the duration over which events take place (e.g., Fredrickson and Kahneman 1993), and duration is difficult to evaluate in isolation in retrospective evaluation (e.g., Ariely and Loewenstein 2000; Hsee 2000). However, whether estimation of prospective duration is similarly biased and the implications of such subjective judgments for intertemporal preferences are unresolved issues.

Sensitivity to Time Horizon and Present-Biased Preferences

As discussed above, most research has used hyperbolic or quasi-hyperbolic models to describe declining discount rates over time. These models assume, at least implicitly, that people evaluate and incorporate the objective time interval t into their decisions and that the valuation of outcomes (c_t) or their assigned weights ($D(t)$ or β) are biased. To illustrate, suppose an individual is indifferent among \$100 today, \$1000 in 1 year, and \$2000 in 3 years. If her perception of time is unbiased (i.e., she perceives a 3 year time horizon as three times longer than a 1 year time horizon), the implied compound annual discount rate for this person is 230% for one year and 100% for 3 years, indicating present biased preferences. This is the type of evidence most commonly reported for hyperbolic discounting (e.g., Thaler 1981).

We suggest an alternative account, namely that consumers are systematically biased in their mapping of objective time (*t*) to subjective time, which can influence preference and choice independent of any effects due to individuals' discount rates. Specifically, suppose that the above consumer has biased subjective time perceptions such that she perceives 3 years to be only 1.3 times longer than 1 year (as opposed to 3 times longer). Keeping the discount factor constant and adjusting the time coefficient, *t*, from 3 to 1.3, we would obtain an implied discount rate of 230% for both the 1 year and 3 year time horizons. In other words, the same set of preferences (100 today = 1000 in one year = 2000 in three years) can be modeled as accurately by using a constant discount rate with respect to *subjective* time as by using declining discount rates with respect to *objective* time.

The notion that time perception is biased and condensed goes back to the early 20th century. For example, among the early economists, Pigou (1920) stated "*this preference for present pleasure does not imply that a present pleasure of given magnitude is any greater than a future pleasure of the same magnitude. It implies only that our telescopic faculty is defective* (re-cited from Ainslie and Haslam, 1992)." Later, when introducing Herrnstein's matching law, Gibbon (1977) suggested "*this law simply represents the Weber-Fechner law* (Ainslie and Haslam, 1992)." That is, psychophysics has shown that sensation and perception are subject to contraction. Weber's Law states that the threshold of discriminating two stimuli, such as brightness, loudness, or duration, increases monotonically as the intensity of stimuli increases, and the Weber-Fechner law depicts the relationship between physical stimulus and the corresponding human sensation as a logarithmic function (Grodin 2001; Dehanene 2003).[2]

Our perspective builds on these ideas and is psychologically distinct from previous explanations, since it separates discounting the outcome itself from the perception of the time interval relevant to that decision. An individual can show decreasing impatience either due to decreasing discount rates for longer time intervals (as implied by current explanations of hyperbolic discounting) or by having a contracted perception of time with non-decreasing discount rates. Our view, although developed independently, is consistent with recent theoretical notes published in *Medical Hypotheses* that argue that error in time estimation following the Weber-Fechner law can explain both sub-additive discounting (Takahashi 2006) and hyperbolic discounting (Takahashi 2005). Thaler (1981) and Loewenstein and Prelec (1992) also speculated that different perceptions of time intervals or clocks running at different speeds for outcomes could be the cause of non-exponential discounting. These notes and explanations, however, provide no empirical tests. The goal of the current paper is to examine our proposed time perception mechanism by providing empirical evidence that consumers' subjective time perceptions are more contracted than differences in objective time, which in turn can explain present-biased preferences.

In sum, we hypothesize that if consumers' subjective estimates of duration are not adequately responsive to changes in objective duration and if present-biased preferences are caused partly by this bias in time perception, then hyperbolic discounting will be significantly reduced when subjective time horizon estimates are measured and used as the time variable (t) in calculating an implicit discount rate. We further propose that if the lack of sensitivity to duration is, in part, due to attention, then making duration more salient to consumers can trigger a more consistent mapping from objective to subjective time and more consistent discount rates over time horizons, resulting in a diminished level of hyperbolic discounting (see Ebert and Prelec

(2007), Block and Zakay (1997, 2001), and Wittmann and Paulus (2007) for related attentional arguments). We test our ideas in four experiments as well as several follow-up studies. Experiments 1 and 2 test the sensitivity of subjective time estimates to changes in objective time horizon and examine the effect of these subjective time estimates on hyperbolic discounting. Experiments 3 and 4 use a priming paradigm to test the implications of making duration more accessible: when duration is primed, hyperbolic discounting was reduced (Experiment 3) which is then also reflected in changes in subjective time perception (Experiment 4). We will discuss the implications of our work for intertemporal preferences in the General Discussion section.

EXPERIMENT 1

Experiment 1 examined the sensitivity of consumers' subjective time perceptions to changes in the objective time horizon and the role of such time perceptions in present-biased preferences. We directly measured how subjective assessments of differing prospective time horizons correspond to the changes in objective time horizons. To measure consumers' time preference, we used an intertemporal task commonly used in past research (e.g., Thaler 1981) in which we asked people to put a value on delaying an outcome (a gift certificate).

As implied by psychophysical principles, we expect that participants' subjective estimates of duration will not be adequately sensitive to the changes in the actual objective duration and will display smaller relative differences between time horizons than the objective differences. When objective time horizons are used in the calculations, we expect to replicate standard results showing hyperbolic discounting (e.g., Strotz 1955; Thaler 1981), namely that people behave as if they have higher discount rates for shorter periods compared to longer periods. Importantly, however, when participants' subjective estimates of time horizon are used, we expect that their time preferences will appear more consistent and that the discount rates implied in participants' preferences over time will not decrease over time horizon length.

Method

Participants and Design. Fifty seven undergraduate students completed the study as a partial requirement for an introductory marketing course. Participants were randomly assigned to one of three between-subjects time horizon conditions (3 months vs. 1 year vs. 3 years) and responded to two types of measures within-subjects, intertemporal preference and subjective time estimates.

Stimuli and Procedure. Participants first were presented with a scenario asking them to imagine receiving a gift certificate worth $75. They were then told that the gift certificate was valid today and were asked to indicate how much they would have to be paid in order to wait for 1 month (1 year or 3 years) before using the gift certificate. On the next page, participants were given a 180*mm* line with end-points labeled '*Very Short*' on the left end and '*Very Long*' on the right end. They were asked to imagine a day 3 months (1 year or 3 years) in the future and to place a mark on the line indicating "how long do you consider the duration between today and a day 3 months (1 year or 3 years) later?". The distance from the left end of the scale to each participant's mark was measured with a ruler and used as an indicator of subjective time horizon.

Results

Subjective Time horizon. The between-subjects factor, time horizon, was transformed into months and used as *objective time horizon*: 3 months, 1 year, and 3 years. *Subjective time horizon* was calculated as the distance from the left end of the 180*mm* line that participants marked. The mean distance was 105.85*mm* (SD = 37.5) in the 3 month condition, 131.25*mm* (SD = 33.6) in the 1 year condition, and 140.00*mm* (SD = 28.0) in the 3 year condition. The subjective time horizon estimate for 3 months was shorter than the estimate for 1 year ($t(38) = -2.26$, $p < .03$), which in turn was not different from the estimate for 3 years ($t(35) = -.85$, $p = .40$). See table 1 for descriptive statistics.

Insert table 1 about here

To compare relative changes in subjective and objective time horizons, for every participant we computed a measure that transforms the measured distance in millimeters into time units, anchoring on the 3 month condition.[3] Specifically, the mean value of the distance for the 3 month condition (M = 105.85*mm*) was set equivalent to the 3 months time horizon, and the subjective time horizons for one year and three years were calculated based on this figure. Thus, the mean subjective time horizon for the 1 year condition was 131.25*mm*, which is equal to 3.72 months relative to the anchor at 3 months (calculated as (131.25/105.85)×3). Whereas the objective time horizon grows 300% from the 3 month condition to the 1 year condition, the subjective time horizon grows only 24% for the same duration. The mean subjective time horizon for the 3 year condition was 140.00*mm*, which is equal to 3.97 months. Here the objective time horizon grows 1100% from the 3 month condition to the 3 year condition, but the subjective time horizon grows only 32.33% for that duration. Thus, subjective time horizon is far more compressed and less sensitive to changes than objective time horizon (see figure 1).

Insert figure 1 about here

Discount rate. To illustrate the implications of this relative subjective insensitivity to prospective duration for discounting, we examined changes in participants' delay premiums as a function of the objective and subjective time horizons. For objective time, the delay premium means were \$43.35 for 3 months, \$109.50 for 1 year, and \$195.65 for 3 years. We first calculated compound annual discount rates based on the objective time horizon (i.e., 3 months, 12 months, or 36 months).[4] One-way ANOVA with the objective time horizon as a between-subjects factor and discount rate as the dependent variable revealed a significant main effect of time horizon ($F(2, 54) = 11.65$, $p < .001$). The annual discount rate for the 3 month condition ($M = 159.73\%$) was higher than the discount rate for the 1 year condition ($M = 82.82\%$, $t(38) = 2.61$, $p < .02$), which in turn was higher than the discount rate for the 3 year condition ($M = 35.67\%$, $t(35) = 4.60$, $p < .0001$; see figure 2), replicating the standard pattern of hyperbolic discounting

Next, we computed adjusted compound annual discount rates based on the participants' individual subjective time horizon estimates reported above. These discount rates based on subjective time revealed no reliable differences across conditions ($M_{3m} = 214.46\%$ vs. $M_{1y} = 276.04\%$ vs. $M_{3y} = 350.47\%$, $F(2, 54) = 1.71$, $p = .19$). Even the discount rates for the 3 month condition and 3 year condition were not significantly different ($t(35) = 1.57$, $p = .13$). Thus, when calculated using subjective estimates of duration, discounting is not hyperbolic but instead is more constant over time horizon (and the trend as time horizon increases is directionally opposite what would be expected for hyperbolic discounting).

Finally, we computed a 3 (time horizon: 3 months vs. 1 year vs. 3 years) x 2 (time horizon measure: objective vs. subjective) mixed ANOVA with time horizon as the between-subjects factor and time horizon measure as a within-subjects factor. This analysis revealed a significant interaction of time horizon by time horizon measure ($F(2, 54) = 10.74$, $p < .001$), indicating differences in the extent of hyperbolic discounting as a function of the measure used. Specifically, when the discount rate was calculated using objective time horizon, we observed the hyperbolic discounting pattern. As predicted, however, this pattern was eliminated when discount rates were calculated using subjective time horizon.

Insert figure 2 about here

Discussion and Evidence of Robustness of Findings

Discussion of Experiment 1. The first experiment confirms our predictions that consumers show relative insensitivity to time horizon. Subjective estimates of future time horizon change less than the corresponding change in objective time, and internal discount rates calculated using subjective estimates of time horizon do not decrease over time. These results have important implications for intertemporal preferences, suggesting that we may observe declining rates of discounting with increased time intervals not because people's internal discount functions are approximated by hyperbolas, but because discount rates are calculated using objective time horizon. This finding provides a provocative new look at the underlying drivers of hyperbolic discounting. Current theories focus on the valuation of the outcome at different points over objective time intervals. We show that simply examining how people perceive time and taking into account the relative insensitivity in those perceptions can account for hyperbolic discounting.

Evidence of Robustness of the Findings. Because of the potential importance of these findings, we briefly present three follow-up experiments testing the robustness of our findings (for further information, see the Web Appendix). It is important to address this issue within the same paradigm we used in Experiment 1 because it matches many of the experimental tasks used in prior research.

Several aspects of the design of Experiment 1 require attention. Specifically, Experiment 1 (1) utilized a fully between-subject design, (2) measured subjective time perception after completing the intertemporal preference task, (3) used inconsistent descriptions of time horizons (e.g., “3 months” time horizon was compared to “1 year” time horizon, instead of “12 months”), leaving open the possibility that participants underestimated duration of the 1 year horizon because it had a smaller numerical value, and (4) used one specific pair of scale anchors to measure time perception. A follow-up experiment ($N = 36$) started to address these issues in a within subjects design with time units expressed consistently in months and replicated the results of Experiment 1, thus reducing the possibility that our results are an artifact of the experimental design. These within subjects results also rule out the alternative explanation that the insensitivity to time horizon is an artifact of eliciting separate evaluations of time horizons (Hsee 2000). Demonstrating that this phenomenon is robust to different unit descriptions of time horizon (months vs. years) further suggests that we are measuring the psychophysics of time, rather than the psychophysics of numerical values.

In both Experiment 1 and the follow-up reported above, we measured time separately from the intertemporal preference task itself in order to allow a clean independent measurement of each. To further show robustness, we replicate and extend our findings in a second follow-up study ($N = 133$) in which subjective estimates are directly linked to the focal intertemporal decision, with participants estimating subjective time in terms of the distance to the transaction. This is potentially important, because our day-to-day utilization of such time estimates is likely to be in the context of the transaction in question. We also manipulate whether the measurement of subjective time occurs before or after the preference task. The results replicate our findings from Experiment 1, providing further support for our hypothesis that time perception is a robust driver of hyperbolic discounting.

In a third follow-up study we wanted to address the scale that we used to measure time perception, an important and controversial issue in psychophysics (Gescheider 1985). We leave systematic validation of the use of the scale to future research; however, to begin to address this issue we ran a follow-up study ($N = 96$) systematically manipulating the scale anchors, but otherwise using the same procedure as in Experiment 1. We chose several pairs of words indicating subjective feelings of a short and long time horizon to use as anchors. Specifically, participants were randomly assigned to one of the five conditions in which they were given a continuous line scale with different anchors: 1) very short – very long, 2) instant – distant, 3) near – far, 4) now – forever, or 5) now – eternity. Their task was to indicate the subjective feeling of duration between today and a day in 1 month or 3 months (within-subjects). As before, we compared how much participants estimated duration to grow from 1 month to 3 months. Repeated measures ANOVA revealed only a significant main effect of time horizon, but no significant main effect of anchor and no significant time horizon by anchor interaction, with estimated 3 months objective time horizons between 1.41 and 1.67. Replicating our effects across scale anchors indicates that the our continuous line scale captures participants' subjective estimates of time horizon consistently regardless of the specific anchors, as long as one anchor indicates the feeling of short time horizon and the other indicates the feeling of long time horizon.

EXPERIMENT 2

The first experiments support our time horizon insensitivity hypothesis using both between and within subjects designs, having the elicitation of time perception before or after the valuation task, and using different descriptors (months and years) to indicate time. However, in staying close to existing intertemporal research paradigms, we utilized a simple design with only a few time horizons (three levels in Experiment 1 and two levels in follow-up experiments). Although such designs allow us to test declining discount rates, it is difficult to conclusively argue for hyperbolic discounting (versus a simple decline in impatience; see Rubinstein's 2003 critique). To address this gap, we borrow from experimental designs in psychophysics that utilize blocked randomized repeated responses across multiple trials.

Experiment 2 was again designed to map time discounting of participants over multiple (objective vs. subjective) time horizons. We measured subjective assessments of 12 time horizons in a block, from 3 months to 36 months in 3-month increments. To elicit discount rates, each participant's time preference (rate of discounting) was also measured in a separate block over the same multiple time horizons using a task similar to that used in our first set of experiments. Moreover, to deal with any scaling accounts of our previous results, participants were informed ahead of time that they would evaluate 12 time periods ranging from 3 to 36 months, and each participant responded to a random order in each block, following procedures from psychophysics. This design allows us to directly examine the pattern of hyperbolic discounting with respect to objective and subjective time, to further eliminate alternative accounts for our explanation, and to directly examine whether subjective time perception indeed follows the non-linear logarithmic function implied by the Weber-Fechner law. We consider the issue of modeling subjective time perceptions further in the discussion of this experiment.

Method

Participants and Design. One hundred and six students completed this experiment. The experimental design was a 12 (time horizons: from 3 months to 36 months, in 3 month increments, presented in a random order within subjects) by 2 (types of measures: intertemporal preference and subjective time) presented in two blocks within-subjects.

Stimuli and Procedure. This experiment was conducted on a laboratory computer. Participants were introduced to the experimental task. For the subjective time estimation task they were told that "In this study, you will be asked to indicate your subjective feeling of duration between today and various days in the future. Days in the future range from 3 MONTHS to 36 MONTHS. Please read the instructions carefully and indicate your responses." For each of the 12 trials, they were presented with a screen on which they were asked to imagine a day that was one of the 12 future time horizons. On the screen below the instruction, a 180*mm* line with end-points labeled as '*Very Short*' on the left end and '*Very Long*' on the right end was also shown. Participants were asked to move the bar, set in the middle at the beginning, to indicate how long they consider the duration between today and the day that was the specified time horizon in the future. After the completing the task, they moved to the next screen, which had the same task for a different time horizon. All participants indicated their subjective estimation of duration for 12 time horizons from 3 months to 36 months. The order of the 12 time horizons was randomized for each individual. After completing all of the twelve time estimation tasks, the screen presented a gift certificate scenario similar to the one used in Experiment 1. Participants were asked to indicate how much they would have to be paid to wait for each of the same 12 durations (delay discounting), again in random order.

Results and Discussion

Subjective Time horizon. The distance from the left end of the line to the final location of the bar participants moved was the subjective time horizon. This was transformed into month units based on the mean value for the 3 months time horizon. The results of the current multi-period experiment replicated our prior findings, showing a strong time contraction. For instance, whereas the growth in objective time from 3 to 36 months is 12 fold, the growth in subjective time perception was less than two fold, with 36 months subjectively perceived to be only 5.7 months. Recall that participants knew ahead of time the range of time horizons that they would judge on the scale, and the order of time horizons was random for each subject. See table 2 and figure 3 for detailed results for all 12 periods.

Insert table 2 about here
Insert figure 3 about here

Next, we explicitly examined non-linear perception of time by testing whether a logarithmic transformation of objective time matched the pattern of subjective time estimates. To do this, we scaled objective time horizon into logarithms and compared this logarithmic transformation of objective time to the subjective time estimates. As Figure 4 shows, this logarithmic transformation of objective time matches the subjective time estimates. To show this match statistically, we tested whether participants' subjective time estimates for the 12 time horizons follow a logarithmic rather than linear function. For this purpose, we defined two subjective time perception functions, using objective time and log-transformed time, consistent with the Weber-Fechner Law:

$$T_{ik}^{sbj(1)} = \alpha_i + \beta_i * T_{ik}^{obj} + \varepsilon_{ik} \quad \text{--- (1)}$$

$$T_{ik}^{sbj(2)} = \alpha_i + \beta_i * \ln(T_{ik}^{obj} + 1) + \varepsilon_{ik} \quad \text{--- (2)}$$

$T_{ik}^{sbj(m)}$ is the subjective time estimate of the corresponding objective time, T_{ik}^{obj}, of the i^{th} individual for the k^{th} time horizon for the m^{th} model, where m = 1 uses objective time and m = 2 uses log-transformed time and errors are independently, identically normally distributed. Using maximum likelihood estimation with random effects for both the α and β parameters, we found that the model using log-transformed time fit the data better than the simple linear model (BIC = 3706.3 for model (1) and 3663.4 for model (2), a 42.9 BIC difference in favor of the log time model).[5] Thus, our data support the conclusion that people perceive objective time not linearly, but logarithmically (we examine this issue further in the discussion for this study).

Insert figure 4 about here

Discount rates. To explore the implications of this observed time contraction for discounting, we first calculated compound annual discount rates with respect to the 12 objective time horizons and then calculated adjusted discount rates with respect to the subjective estimates. A one-way repeated measure ANOVA with objective time horizon as a within-subjects factor and discount rate as the dependent variable revealed a significant main effect of time horizon ($F(11, 1155) = 686.43$, $p < .0001$), with objective discount rates decreasing as time horizon increases, consistent with hyperbolic discounting (see Table 3 for statistics). For adjusted discount rate, a one-way ANOVA revealed a significant main effect of time horizon ($F(11, 1155) = 9.47$, $p < .001$) and also a significant decline, albeit much smaller in size. However, the decline in the adjusted discount rates was significant only between 3 months and 6 months and between 6 months and 9 months, not any of the other time periods, and these magnitudes were much smaller than those observed for objective time. Importantly, as predicted, a 12 (time horizons) x 2 (time horizon measure: objective vs. subjective) repeated measure ANOVA with both time horizon and time horizon measure as within-subjects factors revealed a significant interaction of time horizon by time horizon measure ($F(11, 95) = 2.31$, $p = .015$), indicating differences in the extent of hyperbolic discounting as a function of whether time was taken as objective duration or subjective perceptions (see Figure 5).

Insert figure 5 about here

Testing for hyperbolic discounting. To further test our hypothesis, we utilized the repeated measures design to explicitly test for hyperbolic discounting using objective and subjective time. We first defined a one-parameter hyperbolic discount function as $D(t) = 1/(1+\alpha t)$ (Mazur 1984) and calculated the discount rate r_{it} of individual i for time period t from this discount function using the following formula:

$$r_{it} = \frac{\alpha_i}{1+\alpha_i t_i} \quad \text{--- (3)}$$

Using nonlinear maximum likelihood estimation with identically normally distributed errors, both with and without random effects specification for each participant, we tested whether the one-parameter hyperbolic discount function provided a better fit with discount rates calculated with objective time or with subjective time estimates. Likelihood estimation revealed good model fit when the discount rates were calculated with objective time (BIC = 1387.1 with random effects and 1823.5 without random effects). However, when using the adjusted discount rates calculated with subjective time estimates, the likelihood estimation did not converge, indicating that the hyperbolic discount function is the wrong model for these data and fits only for discount rates over objective time.

In addition, having 12 periods of data and a single parameter model allowed us to use nonlinear maximum likelihood estimation to estimate the parameters of an individual level discount function for each participant with respect to objective and subjective time. If the α parameter is significantly different from zero in the estimation process, this implies that the discount rate is decreasing over time horizons (t) and the individual is discounting hyperbolically. If α is not significantly different from zero, however, the person does not discount future outcomes hyperbolically. For discount rates calculated using objective time, the α_1 parameter was significant for a majority of participants (84 of 106 participants, or 79.2%), indicating that a majority of participants indeed display hyperbolic discounting with respect to objective time. For the subjective time discount rates, however, the α_2 parameter was only significant for 5 of the participants, or 4.7%. Thus, when subjective time estimates are accounted for, there is very little evidence for hyperbolic discounting on the individual level.

Modeling Time Perception. An important issue relating to the modeling of time perception that requires further attention is the functional form used to model subjective time estimates. For simplicity, we used the logarithmic function associated with the Weber-Fechner law rather than Stevens' power law (and the power function associated with it). Our main goal in this paper is not to determine the precise functional form of the future duration psychophysical function, but to demonstrate the importance of using a concave function of time when estimating discounting models. However, we ran a series of model comparisons using logarithmic, power, and linear functions for duration estimations. Our results show that the logarithmic function (BIC = 3663.4) fit our data better than the power function (BIC = 3684.6). But the most important aspect was that both fit the data better than a linear function (BIC = 3706.3). We allowed for any linear function, not one associated with a one-to- one correspondence between objective and subjective time (i.e., 45 degrees), so these results strongly support that individuals' time perception mapping is concave, with a better fit to a logarithmic function than a power function.

Obviously, this is an important and often contentious issue in psychophysics (Gescheider 1985), and future research should investigate more systematically the functional form of future time perception.

Discussion of Experiment 2. In sum, the repeated measures design of experiment 2 allowed us to test explicitly for hyperbolic discounting and the role of subjective time estimates in such discounting patterns. To our knowledge, this is a unique experiment in both regards. Our results also provide some evidence that perception of future time horizon is consistent with a non-linear logarithmic function, suggesting a general psychophysical relationship. Taken together, the results of Experiment 2 provide strong support for our hypothesis that hyperbolic discounting patterns can be the result of biased perceptions of duration. The repeated measures design of this experiment also helps us deal with experimental procedure issues such as regression effects of scale responses.

EXPERIMENT 3

The first two experiments and their follow-ups demonstrate across multiple experimental settings and conditions that subjective sensitivity to time is an important determinant of declining rates of discounting with time. The goal of the next two experiments is to provide converging evidence for our theory and further examine the role of time perception by testing the role of duration accessibility. Experiment 3 explicitly manipulates duration saliency and examines the moderating effects of duration priming on hyperbolic discounting. We hypothesize that making duration more salient to participants will lead to be more sensitivity to time horizon and thus result in a reduced level of hyperbolic discounting. For this purpose, we employed a supraliminal priming task, followed by a common intertemporal preference task similar to the one we used in our earlier studies.

Method

Participants and Design. One hundred and ninety undergraduate student participants completed this study and were paid $10 for their participation in the session. The experimental design was a 2 (prime: duration vs. control) x 2 (time horizon: 1 month vs. 3 months) mixed design with order of time horizon as a counterbalancing between-subjects factor. Priming was a between-subjects factor and time horizon was manipulated within-subjects.

Stimuli and Procedure. This experiment included several parts. The first part included the priming task, implemented by having participants estimate the duration of seven activities for the duration-priming condition and the number of calories contained in seven food items in the control condition (for detailed information, see section 4 in the Web Appendix). Immediately following the priming task, presented as a separate experiment, participants were given the gift certificate scenario used in the previous experiments and were asked to indicate the amount they would have to be paid to accept delay of the $75 gift certificate. The time horizon relevant to the delay of the gift certificate was manipulated within-subjects by varying the duration of the wait period to be 1 month or 3 months, with the presentation order of the two durations counterbalanced. Order had only a main effect ($F(1, 186) = 10.85$, $p < .01$) but did not significantly interact with the variables of interest (largest $F = .628$, smallest $p = .43$), so the data were collapsed across order. Finally, participants completed a written funnel debrief, and no participant reported detecting a relationship between the prime and the main task.

Results and Discussion

The overall model was a two-factor mixed ANOVA with priming as the between-subjects factor and time horizon as the within-subjects factor. The dependent measure was annual discount rate, calculated using the amount participants indicated they would need to be paid for the length of the delay (1 month or 3 months). Priming did not have a main effect ($F(1, 188) = .88$, $p = .35$). Consistent with prior findings, the analysis produced a significant main effect for time horizon ($F(1, 188) = 47.88$, $p < .01$), indicating that the discount rate implied in participants' preferences was higher when delaying the usage of the gift certificate for 1 month ($M = 160\%$) compared to 3 months ($M = 100\%$).

More importantly, the results showed the expected time horizon by priming interaction ($F(1, 188) = 3.75$, $p = .05$), indicating a reduced level of hyperbolic discounting in the duration-priming condition. Specifically, the discount rate participants required to delay declined with time horizon in the control condition ($M_{1m} = 178\%$ vs. $M_{3m} = 102\%$), replicating our results above and prior findings (e.g., Thaler 1981). However, when duration was primed, the extent of hyperbolic discounting was attenuated ($M_{1m} = 141\%$ vs. $M_{3m} = 98\%$); see figure 6.

Insert figure 6 about here

The results of this experiment further demonstrate the importance of subjective time horizon perceptions in consumer intertemporal preferences. Consistent with our theorizing, we show that making duration more salient moderates one of the most robust effects in intertemporal choice research - the degree of hyperbolic discounting. This moderating effect adds to the results of our earlier studies and provides further evidence that the way people perceive prospective time horizon is one mechanism leading to behavior consistent with hyperbolic discounting. People are insensitive to time horizon, but when time horizon is made more accessible, even non-consciously, people are more sensitive to this dimension.

EXPERIMENT 4

The previous experiment was designed to manipulate sensitivity to time horizon and examine its effect on time discounting. In Experiment 3, we assumed that making duration salient would lead people to become more sensitive to time horizon, but it was not empirically tested. Experiment 4 was designed to show that duration priming indeed affects sensitivity to time horizon and subsequent intertemporal preferences.

Method

Participants and Design. Fifty four undergraduate student participants participated in this study. The experimental design was a 2 (prime: duration vs. control) x 2 (time horizon: 1 month vs. 3 months) mixed design with prime as a between-subjects factor and time horizon as a within-subjects factor.

Stimuli and Procedure. First, the same priming task used in Experiment 3 was implemented by having participants estimate the duration of seven activities in days for the duration-priming condition. This task was not implemented for those in the control condition. Immediately following the priming task, participants were given a 180*mm* continuous line with end-points labeled as '*Very Short*' on the left end and '*Very Long*' on the right end to indicate their subjective assessments of time horizons. In the control condition, participants were given the time assessments measure without the priming manipulation. Finally, all participants were given a gift certificate scenario in which they indicated their preference for the timing of two outcomes as a function of time delay (1 month vs. 3 months).

Results

Subjective Time horizon. As before, subjective time horizon was calculated as the distance from the left end of the 180*mm* line that participants marked. In the priming condition, the mean distance was 74.31*mm* (SD = 34.89) for the 1 month time horizon and 120.73*mm* (SD = 44.82) for the 3 months time horizon. In the control condition, the mean distance was 72.36*mm* (SD = 43.92) for the 1 month time horizon and 104.61*mm* (SD = 41.84) for the 3 months time horizon. As previously, the measured distance in millimeters was transformed into month units for each participant based on the mean value of the distance for the 3 months time horizon for all participants (M = 73.30*mm*). After transformation, the mean subjective estimates are equal to 1.01 months for the 1 month time horizon and 1.65 months for the 3 months time horizon in the priming condition and .99 months for the 1 month time horizon and 1.43 months for the 3 months time horizon in the control condition. We ran a 2 (prime: duration vs. control) x 2 (time horizon: 1 month vs. 3 months) mixed ANOVA and found a significant prime by time horizon interaction ($F(1, 52) = 4.16$, $p < .05$), indicating that the changes in the subjective assessments of time horizon are a function of duration saliency. This result confirms the relationship between duration priming and sensitivity to time horizon that we assumed in Experiment 3.

Insert figure 7 about here

Discount rate. In the control condition, the discount rates participants required to delay an outcome declined with time (M_{1m} = 242.33% vs. M_{3m} = 146.11%, $t(27) = 3.08$, $p < .01$), a change of 96.2%, indicating a hyperbolic pattern of discounting. When duration was primed, the discount rate also declined with time horizon (M_{1m} = 205.80% vs. M_{3m} = 124.02%, $t(27) = 2.68$, $p < .05$), showing a slightly smaller 81.8% change. Thus, discount rates became slightly more consistent over time; however, unlike the results of Experiment 3, the observed difference in the degree of decline in discount rates was not statistically significant. A two-factor mixed ANOVA with compound annual discount rate as a dependent measure revealed no significant priming by time horizon interaction ($F(1, 52) < 1$). The reason that the priming effect did not carry over across the two tasks is discussed below.

Importantly, however, when using the subjective time estimates (that were impacted by the priming task) and comparing the resulting pattern of discounting to the pattern of discounting with respect to objective time (our standard analysis in Experiments 1-3), we replicate our established results. As in our other experiments, we first calculated compound annual discount rates based on objective time. As expected, the objective discount rate for the 1 month time horizon (M = 224.74%) was significantly higher than the discount rate for 3 months (M = 135.48%, $t(53) = 4.11$, $p < .0001$), implying a hyperbolic pattern of discounting. Next, adjusted discount rates were calculated based on individual subjective estimates of time horizon. For these adjusted discount rates, there was no reliable difference between 1 month (M = 294.96%) and 3 months (M = 308.57%) time horizons ($t(53) = -.50$, $p = .62$). A 2 (time horizon: 3 months vs. 12 months) x 2 (time horizon measure: objective vs. subjective) fully within-subjects ANOVA revealed a significant interaction of time horizon by time horizon measure ($F(1,53) = 13.28$, $p < .001$), demonstrating differences in the level of discounting as a function of the measure used, replicating our previous results. These results also replicate separately for the priming and control conditions.

Discussion

Making duration salient makes people more sensitive to time horizon. Without duration priming, the subjective time horizon grows only 44% from a 1 month time horizon to 3 months. With duration priming, however, the subjective time horizon grows 64% for the same duration, indicating increased sensitivity to time horizon. Given that objective time horizon grows 200% for the same duration, participants in the priming condition were still relatively insensitive to time horizon, however.

Experiment 4 does not find the same relationship between duration saliency and discount rates shown in Experiment 3. Note that it is conceptually reasonable *not* to expect the priming manipulation to carry over to the intertemporal preference task. Several researchers have reported that the effect of priming often decreases with time and thus does not carry over to other tasks coming after a focal task (e.g., subjective assessments of time horizon in this experiment) if the focal task has already been influenced by the prime (Higgins, Bargh, and Lombardi 1985; Cho and Schwarz 2004; Schwarz and Clore 2006). That is, because participants had already used the primed information to judge their subjective time horizon, the later (intertemporal preference) task is less likely to be influenced by the same information. Our critical result is that manipulating the saliency of duration in an unrelated task shifts people's attention and perception of the time horizon. That shift affects the mapping of subjective time (Experiment 4) and the pattern of discounting (Experiment 3). Importantly, Experiment 4 does replicate our central finding that discount rates decline with respect to objective time, but not with respect to subjective time estimation. This experiment also suggests that any changes to the attention given to time duration could then influence these subjective estimations and thus the resulting pattern of discounting.

GENERAL DISCUSSION

The main goals of this article are to examine how consumers perceive and incorporate prospective duration into their decisions and to offer a new time perception account for intertemporal preferences. We propose and demonstrate that consumers' subjective perception of changes in time duration is not adequately sensitive to objective changes in time horizon, consistent with psychophysical principles. We also show that such insensitivity can explain hyperbolic discounting and is attenuated when duration is made salient. Taken together, our results suggest a new perspective for explaining consumer intertemporal behavior.

Summary and discussion of results

The results of our experiments directly demonstrate that consumers are not sensitive to changes in objective duration *per se* but that their subjective time perceptions are logarithmic in objective time, consistent with general psychophysical principles. Our findings then point to the role of these non-linear time perceptions in intertemporal preferences. As predicted, throughout our experiments we observe a declining rate of discounting and hyperbolic discounting explicitly (Experiment 2) when discount rates are calculated with respect to objective time horizons. These findings replicate robust prior findings in the literature. However, when discount rates are calculated with respect to individuals' subjective estimates of duration, we no longer observe a hyperbolic pattern; instead, discount rates are relatively constant with time. Our data also support our contention that making duration more salient and accessible makes consumers more sensitive to time horizon (Experiment 4) and reduces the extent of declining discount rates with time (Experiment 3).

Taken together, our results demonstrate across multiple experimental settings, within and between subjects, with multiple time horizons and multiple descriptors, and with different measurement orders that consumers' subjective time estimates are contracted relative to objective time, making consumers insensitive to the prospective duration over which events take place. More importantly, we provide evidence that such prospective duration insensitivity is an important driver of consumers' display of declining rates of discounting with time.

Subjective Time Perception and Theories of Intertemporal Tradeoffs

The Psychophysics of Prospective Duration. As we have noted above, we do not claim that a logarithmic function is necessarily the most accurate functional form for the psychological mapping between objective and subjective time. Although our model estimation results better fit a logarithmic function than a power function, future research should further investigate this relationship based on specific psychophysical theories of sensory and cognitive processes and corresponding estimation methods (e.g., discriminability of stimuli or direct magnitude estimation; Gescheider 1985). It is also important to note that when conceptualizing future duration, there are several strong assumptions relating to the fact that there is no physical reality to be perceived such as brightness or weight, but only the more abstract conceptualization of the future. This, as well as the context dependency of retrospective time perception, calls for caution when comparing the perception of prospective duration to more standard psychophysical transformations. In this paper, we focus more on the robust regularity of this mapping and the importance of non-linear time perception to theories of intertemporal tradeoffs.

Hyperbolic Discounting as a Multiply Determined Phenomenon. A great deal of research across multiple disciplines has examined how people value different outcomes at different points in time, whether due to a shift of mental representations (e.g., Malkoc and Zauberman 2006;

Trope and Liberman 2003; Zauberman and Lynch 2005), to affective visceral factors (e.g., Ainslie 1975; Loewenstein 1996), or to an inherent orientation towards the present or the future (e.g., Zimbardo and Boyd 1999). In this paper, we offered a different perspective, focusing on the effect of people's perceptions of duration itself on intertemporal preferences. Our explanation is consistent with findings of subadditivity (Read 2001) as well as findings regarding the role of attention in time discounting (Ebert and Prelec 2007).

We do not argue, however, that all instantiations of hyperbolic discounting are fully accounted for by (in)sensitivity to prospective duration. For instance, choosing to have one cookie now rather than two tomorrow, but two in eight days over one in seven days may perhaps be better explained in terms of emotional or visceral effects on the value of the outcomes (Loewenstein 1996; Metcalfe and Mischel 1999). Cognition may play a role in other instances of decreasing impatience. Indicating that you will search extensively online for the best price the next time that you buy a book, but ending up at Amazon.com again when the time arrives could be better explained by misprediction of resource slack (Zauberman and Lynch 2005). Similarly, a differential decline in discount rates with time in defer versus expedite decisions might be explained using changes in level of representation of the outcomes (Malkoc and Zauberman 2006). Finally, subjective time horizon may have less predictive power for very short durations (hours or days), where emotional reactions and or shifts in mental representations may be most dramatic. Even in these cases, however, it is possible that some of these cognitive and affective mechanisms could work, at least in part, by changing perceptions of time. This conjecture deserves further research. Our point in this paper is to introduce sensitivity to time horizon as an additional important factor in choice over time that has been mostly neglected in prior research. Future research should examine in more depth the relationship between affective and cognitive factors and changes in time perception and discounting. This line of investigation could also contribute to the discussion about the psychological validity of Hyperbolic versus Quasi-hyperbolic models.

Generalizing time horizon insensitivity to other findings of intertemporal preferences

Our current paper has focused on how insensitivity to time horizons can provide an explanation for why discount functions decline with time horizons and why they could be approximated by hyperbolic functions. In this section, we further argue that contracted non-linear time perception is an important driver in consumer choice over time that can be generalized to explain effects other than hyperbolic discounting. We discuss and present some empirical evidence for the more general role of subjective time perception in two established intertemporal effects: subadditive discounting (Read 2001; Scholten and Read 2006) and the date/delay effect (LeBoeuf 2006; Read et al. 2005).

Subadditive discounting. Although most current behavioral models of intertemporal choice assume that an individual's discount rate is a function of how far an outcome is delayed from the present, Read (2001; Scholten and Read 2006) argues that it is also a function of the length of the interval itself. The effect of the duration interval on discounting implies that total discounting is greater when the duration interval is broken into sub-intervals, termed subadditive discounting. While this observation challenges the generalizability of hyperbolic discounting and is consistent with our findings, why it happens is not fully explained. Read (2001) reasons that it could be related to attention or a more simple regression to the mean effect. Our work is complementary to that of Read in that we can offer an explanation for why subadditive discounting is observed.

We tested our hypothesis with a simple study (*N* = 37) replicating the relevant subadditive aspect of Read's experimental design (e.g., Read and Roelofsma 2003). In addition to their intertemporal preference measure, we also added our standard elicitation of subjective time perception before the preference measure. The time horizon we used was 24 months, with two conditions: the time horizon was either undivided or divided. Participants in the undivided duration condition (*N* = 20) estimated duration between today and a day in 24 months on a 180*mm* continuous line scale. Participants in the divided duration condition (*N* = 17) first estimated the duration between today and a day in 12 months and then the duration between a day in 12 months and a day in 24 months. We used the mean estimation for 24 months in the undivided condition (*M* = 110.75*mm*) as the anchor and compared it to the summed parts in the divided conditions (97.65*mm* + 110.06*mm* = 207.71*mm*), which equals 45.01 months ($t(35)$ = 5.75, $p < .0001$). This result implies that participants perceive the total time horizon to be longer when it is divided into sub-intervals than when it is not divided, consistent with our hypothesis. Moreover, for the annual compound discount rate calculated using objective time, those in the divided duration condition had a higher discount rate (*M* = 60.37%) than those in undivided duration condition (*M* = 32.09%, $t(35) = 3.35$, $p = .002$), replicating Read's subadditive discounting effect. However, as we would predict, when discount rate is calculated with respect to the subjective estimate of time horizon, the discount rates revealed no difference between the divided (*M* = 34.19%) and undivided (*M* = 34.20%) conditions, $t(35) = .002$, *ns*. These findings suggest that individuals' subjective time perceptions lead them to show subadditivity. Thus, although subadditive and hyperbolic discounting offer conflicting accounts for declining discount rates with time, they are both consistent with our subjective time perception theory. Obviously, these are only initial data; further research is needed to more fully explore this link.

Date/delay effect. Another intertemporal choice phenomenon that we try to explain using our time perception based theory is the date/delay effect (Read et al. 2005; LeBoeuf 2006). This effect demonstrates that the discount rate is higher when time is described as a delay (e.g., in 3 months) than as a calendar date (e.g., November 1st). We hypothesize that people's subjective time perception is more contracted when time is expressed as calendar dates than when expressed as delay. To provide initial evidence for this conjecture, we asked 28 undergraduate students to estimate duration between two time points on a 180*mm* continuous line scale. For half of them, the duration was described as delay (e.g., duration between a day in 1 week and a day in 2 weeks). For the other half, it was described as calendar dates (e.g., the duration between October 24th and November 1st). The results show that participants perceive duration to be significantly longer when given as delay (M = 65.36*mm*) than as a calendar date (M = 38.79*mm*, $t(26) = 3.09$, $p < .01$). These findings imply that sensitivity to time horizon could be an important driver of the date/delay effect.

Conclusions

Our focus on sensitivity to prospective duration has implications for intertemporal judgment and choice. Previous research on preference and choice over time has documented multiple anomalies compared to normative discounted utility theory. We propose that one important determinant of such anomalies (and hyperbolic discounting, in particular) is the way in which people perceive and integrate prospective duration. Since the roots of contemporary intertemporal choice research have largely been in economics, the perspective we offer has not previously been systematically explored. Most intertemporal choice models, whether standard or modified to include psychological elements, such as hyperbolic and quasi-hyperbolic models, assume that consumers discount utility over the length or duration of the objective time horizon. As a result, our demonstration of consumers' relative insensitivity to such duration and biased subjective time horizon estimates calls into question the psychological validity of these theories. We suggest that the recent trend in incorporating psychologically accurate individual behavior into economic models of intertemporal choice would benefit from considering individuals' subjective perceptions of time.

REFERENCES

Ainslie, George (1975), "Specious Reward: A Behavioral Theory of Impulsiveness and Impulse Control," *Psychological Bulletin,* 82 (4), 463–69.

——— and Nick Haslam (1992), "Hyperbolic Discounting," in *Choice Over Time*, ed. G. Loewenstein and J. Elster, New York, NY: Russell Sage Foundation, 57–92.

Ariely, Dan and George Loewenstein (2000), "When Does Duration Matter in Judgment and Decision Making," *Journal of Experimental Psychology: General*, 129 (December), 508–523.

Block, Richard A. and Dan Zakay (1997), "Prospective and Retrospective Duration Judgments: A Meta-Analytic Review," *Psychonomic Bulletin and Review*, 4 (June), 184–97.

——— and ——— (2001), "Retrospective and Prospective Timing: Memory, Attention, and Consciousness," in *Time and Memory. Issues in Philosophy and Psychology*, ed. Christoph Hoerl and Teresa McCormack, Oxford: Oxford University Press, 59–76.

Carstensen, Laura L., Derek M. Isaacowitz, and Susan T. Charles (1999), "Taking Time Seriously: A Theory of Socioemotional Selectivity," *American Psychologist,* 54 (3), 165–81.

Cho, Hyejeung and Norbert Schwawrz (2004), "Of Great Art and Untalented Artists: Diverging Inferences from Effort Information," *Working Paper*, University Michigan.

Dehaene, Stanislas (2003), "The Neural Basis of the Weber-Fechner Law: A Logarithmic Mental Number Line," *Trends in Cognitive Sciences*, 7 (April), 145–47.

Ebert, Jane and Drazen Prelec (2007), "The Fragility of Time: Time-Insensitivity and Valuation of the Near and Far Future," *Management Science*, 53 (September), 1423–38.

Fraisse, Paul (1984), "Perception and Estimation of Time," *Annual Review of Psychology*, 35, 1–

36.

Fredrickson, Barbara L. and Daniel Kahneman (1993), "Duration Neglect in Retrospective Evaluations of Affective Episodes," *Journal of Personality and Social Psychology*, 65 (July), 44–55.

Gescheider, George A. (1985), *Psychophysics: Method, Theory, and Application*, Hillsdale, NJ: Erlbaum.

Gibbon, John (1977), "Scalar Expectancy Theory and Weber's Law in Animal Timing," *Psychological Review*, 84 (March), 279–325.

Grondin, Simon (2001), "From Physical Time to the First and Second Moments of Psychological Time," *Psychological Bulletin*, 127 (1), 22–44.

Higgins, Tory E., John A. Bargh, and Wendy J. Lombardi (1985), "Nature of Priming Effects on Categorization," *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 11 (1), 59–69.

Hsee, Christopher K. (2000), "Attribute Evaluability and its Implications for Joint-Separate Evaluation Reversals and Beyond," in *Choices, Values and Frames*, ed. Daniel Kahneman and Amos Tversky, Cambridge: Cambridge University Press, 543–63.

Kirby, Kris N. (1997), "Bidding on the Future: Evidence Against Normative Discounting of Delayed Rewards," *Journal of Experimental Psychology: General*, 126, 54–70.

Laibson, David (1997), "Golden Eggs and Hyperbolic Discounting," *Quarterly Journal of Economics,* 112 (May), 443–78.

LeBoeuf, Robyn A. (2006), "Discount Rates for Time Versus Dates: The Sensitivity of Discounting to Time-Interval Description," *Journal of Marketing Research*, 43 (February), 59–72.

Loewenstein, George F. (1996), “Out of Control: Visceral Influences on Behavior,” *Organizational Behavior and Human Decision Processes,* 65 (February), 272–92.

——— and Drazen Prelec (1992), “Anomalies in Intertemporal Choice: Evidence and an Interpretation,” *Quarterly Journal of Economics*, 107 (2), 573–97.

Malkoc, Selin A. and Gal Zauberman (2006), “Deferring versus Expediting Consumption: The Effect of Outcome Concreteness on Sensitivity to Time Horizon,” *Journal of Marketing Research,* 43 (November), 618–27.

Mazur, James E. (1984), “Tests of an Equivalence Rule for Fixed and Variable Delays,” *Journal of Experimental Psychology: Animal Behavior Processes*, 10 (October), 426–36.

McClure, Samuel M., David I. Laibson, George Loewenstein, and Jonathan D. Cohen, J.D. (2004). “Separate Neural Systems Value Immediate and Delayed Monetary Rewards,” *Science*, 306 (October 15), 503–507.

Melcalfe, Janet and Walter Mischel (1999), “A Hot/Cool-System Analysis of Delay of Gratification: Dynamics of Willpower,” *Psychological Review*, 106 (1), 3–19.

O'Donoghue, Ted and Matthew Rabin (1999), “Doing It Now or Later,” *American Economic Review*, 89 (March), 103–124.

Pigou, Arthur C. (1920), *The Economics of Welfare*, London: Macmillan.

Raftery, Adrian E. (1995), “Bayesian Model Selection in Social Research,” *Sociological Methodology*, 25, 111–163.

Read, Daniel (2001), “Is Time-discounting Hyperbolic or Subadditive?” *Journal of Risk and Uncertainty*, 23 (1), 5–32.

——— and George Loewenstein (1995), “The Diversification Bias: Explaining the Difference between Prospective and Real-time Taste for Variety,” *Journal of Experimental Psychology:*

Applied, 1 (1), 34–49.

———, Shane Frederick, Burcu Orsel, and Juwaria Rahman (2005), “Four Score and Seven Years from Now: The Date/Delay Effect in Temporal Discounting,” *Management Science*, 51 (September), 1326–35.

——— and Peter H.M.P Roelofsma (2003), “Subadditive versus Hyperbolic Discounting: A Comparison of Choice and Matching,” *Organization Behavior and Human Decision Making Processes*, 91 (July), 140–53.

Rubinstein, Ariel (2003) "Economics and Psychology"? The Case of Hyperbolic Discounting, *International Economic Review*, 44 (4), 1207–1216.

Scholten, Marc and Daniel Read (2006), “Discounting by Intervals: A Generalized Model of Intertemporal Choice,” *Management Science*, 52 (9), 1426–38.

Schwarz, Norbert and Gerald L. Clore (in press), “Feelings and Phenomenal Experiences,” in Social Psychology. *A Handbook of Principles*., Second edition, ed. E. Tory Higgins and Arie Kruglanski, New York: Guilford Press, 1–74.

Sherover, Charles M. (1975), *The Human Experience of Time: The Development of Its Philosophic Meaning*, New York: New York University Press.

Stevens, Stanley S. (1957), “On the Psychophysical Law,” *Psychological Review*, 64 (3), 153–81.

Strotz, Robert. H. (1955), “Myopia and Inconsistency in Dynamic Utility Maximization,” *Review of Economic Studies*, 23 (3), 165–80.

Takahashi, Taiki (2005), “Loss of Self-Control in Intertemporal Choice May Be Attributable to Logarithmic Time Perception, *Medical Hypotheses*, 65 (4), 691–93.

——— (2006), "Time-Estimation Error Following Weber-Fechner Law May Explain Subadditive Discounting, *Medical Hypotheses*, 67 (6), 1372–74.

Thaler, Richard H. (1981), "Some Empirical Evidence on Dynamic Inconsistency," *Economic Letters*, 8 (3), 201–207.

Trope, Yaacov and Nira Liberman (2003), "Temporal Construal," *Psychological Review,* 110 (3), 403–421.

Tversky, Amos and Derek J. Koehler (1994), "Support Theory: A Nonextensional Representation of Probability," *Psychological Review*, 101 (4), 547–67.

Turetzky, Philip (1998), *Time*, London and New York: Routledge.

Wittmann, Marc and Martin P. Paulus (2007), "Decision Making, Impulsivity and Time Perception," *Trends in Cognitive Sciences*, 12 (1), 7–12.

Zauberman, Gal (2003), "The Intertemporal Dynamics of Consumer Lock-In," *Journal of Consumer Research*, 30 (December), 405–419.

——— and John G. Lynch (2005), "Resource Slack and Propensity to Discount Delayed Investments of Time versus Money," *Journal of Experiment Psychology: General*, 134 (1), 23–37.

Zimbardo, Philip G. and John N. Boyd (1999), "Putting Time in Perspective: A Valid, Reliable Individual-Differences Metric," *Journal of Personality and Social Psychology*, 77 (December), 1271–88.

FOOTNOTES

1. An alternative model to capture this effect is quasi-hyperbolic discounting (e.g., Laibson 1997; O'Donoghue and Rabin 1999; Zauberman 2003). This model states that:

$$U(c_0,...,c_T) = D(0)u(c_0) + \beta \sum_{t=1}^{T} D(t)u(c_t), \textit{ where } D(t) = \left(\frac{1}{1+r}\right)^t \textit{ and } 0 < \beta < 1$$

The key difference between this model and hyperbolic discounting is that the declining rate of discounting with time delay comes from the differential weight given to first period consumption (c_0) compared to all other periods ($c_1, \ldots c_T$). As β gets smaller, first period utility $U(c_0)$ gets greater weight compared to utility in all other periods, $U(c_1, \ldots c_T)$. We consider the implications of our results for these models in the General Discussion section.

2. For simplicity, we used the logarithmic function associated with the Weber-Fechner law rather than the power function associated with Stevens' power law (Stevens 1957). Our main goal is not to demonstrate the precise functional form of the future duration psychophysical function, an important and controversial issue in psychophysics (Gescheider 1985), but to demonstrate the importance of using a non-linear concave function of subjective time when estimating discounting models. However, we address this point empirically following Experiment 2.

3. In this and the other experiments we normalize the subjective time estimate for each individual based on the first time period because our core hypothesis concerns how relative time contraction relates to changes in discounting levels. Note that by doing so we eliminate the effect of between-subjects differences in how the duration of the first period is perceived and the ability to simultaneously test its effect on absolute level of discounting; that is, the longer the time horizon is perceived to be, the greater the level of discounting. We tested and found this absolute effect separately (e.g., Wittmann and Paulus 2007) in this and the other experiments. However, such effects are not the focus of this paper and will not be discussed further.

4. The discount rates were calculated with the following formula adapted from Thaler (1981): $r = \left[\ln(X_{t+k} / X_t)\right] / k$, where X_t is the amount at the initial period and k is the length of time expressed in terms of years.

5. When using the Bayesian information criterion (BIC), a difference greater than 10 indicates very strong evidence that one model fits better than the other (Raftery 1995). We report estimation results above that allow random effects for both the α and β parameters. Allowing random effects only for α, serial correlation in errors, or both random and serial correlation generates similar results, all confirming that a model using log-transformed time fits better than a model using objective time.

TABLE 1

EXPERIMENT 1 DESCRIPTIVE STATISTICS.

		Time Horizon		Time Horizon Growth		Discount Rate	
Conditions	Distance (mm)	Objective in months	Subjective In months	Objective	Subjective	Based on Objective time	Based on Subjective time
3 mos.	105.85	3	3	-	-	159.73%	214.46%
1 year	131.25	12	3.72	300%	24%	82.82%	276.04%
3 years	140.00	36	3.97	1100%	32.33%	35.67%	350.47%

Note. - The discount rates based on objective and subjective times are not exactly equal since they are based on individual level measures of distance rather than the group average.

TABLE 2

EXPERIMENT 2 MEAN SUBJECTIVE TIME HORIZON ESTIMATES.

		Time Horizon	
Conditions	Distance (mm)	Objective in months	Subjective In months
3 mos.	66.28 (32.53)*	3	3 (1.47)
6 mos.	80.82 (32.53)	6	3.66 (1.47)
9 mos.	85.42 (30.31)	9	3.87 (1.37)
12 mos.	89.80 (26.01)	12	4.06 (1.18)
15 mos.	98.16 (25.59)	15	4.44 (1.16)
18 mos.	102.57 (26.06)	18	4.64 (1.18)
21 mos.	108.71 (26.62)	21	4.92 (1.21)
24 mos.	112.42 (27.09)	24	5.09 (1.23)
27 mos.	114.16 (25.71)	27	5.17 (1.16)
30 mos.	115.98 (27.90)	30	5.25 (1.26)
33 mos.	120.04 (23.55)	33	5.43 (1.07)
36 mos.	125.47 (26.87)	36	5.68 (1.22)

* Numbers in parentheses show standard deviation.

TABLE 3

EXPERIMENT 2 MEAN DISCOUNT RATES.

	Objective Time Horizon			Subjective Time Horizon		
Time Horizon	Discount Rate	Decrease in Discount Rate	t value	Discount Rate	Decrease in Discount Rate	t value
3 mos.	312.75% (90.02)†			464.99% (424.99)		
6 mos.	181.55% (88.79)	131.20	19.162***	381.11% (309.58)	83.88	2.062*
9 mos.	124.00% (51.07)	57.54	11.044***	332.81% (179.54)	48.30	2.031*
12 mos.	99.79% (46.79)	24.21	8.667***	319.64% (165.86)	13.17	.846
15 mos.	86.20% (40.63)	13.59	6.850***	306.00% (143.67)	13.64	1.091
18 mos.	75.38% (36.88)	10.82	7.062***	306.80% (144.58)	-0.80	-.076
21 mos.	68.14% (34.37)	7.25	6.160***	299.89% (138.88)	6.91	.788
24 mos.	59.00% (26.96)	9.14	4.829***	292.55% (144.09)	7.33	.639
27 mos.	55.20% (25.52)	3.80	2.932**	302.07% (142.54)	-9.51	-.946
30 mos.	52.70% (25.27)	2.50	2.981**	321.04% (167.42)	-18.97	-1.608
33 mos.	50.45% (24.40)	2.25	2.691**	314.37% (149.00)	6.67	.577
36 mos.	46.13% (22.09)	4.32	4.723***	308.87% (161.22)	5.49	.503

† Numbers in parentheses show standard deviation.

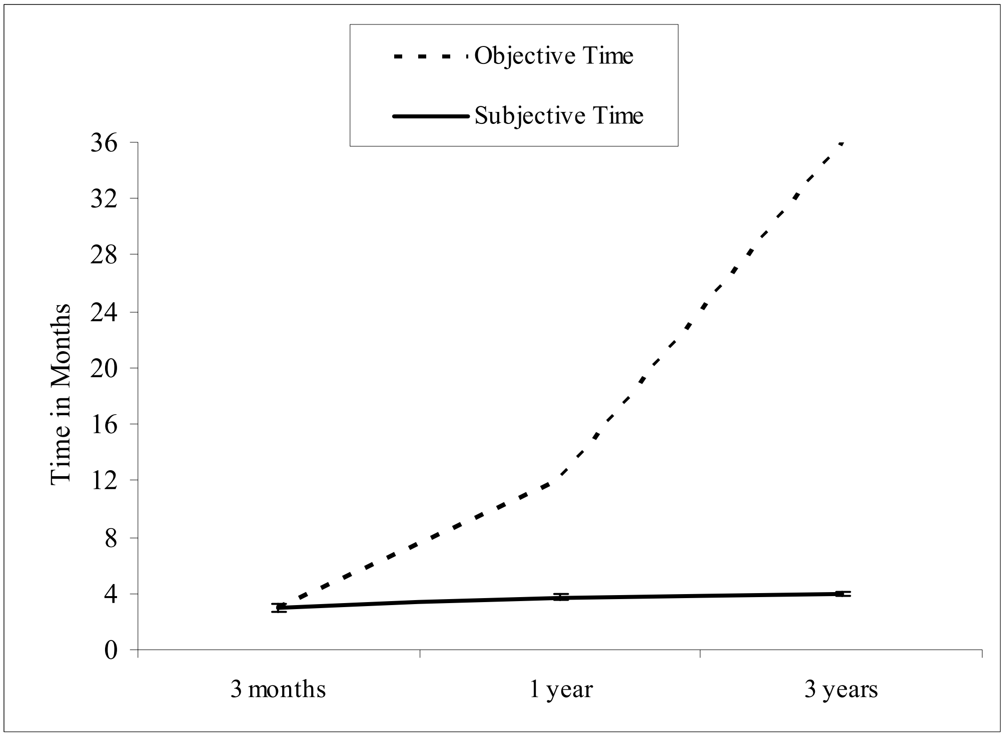
* $p < .05$

** $p < .01$

*** $p < .001$

FIGURE 1

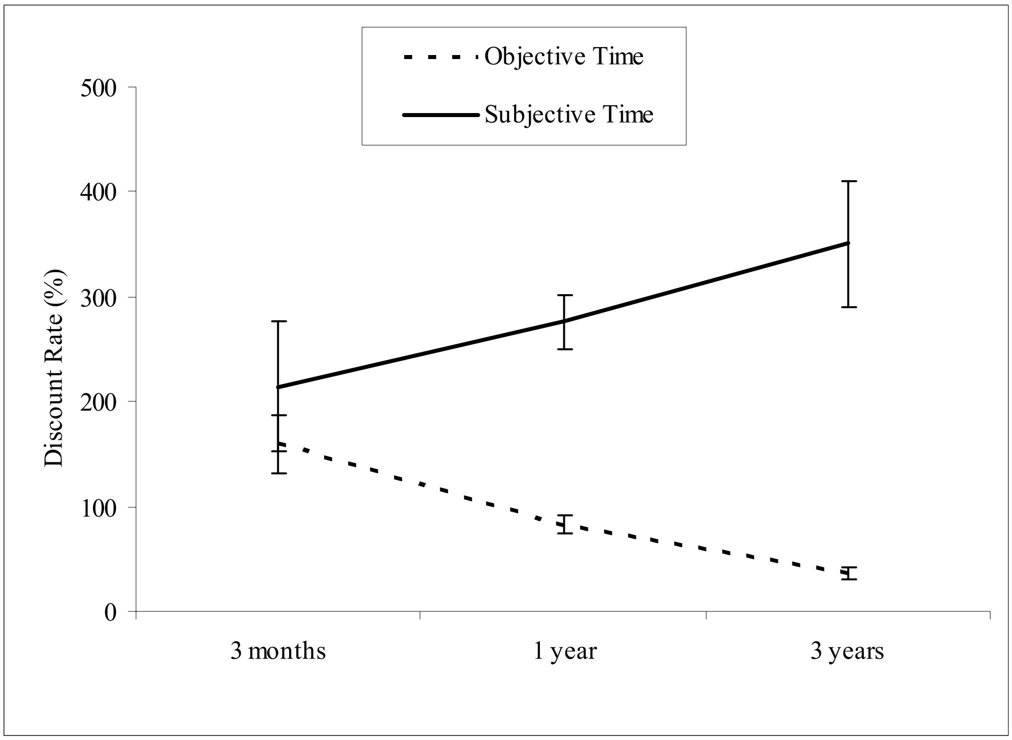
EXPERIMENT 1: OBJECTIVE AND SUBJECTIVE TIME



Note. - Error bars reflect standard error of the mean

FIGURE 2

EXPERIMENT 1: DISCOUNTING CALCULATED WITH OBJECTIVE AND SUBJECTIVE TIME



Note. – The discount rates based on objective and subjective times in the 3 months condition are not exactly equal since they are based on individual level measures of subjective time duration rather than the group average that anchors the mean subjective time estimation at 3 months term. Error bars reflect standard error of the mean

FIGURE 3

EXPERIMENT 2: OBJECTIVE AND SUBJECTIVE TIME

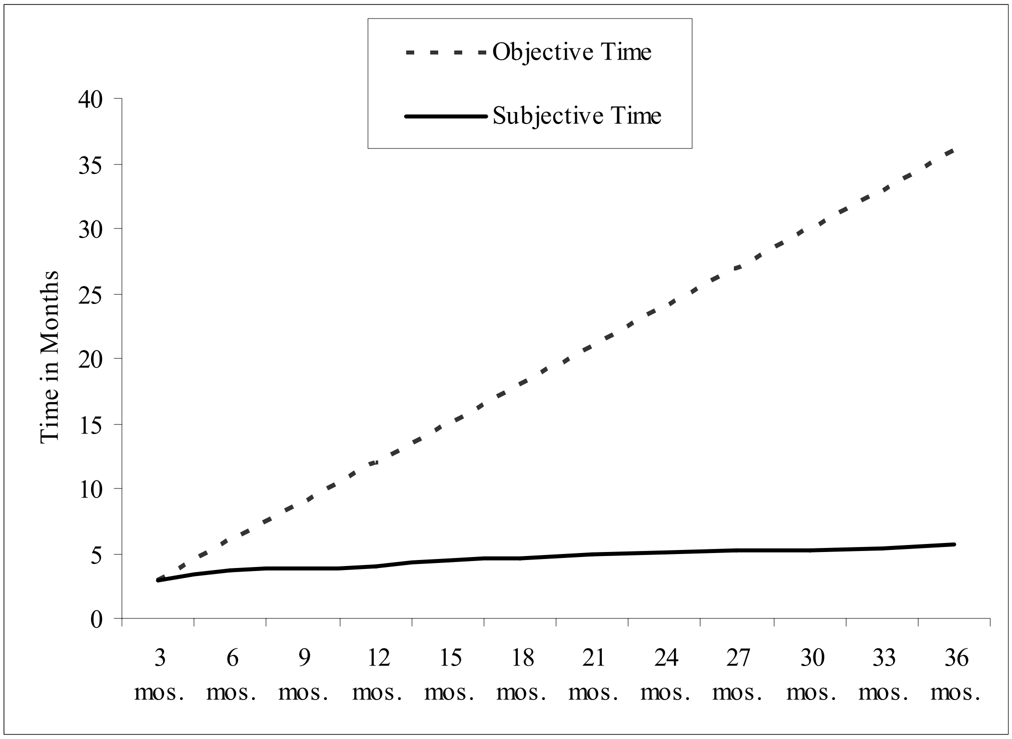
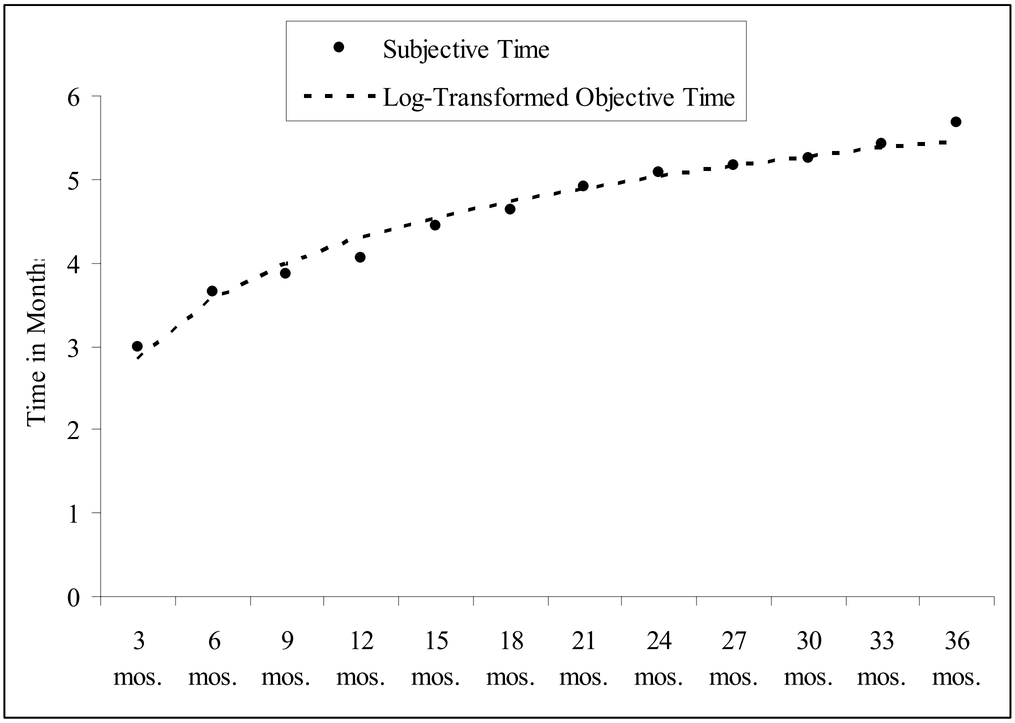


FIGURE 4

EXPERIMENT 2: SUBJECTIVE TIME AND LOG-TRANSFORMED OBJECTIVE TIME



Note. - Log-Transformed Objective Time = 1.67 + 1.06ln(Objective Time)

FIGURE 5

EXPERIMENT 2: DISCOUNTING CALCULATED WITH OBJECTIVE AND SUBJECTIVE TIME (MEDIAN)

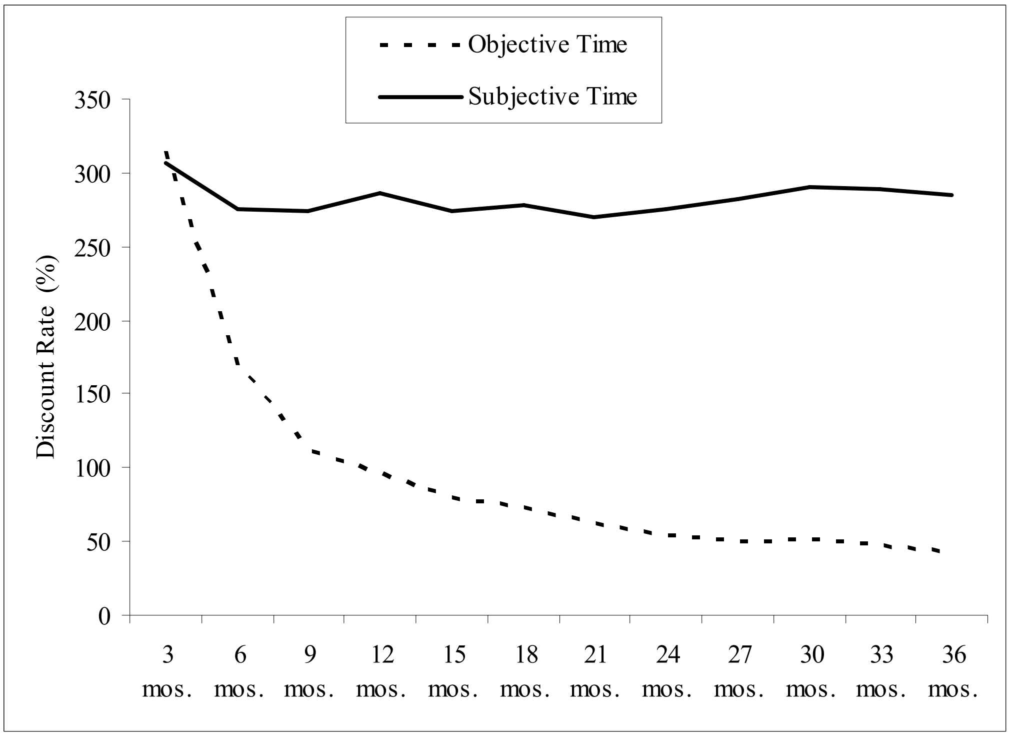
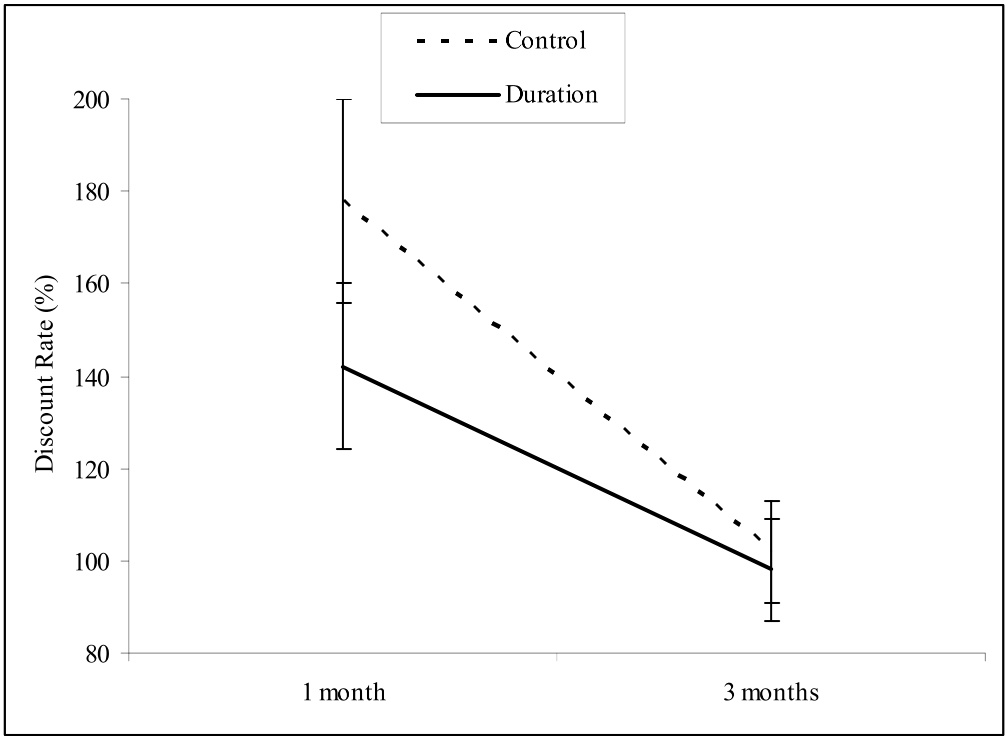


FIGURE 6

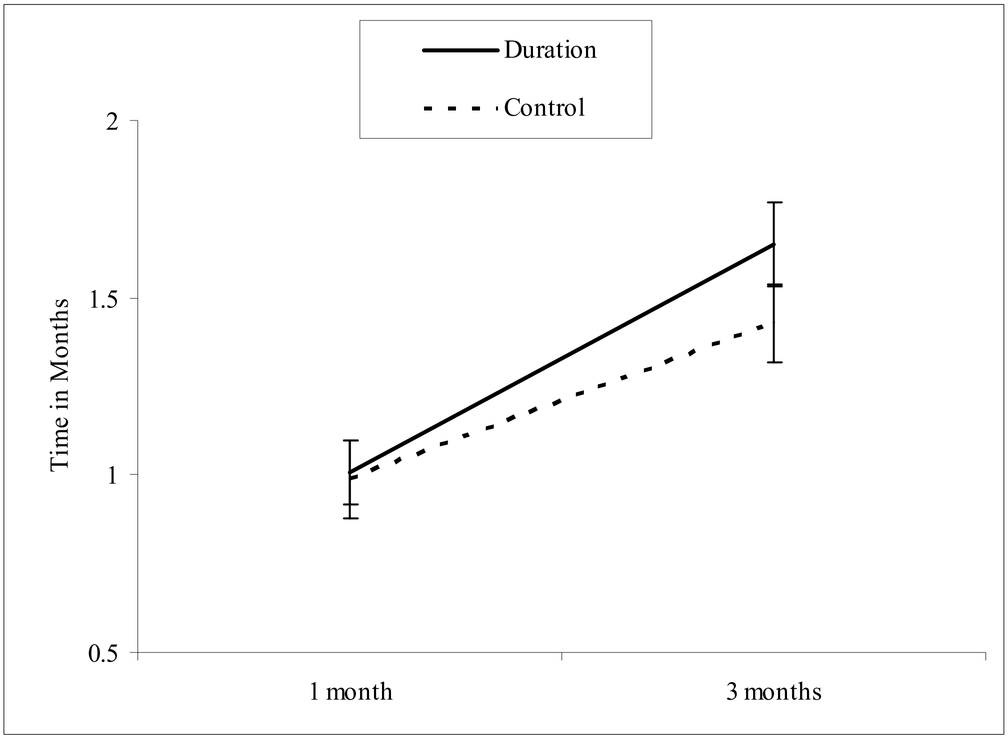
EXPERIMENT 3: DURATION PRIMING EFFECTS ON HYPERBOLIC DISCOUNTING



Note. - Error bars reflect standard error of the mean

FIGURE 7

EXPERIMENT 4: DURATION PRIMING EFFECTS ON TIME PERCEPTION



Note. - Error bars reflect standard error of the mean

Discounting Time and Time Discounting:

Subjective Time Perception and Intertemporal Preferences

GAL ZAUBERMAN, B. KYU KIM, SELIN A. MALKOC, and JAMES R. BETTMAN

WEB APPENDIX

SECTION 1

This experiment replicates the findings of Experiment 1 in a within-subjects setting. Although hyperbolic discounting has been observed in between-subjects and within-subjects experiments, one could argue that if different time horizons were evaluated jointly, consumers would show more sensitivity to changes in time horizon. Instead, we hypothesize that insensitivity to time horizon is a more perceptual effect and should impact hyperbolic discounting regardless of experimental modes and thus prevail even in within-subjects designs.

This study also addressed some other limitations of Experiment 1. In Experiment 1, time horizon confounded the length of duration and the description of duration: “3 months” time horizon was compared to “1 year” time horizon (instead of 12 months), which leaves open the possibility that participants underestimated duration of the 1 year horizon because it has a smaller numerical value. To control for the effect of time horizon description, in this study we described time horizon only in units of months. In addition, in Experiment 1, subjective time perception was measured after completing the intertemporal preference task. To avoid any influence of the intertemporal preference task on subjective estimates of time horizon, in this study we switched the order of the tasks.

Method

Participants and Design. Thirty six undergraduate students participated in this study as part of an hour long session and were paid $10 for their participation. Time horizon (3 months and 12 months) and the two types of measures (intertemporal preference and subjective time) were manipulated within-subjects.

Stimuli and Procedure. Stimuli and procedure were similar to those used in Experiment 1. The first part included subjective assessments of time horizon. Participants were given a 180*mm* line with end-points labeled as '*Very Short*' on the left end and '*Very Long*' on the right end and asked to mark the duration between today and a day 3 months later. On the next page, as in Experiment 1, participants were presented with a scenario of receiving a $75 gift certificate and indicated how much they would have to be paid in order to wait for 3 months. After completing these two tasks, participants repeated this procedure for a 12 months time horizon.

Results

Subjective Time horizon. The mean distance from the left end of the 180*mm* scale was 85.20*mm* (SD = 39.35) for the 3 months time horizon and 129.73*mm* (SD = 35.41) for the 12 months, which are significantly different ($t(36) = -7.38$, $p < .0001$). As in Experiment 1, the mean value of the distance for 3 months time horizon ($M = 85.20$*mm*) was set equivalent to 3 months and the mean subjective estimate for 12 months was 135.37*mm*, which corresponds to 4.57 months. That is, whereas the objective time horizon grows 300% from the 3 months to 12 months, the subjective time horizon grows only 52.33% for the same duration, replicating the results of Experiment 1.

Discount rates. We first calculated compound annual discount rates based on objective time. As expected, the objective discount rate for the 3 months (M = 104.26%) was significantly higher than the discount rate for 12 months (M = 47.83%, $t(35) = 4.90$, $p < .0001$), implying a hyperbolic pattern of discounting. Next, adjusted discount rates were calculated based on individual subjective estimates of time horizon. For these adjusted discount rates, there was no reliable difference between 3 months and 12 months (M_{3m} = 119.80% vs. M_{12m} = 137.88%, $t(35) = -1.09$, $p = .28$), showing that participants' implied discount rates do not decrease over time after taking subjective time perception into account.

A 2 (time horizon: 3 months vs. 12 months) x 2 (time horizon measure: objective vs. subjective) fully within-subjects ANOVA revealed a significant interaction of time horizon by time horizon measure ($F(1,35) = 20.57$, $p < .0001$), indicating differences in the level of discounting as a function of the measure used, replicating our Experiment 1 results (see figure 2).

Discussion

This experiment replicates Experiment 1's findings with within-subjects measures of time horizon sensitivity. As before, we find that consumers' subjective duration perceptions are relatively insensitive to the objective changes in time horizon and that accounting for this insensitivity significantly reduces the extent of hyperbolic discounting. These results from a within-subjects design rule out the alternative explanation that the insensitivity to time horizon is an artifact of eliciting separate evaluations of time horizons (Hsee 1998). In this study, each participant estimated multiple time horizons and still showed lack of sensitivity to time. This experiment also demonstrated that this phenomenon is robust to different descriptions of time horizon (months versus years) and to time perception measurement being the first task.

SECTION 2

In Experiment 1 and 2 we measured time perception and intertemporal preferences separately, providing a strong, conservative test of our theory. In doing so, we demonstrated across multiple experimental conditions that subjective estimates of time horizon measured independently from the focal preference task drive the pattern of participants' intertemporal preferences. To further show the robustness of our results, in this section we replicate our findings when subjective estimates are directly linked to the focal intertemporal decision. This is potentially important, because our day-to-day utilization of such time estimations is likely to be in the context of the transaction in question. We also manipulate in a single experiment whether the measurement of subjective time occurs before or after the preference task. Thus, in this experiment, we examine our hypotheses with participants estimating subjective time in terms of the distance to the transaction and manipulate whether the estimate comes before or after the preference task.

Method

Participants and Design. One hundred and thirty three undergraduate students completed the study as part of an hour long session and were paid $10 for their participation. The experimental design was a 2 (time horizon: 3 month vs. 12 months) x 2 (position of time perception measure: before vs. after) between-subjects design.

Stimuli and Procedure. Stimuli are similar to those used in previous experiments. Unlike prior experiments, however, the time perception task and the intertemporal preferences measure were implemented on the same page. All participants were first asked to imagine receiving a gift certificate worth $75 and delaying the use of it by 3 months (or 12 months). Next, half of the participants were asked to indicate their subjective estimates of this time horizon and then to complete the intertemporal task, reporting the amount they would need to be paid to accept delay of the $75 gift certificate by 3 months (or 12 months). The other half of the participants completed the two tasks in the reverse order. Consistent with our prior studies, the findings replicate for both orders.

Results and Discussion

Subjective time horizon and discount rate. To replicate our previous findings, we first separately analyzed the data from the before (c.f., Experiments 2) and after (c.f., Experiment 1) time perception measurement conditions and then the combined data. For the before condition, the mean distance was 88.15*mm* (SD = 38.02) for the 3 months condition and 126.67*mm* (SD = 36.08) for the 12 months condition. When the mean value of the distance for the 3 months condition was set equivalent to 3 months time horizon, the mean of the 12 months condition was equal to 4.31 months, showing only 44% growth. Next discount rates were calculated using both objective time horizon and subjective estimates of the time horizon. With respect to objective time horizon, the annual compound discount rate for the 3 months condition (*M* = 116.75%) was higher than the discount rate for the 12 months condition (*M* = 36.10%), indicating a hyperbolic pattern of discounting ($t(64) = 4.09$, $p < .001$). With respect to subjective time estimates, however, the adjusted discount rate for the 3 months condition (*M* = 146%) was not statistically different from the discount rate for the 12 months condition (*M* = 104.107%, $t(64) = 1.26$, $p > .21$).

A 2 (time horizon: 3 months vs. 12 months) x 2 (time horizon measure: objective vs. subjective) mixed ANOVA with time horizon as the between-subjects factor and time horizon measure as a within-subjects factor revealed a significant interaction of time horizon by time horizon measure ($F(1, 64) = 4.19$, $p < .05$), indicating differences in the extent of hyperbolic discounting as a function of the measure used.

These results replicated for those in the after condition. When the mean value of the distance for the 3 months condition (87.26*mm,* SD = 34.71) was set equivalent to 3 months time horizon, the mean of the 12 months condition (135.06*mm,* SD = 32.41) is equal to 4.64 months, showing only 55% growth. The objective discount rate for the 3 months condition (*M* = 126.98%) was higher than the discount rate for the 12 months condition (*M* = 44.44%, $t(65) = 3.46$, $p < .001$), and the adjusted discount rate for the 3 months condition (*M* = 143.39%) was not statistically different from the discount rate for the 12 months condition (*M* = 113.94%, $t(65) = .93$, $p > .35$). A significant interaction of time horizon by time horizon measure was also revealed ($F(1, 65) = 4.43$, $p < .05$).

Finally, we collapsed the data from both measurement position conditions and examined subjective estimates of time horizon and intertemporal preferences.

Measurement position had neither a main effect ($F(1, 129) < 1$) nor an interaction ($F(1, 129) < 1$) for subjective estimates of time horizon or discount rates. The overall mean of the 3 months condition (87.70*mm,* SD = 36.10) was set equal to 3 months, implying that the overall mean of the 12 months condition (130.86*mm,* SD = 34.29) was equal to 4.48 months (49% growth). The objective discount rate for the 3 months condition (*M* = 121.94%) was higher than the discount rate for the 12 months condition (*M* = 40.27%, $t(131) = 5.30$, $p < .0001$), and the adjusted discount rate for the 3 months condition (*M* = 144.68%) was not statistically different from the discount rate for the 12 months condition (*M* = 109.04%, $t(131) = 1.57$, $p =.12$). An interaction of time horizon by time horizon measure was also significant ($F(1, 131) = 8.60$, $p < .05$).

In sum, this study replicates and extends our prior findings by demonstrating that consumers' relative insensitivity to changes in the time horizon persists when the subjective time estimation is measured within the context of the transaction, and is robust to when the time perception measure is carried out relative to the intertemporal preference measure. These findings provide further support for our hypothesis that time perception is a significant robust driver of hyperbolic discounting.

SECTION 3

In this section we address the issue of the scale that we used to measure time perception. We used the same procedure to measure time perception as in Experiment 1, but systematically manipulated the scale anchors. We chose several pairs of words indicating subjective feelings of a short and long time horizon to use as anchors: 1) very short – very long, 2) instant – distant, 3) near – far, 4) now – forever, or 5) now – eternity.

Participants indicated the subjective feeling of duration between today and a day in 1 month or 3 months and their estimated growth from 1 month to 3 months were compared.

Method

Participants and Design. Ninety six undergraduate students participated in this study as part of an hour long session and were paid $10 for their participation. Time horizon (1 month and 3 months) were manipulated within-subjects and the five wordings of anchors were manipulated between-subjects.

Stimuli and Procedure. As in previous studies, participants were given a 180*mm* line and indicated the subjective feeling of duration between today and a day in 1 month or 3 months. Participants were randomly assigned to one of five conditions. In one condition, the end-points of the line were labeled as '*Very Short*' on the left end and '*Very Long*' on the right end as in other experiments in the paper. In the other conditions, the end-points were labeled as "*Instant*" on the left end and "*Distant*" on the right end, "*Near*" on the left end and "*Far*" on the right end, "*Now*" on the left end and "*Forever*" on the right end, or "*Now*" on the left end and "*Eternity*" on the right end.

Results and Discussion

For very short – very long anchor, the mean distance was 76.84*mm* (SD = 41.52) for the 1 month time horizon and 120.37*mm* (SD = 36.25) for the 3 months, which are significantly different ($t(18) = -5.87$, $p < .001$). For instant – distant anchor, the mean was 90.05*mm* (SD = 45.24) for the 1 month and 127.20*mm* (SD = 46.89) for the 3 months ($t(20) = -4.82$, $p < .001$). For near – far anchor, the mean was 70.53*mm* (SD = 44.72) for the 1 month and 100.68*mm* (SD = 46.67) for the 3 months ($t(19) = -3.46$, $p < .01$). For now – forever anchor, the mean was 62.68*mm* (SD = 51.71) for the 1 month and 90.37*mm* (SD = 54.44) for the 3 months ($t(18) = -4.30$, $p < .001$). For now – forever anchor, the mean was 58.68*mm* (SD = 46.85) for the 1 month and 97.21*mm* (SD = 53.92) for the 3 months ($t(18) = -5.54$, $p < .001$).

One-way ANOVA revealed no difference for the mean distances for 1 month time horizon among the five conditions ($F(4,91) = 1.41$, $p = .24$). Thus, we normalized the subjective time estimate for each individual based on the mean distance for 1 month time horizon as in Experiment 1 and 2 to compare the growth of time perception from 1 month to 3 months. Based on the 1 month time horizon, the mean subjective time estimate for 3 months were 1.57 months, 1.41 months, 1.43 months, 1.44 months, and 1.66 months separately for each anchors. Repeated measures ANOVA revealed only a significant main effect of time horizon ($F(1,91) = 112$, $p < .0001$), but no significant main effect of anchor ($F(4,91) < 1$) and no significant time horizon by anchor interaction ($F(4,91) = 1$, $p = .41$).

These results replicate the findings of contracted time perception in Experiment 1 regardless of the labels used for scale anchors. In addition, we found no evidence of systematic impact of scales anchors on subjective time perception. It implies that the our continuous line scale captures participants' subjective estimates of time horizon consistently regardless of the specific anchors, as long as one anchor indicates the feeling of short time horizon and the other indicates the feeling of long time horizon.

SECTION 4

Priming tasks used in Experiment 3: Control (Student Diet) and Duration (Student Activities)

Student Diet		Student Activities	
In this task, we ask you to consider the typical food items you would consume and estimate how many calories each of the items would contain. Please think about each food item below and provide your most accurate estimate of the total number of calories each would contain.		In this task, we ask you to consider several activities and estimate how long each of these activities would take you to complete. Please think about each activity below and provide your most accurate estimate of the total time required to complete each of the following activities.	
One slice of a large one-topping pizza:	__________ calories	**Graduating from college (undergraduate):**	______ hours / days / weeks / months / years
A bowl of salad:	__________ calories	**Learning a new language:**	______ hours / days / weeks / months / years
A Whooper with cheese:	__________ calories	**Finding a job (once started searching):**	______ hours / days / weeks / months / years
One serving of chicken wings:	__________ calories	**Studying for a difficult final exam:**	______ hours / days / weeks / months / years
A 6-inch Turkey sandwich with cheese:	__________ calories	**Planning for a Spring Break vacation:**	______ hours / days / weeks / months / years
6 pieces of California roll Sushi:	__________ calories	**Painting the exterior of a 2 story house:**	______ hours / days / weeks / months / years
One beef burrito:	__________ calories	**Driving from NC to California:**	______ hours / days / weeks / months / years