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Consumers often make decisions about outcomes and events that occur over time. This research examines consumers' sensitivity to the prospective duration relevant to their decisions and the implications of such sensitivity for intertemporal trade-offs, especially the degree of present bias (i.e., hyperbolic discounting). The authors 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 important, this lack of sensitivity can explain hyperbolic discounting. The 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. The results are replicated between subjects (Experiment 1) and within subjects (Experiments 2), with multiple time horizons and multiple descriptors, and with different measurement orders. Furthermore, the authors 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

Discounting Time and Time Discounting: Subjective Time Perception and Intertemporal Preferences

Many consumer decisions involve trading off costs and benefits over time. For example, 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 and a larger one that requires a longer wait. Both examples require consideration of prospective duration (e.g., the length of delivery time, the refund waiting period). Thus, examining consumers' sensitivity to prospective duration and its implication for their decisions is critical.

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Research on intertemporal decisions has shown that people are heavily biased toward the present (e.g., O'Donoghue and Rabin 1999; Thaler 1981; Zauberman 2003). An important and robust finding is that the rate at which an outcome is discounted over time (delay discounting) decreases as the time horizon gets longer. This is known as hyperbolic discounting, or "present bias." For example, when evaluating a lottery, people required \$30 rather than \$15 to wait for 3 months (a discount rate of 277%); however, the same people required only \$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), and to individual differences in time orientation (Carstensen, Isaacowitz, and Charles 1999; Zimbardo and Boyd 1999). However, all these research streams attribute hyperbolic discounting to changes in the perception or valuation of outcomes at different times. In this article, we offer an alternative perspec-

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tive, 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 nonlinear and characterized by insufficient sensitivity to changes in duration and that such discrepancy between objective duration and subjective time estimates helps 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), which state (e.g., Mazur 1984) the following:[1]

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

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 (t). Although there are some important differences across models, in general, they show that people's discount rates of future outcomes decrease with time. As we noted previously, 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 times. 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 the time interval is divided. Read (2001) argues that declining impatience could arise due to total discounting being greater when the overall time horizon is partitioned into subintervals, and he suggests two possible explanations. One explanation is that the result is a statistical artifact, similar to a regression-to-the-mean effect. The other explanation posits that a reason people show subadditivity is that partitioned components draw more attention, increasing their salience (for subadditivity in probability judgment, see Tversky and Koehler 1994). Ebert and Prelec (2007) manipulate participants' attention to time and find 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 a reason for hyperbolic discounting is that people do not pay enough attention to time horizon, which relates to the time perception explanation in this article.

However, no empirical research to date has directly examined consumers' perceptions 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 that demonstrate (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 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 (Fraisse 1984; Fredrickson and Kahneman 1993; Read and Loewenstein 1995; Sherover 1975; Turetzky 1998). People have difficulty thinking about time as an independent dimension and often misjudge the duration of events, though much of the evidence pertains to retrospective evaluations of duration rather than prospective evaluation of time. Decision researchers have found that, in general, people 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, unresolved issues are whether estimation of prospective duration is similarly biased and what the implications of such subjective judgments are for intertemporal preferences.

Sensitivity to Time Horizon and Present-Biased Preferences

As we discussed, most research has used hyperbolic or quasi-hyperbolic models to describe declining discount rates over time. At least implicitly, these models assume 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 that a person is indifferent among \$100 today, \$1,000 in 1 year, and \$2,000 in 3 years. If his

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[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 the following:

$$U(c_0, \ldots, c_T) = D(0)u(c_0) + \beta \sum_{t=1}^{T} D(t)u(c_t),$$

$$\text{where } D(t) = \left(\frac{1}{1+r}\right)^t \text{ and } 0 < \beta < 1.$$

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 with all other periods ($c_1, \ldots, c_T$). As β gets smaller, first-period utility $U(c_0)$ gets greater weight than utility in all other periods, $U(c_1, \ldots, c_T)$. We consider the implications of these models in the "General Discussion" section.

or her perception of time is unbiased (i.e., the person 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 1 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 people's discount rates. Specifically, suppose that the aforementioned consumer has biased subjective time perceptions such that he or she perceives 3 years as only 1.3 times longer than 1 year (rather than 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 the 3-year time horizons. In other words, the same set of preferences ($100 today = $1,000 in 1 year = $2,000 in 3 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 twentieth century. For example, among the early economists, Pigou (1920) stated that "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" (cited in Ainslie and Haslam 1992, p. 71). Later, when introducing Herrnstein's matching law, Gibbon (1977) suggested that "this law simply represents the Weber–Fechner law" (cited in Ainslie and Haslam 1992, p. 72). 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 (Dehaene 2003; Grondin 2001).[2]

Our perspective builds on these ideas and is psychologically distinct from previous explanations because it separates discounting the outcome itself from the perception of the time interval relevant to that decision. A person 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 nondecreasing discount rates. Our view, though 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 subadditive discounting (Takahashi 2006) and hyperbolic discounting (Takahashi 2005). Thaler (1981) and Loewenstein and Prelec (1992) also speculate that different perceptions of time intervals or clocks running at different speeds for outcomes could be the cause of nonexponential discounting. However, these notes and explanations provide no empirical tests. The goal of the current article is to examine the 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 summary, 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, 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 due in part to attention, 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 (for related attentional arguments, see Block and Zakay 1997, 2001; Ebert and Prelec 2007; Wittmann and Paulus 2007). We test our ideas across 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 is reduced (Experiment 3), which is then also reflected in changes in subjective time perception (Experiment 4). We discuss the implications of our work for intertemporal preferences in the "General Discussion" section.

EXPERIMENT 1

Experiment 1 examines 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 measure how subjective assessments of different prospective time horizons correspond to the changes in objective time horizons. To measure consumers' time preference, we employ an intertemporal task that is commonly used in prior 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 than for 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

[2]For simplicity, we used the logarithmic function associated with the Weber–Fechner law rather than the power function associated with Stevens's (1957) power law. 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 rather to demonstrate the importance of using a nonlinear concave function of subjective time when estimating discounting models. However, we address this point empirically following Experiment 2.

in their 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 versus 1 year versus 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 need to be paid to wait for 1 month (1 year or 3 years) before using the gift certificate. On the next page, participants were given a 180-millimeter line with endpoints 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 their response to the following question: "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. We transformed the between-subjects factor, time horizon, into months and used it as objective time horizon: 3 months, 1 year, and 3 years. We calculated subjective time horizon as the distance from the left end of the 180-millimeter line that participants marked. The mean distance was 105.85 millimeters (SD = 37.5) in the 3-month condition, 131.25 millimeters (SD = 33.6) in the 1-year condition, and 140.00 millimeters (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 ($t(35) = -.85$, $p = .40$) (for descriptive statistics, see Table 1).

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, we set the mean value of the distance for the 3-month condition (M = 105.85 millimeters) equivalent to the 3-month time horizon, and we calculated the subjective time horizons for 1 year and 3 years on the basis of this figure. Thus, the mean subjective time horizon for the 1-year condition was 131.25 millimeters, 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 millimeters, 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).

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 $195.65 for 3 years. We first calculated compound annual discount rates on the basis of the objective time horizon (i.e., 3 months, 12 months, or 36 months).[4] A one-way analysis of variance (ANOVA) with the objective time horizon as a between-subjects factor and discount rate as the dependent variable revealed a significant main effect of time horizon ($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 on the basis of the participants' individual subjective time horizon estimates. These discount rates based on sub-

[3]In this and the other experiments, we normalize the subjective time estimate for each individual on the basis of the first period because our core hypothesis pertains to how relative time contraction is related 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 is 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 article, and we do not discuss them further.

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

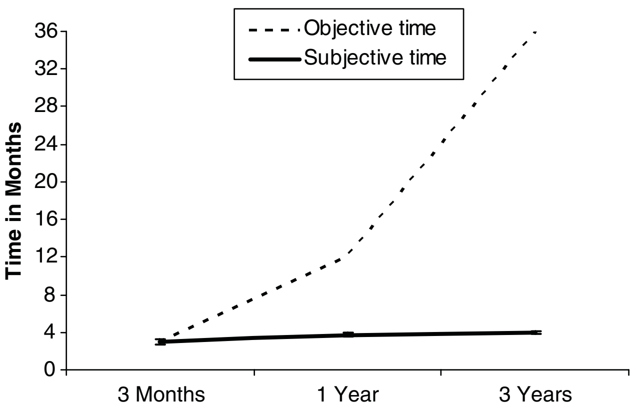
Table 1

EXPERIMENT 1: DESCRIPTIVE STATISTICS

		Time Horizon		*Time Horizon Growth*		*Discount Rate*	
Conditions	*Distance (Millimeters)*	*Objective (in Months)*	*Subjective (in Months)*	*Objective*	*Subjective*	*Based on Objective Time*	*Based on Subjective Time*
3 months	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%

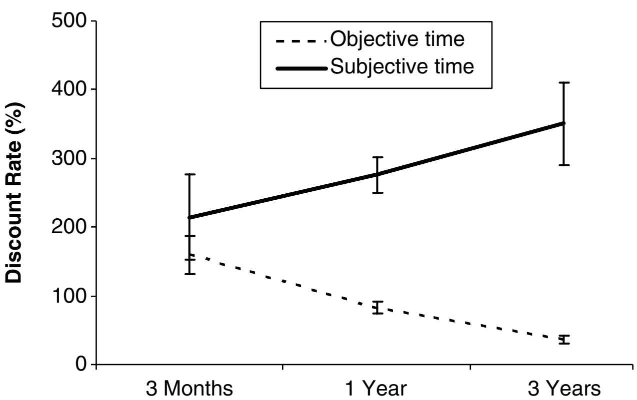
Notes: The discount rates based on objective and subjective times are not exactly equal because they are based on individual-level measures of distance rather than the group average.

Figure 1
EXPERIMENT 1: OBJECTIVE AND SUBJECTIVE TIME



Notes: Error bars reflect standard error of the mean.

Figure 2
EXPERIMENT 1: DISCOUNTING CALCULATED WITH OBJECTIVE AND SUBJECTIVE TIME



Notes: The discount rates based on objective and subjective times in the 3-month condition are not exactly equal because 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. Error bars reflect standard error of the mean.

jective time revealed no reliable differences across conditions (M_{3m} = 214.46% versus M_{1y} = 276.04% versus 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 versus 1 year versus 3 years) × 2 (time horizon measure: objective versus subjective) mixed ANOVA with time horizon as the between-subjects factor and the time horizon measure as a within-subjects factor. This analysis revealed a significant interaction of time horizon × 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 we calculated the discount rate using objective time horizon, we observed the hyperbolic discounting pattern. As we predicted, however, this pattern was eliminated when we calculated discount rates using subjective time horizon.

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, indicating that we may observe declining rates of discounting with increased time intervals not because people's internal discount functions are approximated by hyperbolas but rather because discount rates are calculated using objective time horizon. This finding offers a provocative new perspective on 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 that test the robustness of our findings (for further information, see the Web Appendix at http://www.marketingpower.com/jmraug09). 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) used a fully between-subjects design; (2) measured subjective time perception after the intertemporal preference task was completed; (3) used inconsistent descriptions of time horizons (e.g., we compared a 3-month time horizon with a 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. In a follow-up experiment (N = 36), we begin to address these issues in a within-subjects design with time units expressed consistently in months and replicate 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 versus 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, we measured time separately from the intertemporal preference task itself to allow a clean independent measurement of each. To show robustness further, 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 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 further research; however, to begin to address this issue, we ran a follow-up study (N = 96) that systematically manipulated the scale anchors but otherwise used a similar procedure to that used in Experiment 1. We chose several pairs of words that indicated 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). Again, we compared how much participants estimated duration to grow from 1 month to 3 months. A repeated measures ANOVA revealed only a significant main effect of time horizon but no significant main effect of anchor and no significant time horizon × anchor interaction, with estimated 3-month objective time horizons between 1.41 and 1.67. Replicating our effects across scale anchors indicates that 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 a short time horizon and the other indicates the feeling of a long time horizon.

EXPERIMENT 2

Experiment 1 and the follow-up 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 used a simple design with only a few time horizons (three levels in Experiment 1 and two levels in the follow-up experiments). Although such designs enable us to test declining discount rates, it is difficult to argue conclusively 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 use blocked randomized repeated responses across multiple trials.

Again, we designed Experiment 2 to map participants' time discounting over multiple (objective versus 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, we also measured each participant's time preference (rate of discounting) 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 periods ranging from 3 to 36 months, and each participant responded to a random order in each block, following procedures from psychophysics. This design enables 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 nonlinear 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 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) × 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 the following: "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 in one of the 12 future time horizons. On the screen below the instruction, a 180-millimeter line with endpoints 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, which was set in the middle at the beginning, to indicate how long they considered the duration between today and the day that was the specified time horizon in the future. After 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). We randomized the order of the 12 time horizons for each participant. After participants completed all 12 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 need to be paid to wait for each of the same 12 durations (delay discounting), again in random order.

Results

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. We transformed this into month units based on the mean value for the 3-month time horizon. The results of the current multiperiod experiment replicated our prior findings, showing a strong time contraction. For example, whereas the growth in objective time from 3 to 36 months is twelvefold, the growth in subjective time perception was less than twofold, with 36 months subjectively perceived as being only 5.7 months. Recall that participants knew ahead of time the range of time horizons they would judge on the scale, and the order of time horizons was random for each of them (for detailed results for all 12 periods, see Table 2 and Figure 3).

Next, we explicitly examined the nonlinear 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 with 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 followed 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:

Table 2
EXPERIMENT 2: MEAN SUBJECTIVE TIME HORIZON ESTIMATES

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

Notes: Numbers in parentheses are standard deviations.

Figure 3
EXPERIMENT 2: OBJECTIVE AND SUBJECTIVE TIME

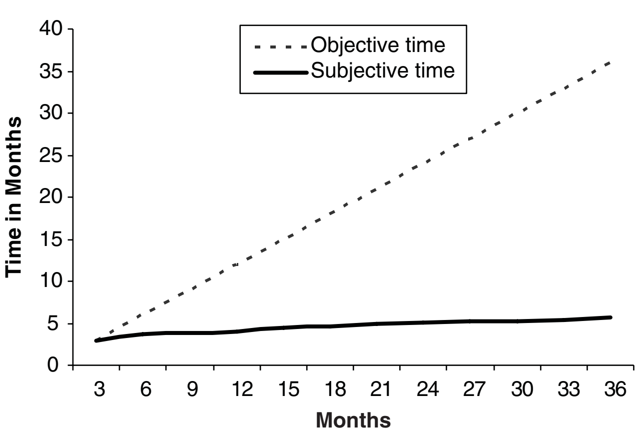
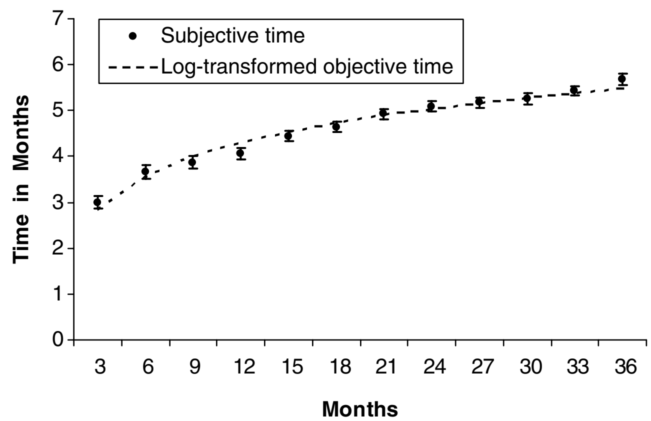


Figure 4
EXPERIMENT 2: SUBJECTIVE TIME AND LOG-TRANSFORMED OBJECTIVE TIME



Notes: Error bars reflect standard error of the mean.

(1) $$T_{ik}^{sbj(1)} = \alpha_i + \beta_i \times T_{ik}^{obj} + \varepsilon_{ik}, \text{ and}$$

(2) $$T_{ik}^{sbj(2)} = \alpha_i + \beta_i \times \ln(T_{ik}^{obj} + 1) + \varepsilon_{ik},$$

where $T_{ik}^{sbj(m)}$ is the subjective time estimate of the corresponding objective time, T_{ik}^{obj}, of the ith individual for the kth time horizon for the mth model, where m = 1 uses objective time and m = 2 uses log-transformed time and errors are independently and 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 (Bayesian information criterion [BIC] = 3706.3 for Model 1 and = 3663.4 for Model 2, for 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 rather logarithmically (we examine this issue further in the discussion for this study).

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 measures 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 (for statistics, see Table 3). 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

[5]When using the BIC, a difference greater than 10 indicates strong evidence that one model fits better than the other (Raftery 1995). We report estimation results 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 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 months	312.75% (90.02)			464.99% (424.99)		
6 months	181.55% (88.79)	131.20	19.162***	381.11% (309.58)	83.88	2.062*
9 months	124.00% (51.07)	57.54	11.044***	332.81% (179.54)	48.30	2.031*
12 months	99.79% (46.79)	24.21	8.667***	319.64% (165.86)	13.17	.846
15 months	86.20% (40.63)	13.59	6.850***	306.00% (143.67)	13.64	1.091
18 months	75.38% (36.88)	10.82	7.062***	306.80% (144.58)	–.80	–.076
21 months	68.14% (34.37)	7.25	6.160***	299.89% (138.88)	6.91	.788
24 months	59.00% (26.96)	9.14	4.829***	292.55% (144.09)	7.33	.639
27 months	55.20% (25.52)	3.80	2.932**	302.07% (142.54)	–9.51	–.946
30 months	52.70% (25.27)	2.50	2.981**	321.04% (167.42)	–18.97	–1.608
33 months	50.45% (24.40)	2.25	2.691**	314.37% (149.00)	6.67	.577
36 months	46.13% (22.09)	4.32	4.723***	308.87% (161.22)	5.49	.503

*$p < .05$.
**$p < .01$.
***$p < .001$.
Notes: Numbers in parentheses are standard deviations.

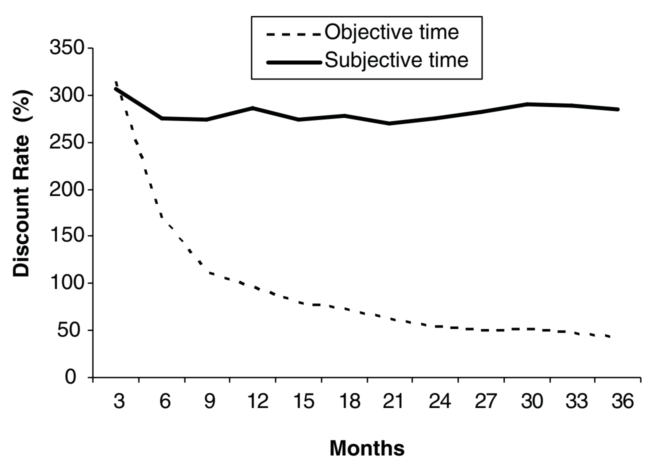
much smaller in size. However, the decline in the adjusted discount rates was significant only between 3 months and 6 months and between 6 months and 9 months, but not for any of the other periods, and these magnitudes were much smaller than those observed for objective time. Importantly, as we predicted, a 12 (time horizons) × 2 (time horizon measure: objective versus subjective) repeated measures ANOVA with both time horizon and time horizon measure as within-subjects factors revealed a significant interaction of time horizon × time horizon measure ($F(11, 115) = 4.36$, $p = .001$), 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).

Testing for hyperbolic discounting. To test our hypothesis further, we used the repeated measures design to test explicitly 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 t from this discount function using the following formula:

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

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.

Figure 5
EXPERIMENT 2: DISCOUNTING CALCULATED WITH OBJECTIVE AND SUBJECTIVE TIME (MEDIAN)



In addition, having 12 periods of data and a single-parameter model enabled 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 person 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 the majority indeed displayed hyperbolic discounting with respect to objective time. For the subjective time discount rates, however, the α_2 parameter was significant only for 5 participants, or 4.7%. Thus, when subjective time estimates are accounted for, there is little evidence for hyperbolic discounting on the individual level.

Modeling time perception. An important issue related 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 instead of Stevens's power law (and the power function associated with it). Our main goal in this article is not to determine the precise functional form of the future duration psychophysical function but rather 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 functions 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 people's time perception mapping is concave, with a better fit to a logarithmic function than a power function. This is an important and often contentious issue in psychophysics (Gescheider 1985), and further research should investigate more systematically the functional form of future time perception.

Discussion

In summary, the repeated measures design of Experiment 2 enabled 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. The results also provide some evidence that perception of a future time horizon is consistent with a nonlinear 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 on scale responses.

EXPERIMENT 3

Experiments 1 and 2 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 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 them to be more sensitive to time horizon, resulting 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 prior experiments.

Method

Participants and design. One hundred 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 versus control) × 2 (time horizon: 1 month versus 3 months) mixed design with order of time horizon as a counterbalancing between-subjects factor. Priming was a between-subjects factor, and we manipulated time horizon within subjects.

Stimuli and procedure. This experiment included several parts. The first part included the priming task, which we implemented by asking participants to 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 at http://www.marketingpower.com/jmraug09). Immediately following the priming task, and 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 need to be paid to accept delay of the $75 gift certificate. We manipulated the time horizon relevant to the delay of the gift certificate within subjects by varying the duration of the wait period to either 1 month or 3 months, with the presentation order of the two durations counterbalanced. Order had only a main effect ($F(1, 186) = 10.85$, $p < .01$) but did not significantly interact with the variables of interest (largest F = .628, smallest $p = .43$), so we collapsed the data across order. Finally, participants completed a written funnel debrief, and no participant reported detecting a relationship between the prime and the main task.

Results

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, which we 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%) than when delaying it for 3 months (M = 100%).

More important, the results showed the expected time horizon × 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% versus M_{3m} = 102%), replicating our previous results and prior findings (e.g., Thaler 1981). However, when we primed duration, the extent of hyperbolic discounting was significantly attenuated (M_{1m} = 141% versus M_{3m} = 98%) (see Figure 6).

Discussion

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—namely, the degree of hyperbolic discounting. This moderating effect adds to the results of our previous experiments 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 nonconsciously, people are more sensitive to this dimension.

EXPERIMENT 4

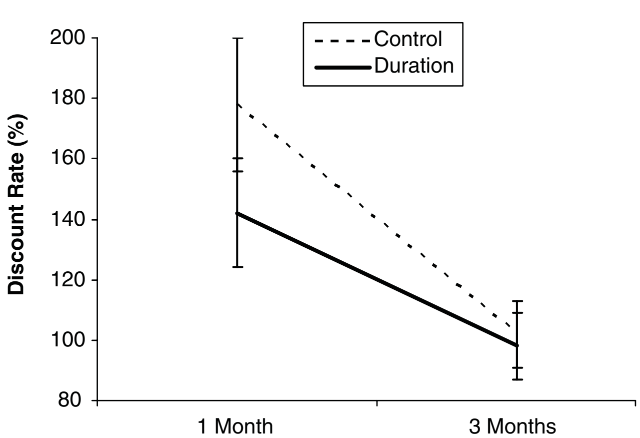
We designed Experiment 3 to manipulate sensitivity to time horizon and examine its effect on time discounting. We assumed that making duration salient would lead people to become more sensitive to time horizon, but it was not empirically tested. We designed Experiment 4 to show that duration priming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

Method

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

Figure 6

EXPERIMENT 3: DURATION-PRIMING EFFECTS ON HYPERBOLIC DISCOUNTING



Notes: Error bars reflect standard error of the mean.

Stimuli and procedure. We implemented a priming task similar to the one used in Experiment 3 by having participants estimate the duration of seven activities in days for the duration-priming condition. We did not implement this task for those in the control condition. Immediately following the priming task, participants were given a 180-millimeter continuous line with endpoints 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 versus 3 months).

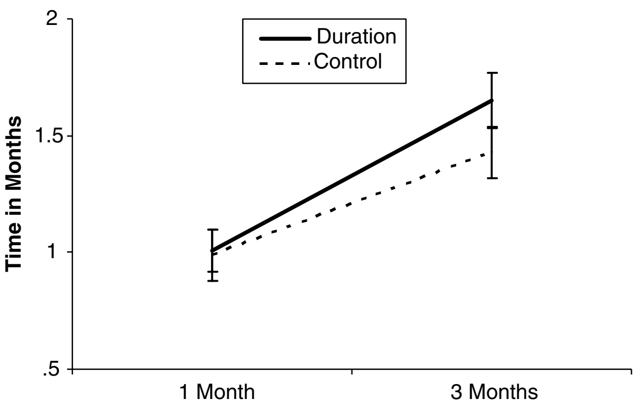
Results

Subjective time horizon. Again, we calculated subjective time horizon as the distance from the left end of the 180-millimeter line that participants marked. In the priming condition, the mean distance was 74.31 millimeters (SD = 34.89) for the 1-month time horizon and 120.73 millimeters (SD = 44.82) for the 3-month time horizon. In the control condition, the mean distance was 72.36 millimeters (SD = 43.92) for the 1-month time horizon and 104.61 millimeters (SD = 41.84) for the 3-month time horizon. As previously, we transformed the measured distance in millimeters into month units for each participant on the basis of the mean value of the distance for the 3-month time horizon for all participants (M = 73.30 millimeters). After transformation, the mean subjective estimates were equal to 1.01 months for the 1-month time horizon and 1.65 months for the 3-month time horizon in the priming condition and .99 months for the 1-month time horizon and 1.43 months for the 3-month time horizon in the control condition. We ran a 2 (prime: duration versus control) × 2 (time horizon: 1 month versus 3 months) mixed ANOVA and found a significant prime × 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 (see Figure 7). This result confirms the relationship between duration priming and sensitivity to time horizon that we assumed in Experiment 3.

Discount rate. In the control condition, the discount rates participants required to delay an outcome declined with time (M_{1m} = 242.33% versus M_{3m} = 146.11%; $t(27) = 3.08$, $p < .01$), for a change of 96.2%, indicating a hyperbolic pattern of discounting. When we primed duration, the discount rate also declined with time horizon (M_{1m} = 205.80% versus M_{3m} = 124.02%; $t(27) = 2.68$, $p < .05$), showing a slightly smaller change of 81.8%. 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 × time horizon interaction ($F(1, 52) < 1$). We discuss the reason the priming effect did not carry over across the two tasks subsequently.

Importantly, however, when using the subjective time estimates (that were affected by the priming task) and comparing the resultant pattern of discounting with the pattern

Figure 7
EXPERIMENT 4: DURATION-PRIMING EFFECTS ON TIME PERCEPTION



Notes: Error bars reflect standard error of the mean.

of discounting for 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 on the basis of objective time. As we 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, we calculated adjusted discount rates on the basis of individual subjective estimates of time horizon. For these adjusted discount rates, there was no reliable difference between 1-month (M = 294.96%) and 3-month (M = 308.57%) time horizons (t(53) = –.50, $p = .62$). A 2 (time horizon: 3 months versus 12 months) × 2 (time horizon measure: objective versus subjective) fully within-subjects ANOVA revealed a significant interaction between time horizon and 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. However, given that objective time horizon grows 200% for the same duration, participants in the priming condition were still relatively insensitive to time horizon.

Experiment 4 does not find the same relationship between duration saliency and discount rates as 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; Schwarz and Clore 2006). That is, because participants 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 to 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 replicates 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 resultant pattern of discounting.

GENERAL DISCUSSION

The main goals of this article are to examine how consumers perceive prospective duration and incorporate it into their decisions and to offer a new time perception account for intertemporal preferences. We propose and demonstrate that consumers' subjective perceptions of changes in time duration are 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, these 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 nonlinear 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 a person's subjective estimates of duration, we no longer observe a hyperbolic pattern; instead, discount rates are relatively constant with time. The 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 important, 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 Trade-Offs

The psychophysics of prospective duration. As noted previously, 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 fit a logarithmic function better than a power function, further research should investigate this relationship using specific psychophysical theories of sensory and cognitive processes and corresponding estimation methods (e.g., discriminability of stimuli or direct magnitude estimation; Gescheider 1985). Note also that when conceptualizing future duration, several strong assumptions exist related to the notion 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 with more standard psychophysical transformations. In this article, we focus more on the robust regularity of this mapping and the importance of nonlinear time perception to theories of intertemporal trade-offs.

Hyperbolic discounting as a multiply determined phenomenon. A great deal of research across multiple disciplines has examined how people value different outcomes at different times, 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 toward the present or the future (e.g., Zimbardo and Boyd 1999). In this article, we offered a different perspective, focusing on the effect of people's perceptions of duration itself on intertemporal preferences. Our explanation is consistent with both findings of subadditivity (Read 2001) and findings regarding the role of attention in time discounting (Ebert and Prelec 2007).

However, we do not argue that all instantiations of hyperbolic discounting are fully accounted for by (in)sensitivity to prospective duration. For example, choosing to have one cookie now rather than two tomorrow but two in eight days rather than one in seven days might 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. For example, a person indicating that he or she will search extensively online for the best price the next time buying a book but then ending up at Amazon.com again when the time arrives might be better explained by misprediction of resource slack (Zauberman and Lynch 2005). Similarly, a differential decline in discount rates with time in deferred versus expedited decisions might be explained by 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), in which emotional reactions and or shifts in mental representations may be most dramatic. Even in these cases, however, 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 here is to introduce sensitivity to time horizon as an additional important factor in choice over time that has been mostly neglected in prior research. Further 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

This article focuses 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 nonlinear 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 a person's discount rate is a function of how far an outcome is delayed from the present, Read (2001; see also 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 subintervals; this is called "subadditive discounting." Although 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) to replicate the relevant subadditive aspect of Read's experimental design (e.g., Read and Roelofsma 2003). In addition to the intertemporal preference measure, we 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-millimeter 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 millimeters) as the anchor and compared it with the summed parts in the divided conditions (97.65 millimeters + 110.06 millimeters = 207.71 millimeters), which equals 45.01 months ($t(35) = 5.75$, $p < .0001$). This result implies that participants perceive the total time horizon as longer when it is divided into subintervals than when it is not divided, consistent with our hypothesis. Moreover, for the annual compound discount rate calculated with objective time, those in the divided-duration condition had a higher discount rate (M = 60.37%) than those in the 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 the undivided (M = 34.20%) conditions (t(35) = .002, not significant). These findings suggest that people's 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. However, these are only initial data; further research is needed to explore this link more fully.

Date/delay effect. The date/delay effect is another intertemporal choice phenomenon we try to explain using our time perception–based theory (LeBoeuf 2006; Read et al. 2005). This effect demonstrates that the discount rate is higher when time is described as a delay (e.g., in 3 months) than when it is described as a calendar date (e.g., November 1). We hypothesize that people's subjective time perception is more contracted when time is expressed as calendar dates than when it is expressed as delay. To provide initial evidence for this conjecture, we asked 28 undergraduate students to estimate duration between two times on a 180-millimeter 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 24 and November 1). The results show that participants perceive duration as significantly longer when given as delay (M = 65.36 millimeters) than when given as a calendar date (M = 38.79 millimeters; 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 with normative discounted utility theory. We propose that an important determinant of such anomalies (and hyperbolic discounting, in particular) is the way people perceive and integrate prospective duration. Because 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 people's subjective perceptions of time.

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