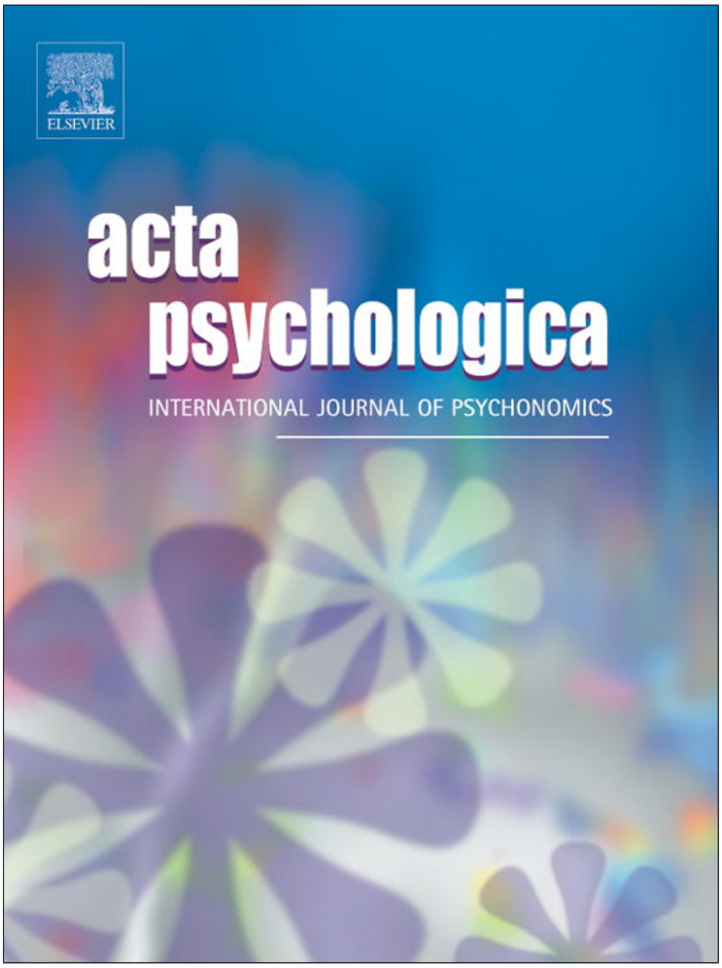

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Four days later in Cincinnati: Longitudinal tests of hyperbolic discounting ☆

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ABSTRACT

Hyperbolic discounting of delayed rewards has been proposed as an underlying *cause* of the failure to stick to plans to forego one's immediate desires, such as the plan to diet, wake up early, or quit taking heroin. We conducted two tests of inconsistent planning in which respondents made at least two choices between a smaller–sooner (*SS*) and larger–later (*LL*) amount of money, one several weeks before *SS* would be received, and one immediately before. Hyperbolic discounting predicts that there would be more choices of *SS* as it became more proximate—and, equivalently, that among those who change their mind, "impatient shifts" (*LL*-to-*SS*) will be more common than "patient shifts" (*SS*-to-*LL*). We find no evidence for this, however, and in our studies shifts in both directions were equally likely. We propose that some of the evidence cited on behalf of hyperbolic discounting can be attributed to qualitatively different psychological mechanisms.

> I started for Texas in my car. I had 1/16-ounce of junk with me. I figured this was enough to taper off, and I had a reduction schedule carefully worked out. It was supposed to take twelve days. I had the junk in solution, and in another bottle distilled water. Every time I took a dropper of solution out to use it, I put the same amount of distilled water in the junk solution bottle. Eventually I would be shooting plain water. This method is well known to all junkies[…]. Four days later in Cincinnati, I was out of junk and immobilized. I have never known one of these self-administered reduction cures to work. You find reasons to make each shot an exception that calls for a little extra junk. Finally, the junk is all gone and you still have your habit. William S. Burroughs, *Junky* (1953/2003)

1. Introduction

William S. Burrough's account of his failure to kick his heroin habit describes a form of *inconsistent planning*. He planned to allocate his remaining heroin (1/16 of an ounce) among a sequence of future consumption occasions (shots). His plan was front-loaded, with each shot allocated more heroin than its successor. He failed, because each time he revisited his plan—at the moment of the next scheduled shot—he consumed more heroin than he had originally allocated, at the expense of future shots. Burroughs viewed such failures as universal ("I have never known one of these self-administered reduction cures to work.").

Around the same time as Burroughs described his experience, William Strotz (1955) advanced a formal model of inconsistent planning by decision makers who have a present-biased preference ("that calls for a little extra junk") and the freedom to revise previous plans ("you find reasons to make each shot an exception"). The implications of Strotz's model, which could be drawn directly from Burrough's passage, are depicted in Fig. 1, which shows time, starting with the present, on the *x*-axis, and consumption on the *y*-axis. The three lines show consumption plans (i.e., allocations of all one's future resources) made at different times (τ_0, τ_1, τ_2) by someone with fixed future wealth. These are *optimal* plans, in the sense that they are made to maximize the expected total value of a stream of discounted utility. However, the discount function is "hyperbolic" which means that the decision maker discounts outcomes at a rate that is a decreasing function of delay, so that each successive unit of delay has a smaller proportional impact than the preceding one. For instance, an outcome might be discounted by 5% over the first month of delay; the remaining 95% discounted by a further 4% over the second month; the remainder from that discounted by 3% over the third

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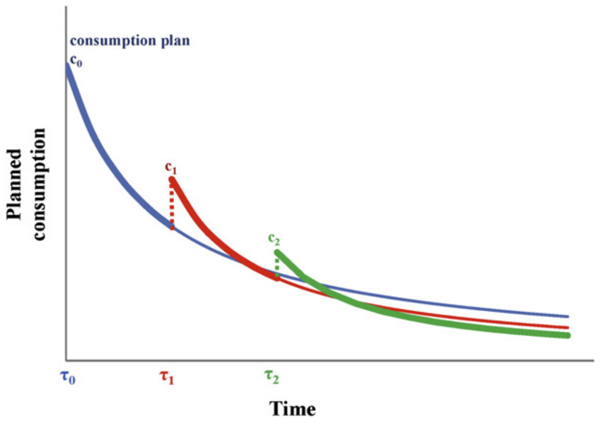

Fig. 1. Inconsistent planning due to myopic or 'hyperbolic' preferences, after Strotz (1955). The figure shows three consumption streams (c_1, c_2, c_3), each having equal net present value assuming to an interest rate of 5%, that would result from hyperbolic discounting with k parameter = .3. The dotted lines show how preferences are revised when new plans are made. The bold lines show the consumption stream that is actually realized.

month, and so on, with what remains always being discounted by proportionally less with each additional delay.

Any positive rate of time discounting will lead to front-loaded consumption plans, such as plan c_0, made at τ_0. Hyperbolic discounting, however, means that when we later revisit that plan, such as at τ_1 in Fig. 1, we will revise it to bring even more consumption forward, further reducing the consumption allocated to the more distant future. This is what Burroughs did, when he consumed more heroin at τ_1 than had been planned at τ_0, and then more at τ_2 than he had planned at τ_1.

Various specifications of hyperbolic discounting have been proposed. Among psychologists, the most familiar is the one proposed by Mazur (1987),

$$V(x,t) = \frac{v(x)}{1+kt} \quad (1)$$

in which $v(x)$ is the value the outcome would have if available immediately, and the parameter k (usually assumed to be positive) reflects discounting for delay. Eq. (1) was used as the basis for Fig. 1. Another highly influential model, especially in economics, is the quasi-hyperbolic function proposed by Phelps and Pollak (1968) and popularized by Laibson (1997), and O'Donoghue and Rabin (1999):

$$V(x,t) = \begin{cases} v(x) & t=0 \\ \beta\delta^t v(x) & t>0; 0<\beta, \delta\le 1 \end{cases} \quad (2)$$

The parameter $\beta<1$ is a 'one time' discount factor applied to all delayed events, while δ is an exponential discount factor which further discounts future events according to the length of their delay. If $\beta=1$ then Eq. (2) is exponential discounting.[1] Several other models have also been proposed which share the hyperbolic feature of time inconsistency (e.g., Killeen, 2009; Loewenstein & Prelec, 1992; Scholten & Read, 2010).

Hyperbolic discounting has been widely discussed as a fundamental characteristic of human motivation. For example, Strotz (1955) supposed that 'most of us are "born" with [such] discount functions' (p. 177). According to Ainslie, who coined the term, "the basic function by which all vertebrates devalue delayed events is hyperbolic" (2005, p. 649). Ainslie and Haslam (1992, p. 71) proposed that "deeply bowed discount functions and consequent temporary preferences for imminent rewards are fundamental properties of motivation." Frank (1988) asserted that hyperbolic discounting 'is apparently part of the hard-wiring of most animal nervous systems.'

2. A study of inconsistent planning

The inconsistent planning frequently attributed to hyperbolic discounting was demonstrated by Read and van Leeuwen (1998), who conducted a study in which respondents chose between junk food (chocolate or beer nuts) or a piece of fruit (banana or apple) on two different occasions. As illustrated in Fig. 2, the first, or *Distant*, choice was made one week prior to consumption, whereas the second, or *Immediate*, choice was made immediately before consumption, enabling respondents to change their original plan. Most respondents were inconsistent, and almost always in the same way—they initially planned to have fruit, but ultimately they changed their mind and took junk food. The respondents acted like stereotypical weak willed dieters, who first plan to eat healthfully, but later succumb to the temptation of fattening foods.

The hyperbolic discounting explanation for such inconsistencies relies on the assumption that the expected short-term benefits ("utility") of junk food exceed those of fruit, but the long term benefits of fruit outweigh those of junk food. This tradeoff is captured in the dieter's proverb "A moment on the lips, a lifetime on the hips." According to hyperbolic discounting, "lip utility" and "hip utility" are weighted similarly when both are significantly delayed (Distant choice), leading many to declare a preference for apples, but when the options are poised to deliver instantaneous utility to the lip (Immediate choice), junk food is chosen.

It is important to appreciate that the differences between the utility profiles is an assumption and not an observation; we directly observe only that preference order changes with the passage of time, but not the reasons for that change. When we explain intertemporal preference reversals with hyperbolic discounting, we risk committing the logical error of the doctor in Moliere's *The Imaginary Invalid*, who "explained" the effect of sleeping powders in terms of their "dormitive virtues." Consider, for instance, someone who

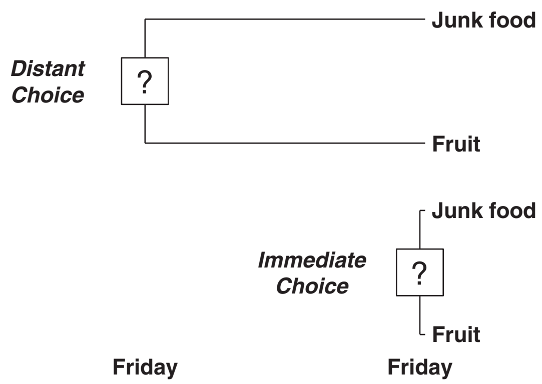

Fig. 2. Design of Read and van Leeuwen (1998). Respondents choose between junk food and fruit on two occasions, one week in advance of consumption, and immediately before consumption.

[1] The two models differ in two key respects. The first concerns the discounting decline profile. The first model holds that the discount rate decreases with time gradually, so that discounting over the first month is greater than that over the second, which is greater than that over the third. The second holds there is a threshold delay which leads to excess discounting, after which there is constant rate discounting thereafter. The time interval corresponding to the "present" is not specified. The second difference between the models concerns long term discounting. Hyperbolic discounting proposes that over the long term the discount rate will be reduced to almost zero, so that while short delays might lead to a lot of discounting, long delays might not lead to appreciably more. This is one reason hyperbolic discounting has been taken up as a good model for the social discount rate (e.g., Gollier, 2002; Harvey, 1995; Weitzmann, 1998). Quasi-hyperbolic discounting proposes that a constant discount rate applies to all delays once the initial delay is past, so even a small discount rate can lead even large outcomes to have zero value which entails disregard for the distant future.

consistently makes reservations at *Thai Taste*, only to later change their mind and eat at *Greek Garden*. Invoking hyperbolic discounting to explain this preference reversal requires some evidence that Greek food has a more front loaded utility profile, but that Thai food yields more utility overall. Without such evidence, hyperbolic discounting is just an impressive sounding label for the phenomenon we wish to explain.

The appeal of the concept sometimes displaces scrutiny of the data cited on its behalf. Consider a study by Christensen-Szalanski (1984), which has been widely interpreted as evidence of hyperbolic discounting (e.g., Bickel & Marsch, 2001; Chapman & Elstein, 1995; Ditto, Jacobson, Smucker, Danks, & Fagerlin, 2006; Prelec & Loewenstein, 1991). That study found that many women who opposed the use of anaesthesia during childbirth changed their mind when labour became painful. A rarely discussed feature of these results is that the preference reversal occurred almost exclusively in first-time mothers, who might understandably have under-predicted how painful the experience would be. Women who had given birth before were largely intertemporally consistent. Thus, the concept of hyperbolic discounting is not needed to explain these data, and distracts readers from the main result.

As the preceding examples suggest, intertemporal preference reversals can be attributed to hyperbolic discounting only if the options can be unambiguously ordered from any temporal perspective, and if one does not gain additional information about their value following the initial decision. Few experiments satisfy these conditions. Most draw upon a design first used in a little known study by Ainslie and Haendel (1983), which we describe next.

3. Ainslie and Haendel's study

Ainslie and Haendel conducted an experimental investigation of inconsistent planning in choices between smaller–sooner and larger–later outcomes. Their design is depicted in Fig. 3. Twenty-three patients in a substance abuse program made one or more choices between receiving a small amount of money on the coming Friday (*SS*), or a 25% larger amount three days later on the following Monday (*LL*). On Friday they were given the opportunity to revise their prior choice, thus choosing between an immediate payment or a larger delayed one. Many did. The most common inconsistency was an *impatient shift*—patients preferred *LL* when both options were Distant, but preferred *SS* when it was Immediate but *LL* was still delayed by 3 days.

One potential problem with this study is that initial choices were not binding, as would become clear to those who participated in multiple successive rounds, or who joined the study after observing others. If respondents in Ainslie and Haendel's study knew they could later reverse their choice, they may have given it less thought, or been more inclined to give a socially desirable response. Thus, the impatient shifts that Ainslie and Haendel observed could have reflected the fact that the first choice was hypothetical and the second real, rather than the change in temporal perspective.

The possibility that Ainslie and Haendel's results *could* reflect something other than hyperbolic discounting suggests a need for further experimentation which retains their basic design but which is less subject to these alternative accounts. This need is underlined by a recent study by Sayman and Onculer (2009), who used a design nearly identical to Ainslie and Haendel's, yet obtained the opposite result. In their study, the subjects were INSEAD MBA students who made Advance and Immediate choices between *SS* and *LL* during successive class sessions. For example, in one class *SS* was delayed by one week, while in the second it was immediate (while *LL* was one week closer). In this setting, Sayman and Onculer observed a majority of *patient* shifts, meaning that as *SS* drew closer their preferences shifted from *SS* to *LL*. They labelled this pattern reverse time inconsistency.

Ironically, the divergent results of these studies may have a common account. Each study was conducted in a group setting, among people who were in daily contact with one another and who would have ample opportunity to discuss the task with their fellow participants. Yet those fellow participants likely differed in their preference for immediate versus delayed gratification, as well as in the views they would come to after reflection and discussion. The 23 participants in Ainslie and Haendel's study were recovering addicts, whereas the 38 in Sayman and Onculer's study were MBA students at INSEAD tested during their course on negotiations analysis. It is easy to imagine how social interaction or discussion or group pressure could move the recovering addicts toward taking money they could spend during the weekend, while the same forces would move the MBA students toward the option with the higher net present value.

These two studies and those we present later are exceptions to the most common tests for hyperbolic discounting because they involve longitudinal rather than cross sectional designs. Before describing our own studies, we discuss this important theoretical distinction.

4. Cross-sectional versus longitudinal time inconsistency

When William Burroughs took the reduction cure, he first planned his heroin consumption, and then changed this plan each time he revisited it. Similarly, in both Ainslie and Haendel's (1983) and Sayman and Onculer's (2009) study, the participants first gave Distant choices which they were later able to revise (if they chose). Such *longitudinal* designs mirror Burrough's ongoing struggle with addiction. However, most other tests of time inconsistency have used a less appropriate *cross-sectional* design, which compares, at a single point in time, preferences between two or more pairs of temporal prospects, separated by a common interval but preceded by different *front-end delays* (see Read, 2004, for further discussion of this distinction). Keren and Roelofsma (1995), for instance, obtained, at a single point in time, both *Immediate* and *Distant* choices in which *SS* and *LL* were separated by four weeks. They found that just 37% of respondents preferred *SS* to *LL* when *SS* was 26 weeks away, whereas 82% did so when *SS* could be obtained immediately.[2]

Such cross-sectional results violate the assumption of a stationary discount rate (Koopmans, 1960), which implies insensitivity to the front-end delay. Perhaps because of this, it is widely assumed that

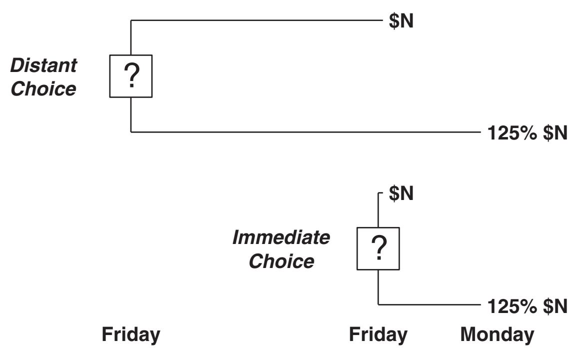

Fig. 3. Design of Ainslie and Haendel (1983). Respondents make two choices between \$N on Friday and \$N(1 + .25) on Monday. The first choice is a Distant choice made on Monday (five days before *SS* can be received and one week before *LL*) and the second choice is an Immediate choice made on Friday (when *SS* can be received, or three days before *LL*).

[2] Keren and Roelofsma's (1995) results are consistent with much of the research using a cross-sectional design (e.g., Bleichrodt & Johanneson, 2001; Cairns & Van der Pol, 1997; Green, Fristoe, & Myerson, 1994; Kirby & Herrnstein, 1995,), although even these studies are not univocal (e.g., Baron, 2000; Holcomb & Nelson, 1992; Read, Frederick, Orsel, & Rahman, 2005; Scholten & Read, 2006). Sayman and Onculer (2009) provide a review.

cross-sectional discrepancies entail *longitudinal inconsistent planning*—that the preference for *LL* when both outcomes are delayed will, with the passage of time, reverse to become a preference for *SS* (e.g., Herrnstein, 1990; Kirby & Herrnstein, 1995; Kirby & Marakovic, 1995; Thaler, 1981). However, this does not follow. As has been discussed previously, cross-sectional, but *not* longitudinal, inconsistencies can occur if the discount rate depends on calendar time rather than temporal distance to the events in question (e.g., Frederick, 2002; Horowitz, 1992; Read, 2004). Suppose a teenage boy wants to buy his girlfriend a gift for her birthday, which is 3 weeks away. It might make sense for him to prefer the $100 now (before her birthday) to $110 in four weeks (after her birthday), but to prefer $110 in 30 weeks to $100 in 26 weeks (since both delays are after her birthday).

Cross-sectional, but not longitudinal, inconsistencies can arise if the risk of default on a promised reward increases at a rate that differs from the standard exponential rate (Azfar, 1999; Sozou, 1998). As both Azfar and Sozou have shown, this can happen if we are uncertain about the magnitude of risks, and adjust our estimates of risk based on experience. Such adjustments will entail cross-sectional inconsistency, but provided that we anticipate them do not entail longitudinal inconsistency.

To illustrate this, consider another variant of Keren and Roelofsma's example. Imagine that "now" is cash with certainty, and all the delayed amounts are post-dated checks. Suppose further you are less than 89% sure any check will be honoured. This doubt would rationalize a preference for the $100 in the Immediate choice. But since the Distant choice involves two postdated checks, which are both approximately equal in risk, it would be rational to take the larger amount. This does not apply to longitudinal decisions — the additional riskiness of a postdated check is not affected by the passage of time. If after 26 weeks the *SS* post-dated check is still valid, then it is likely the 30 week check will also be valid in another four weeks. Sozou (1998) has shown that, holding the interval length constant, the farther it is from the present, the less risk will grow over that interval, leading to cross-sectional but not longitudinal preference reversals.

Although cross-sectional discrepancies are interesting in their own right, they do not imply inconsistent planning, and cross-sectional studies are not true tests of hyperbolic discounting (see Frederick, Loewenstein, & O'Donoghue, 2002). Only a longitudinal design permits such a test. Thus, in the studies reported here, we investigate longitudinal choices, in which individuals' make choices at two different times.

5. Experiment overview

In two experiments, we test for longitudinal preference reversals. Each respondent made their choices in isolation and so social factors were unlikely to have shifted choice in either direction. All the choices were either binding or, in the case of Experiment 2, "apparently" binding. That is, respondents had no reason to anticipate their initial choices were hypothetical or provisional.

Experiments were conducted via email. We measured whether preferences shifted from *LL* to *SS* (*impatient* shifts) or from *SS* to *LL* (*patient* shifts). Participants were recruited through a London School of Economics web page, which advertised the opportunity to participate in paid studies of judgment and decision making. In Experiment 1, participants were compensated with their choice of bank transfers, PayPal payments, Amazon gift certificates, or Ebay gift certificates. Amazon gift certificates proved to be the overwhelming favorite, so we used those exclusively in Experiment 2. Amazon gift certificates have been widely used in studies of intertemporal choice and immediacy effects (Peters & Buchel, 2009; Weber et al., 2007), including some explicitly designed to measure hyperbolic discounting (e.g., McClure, Cohen, Laibson, & Loewenstein, 2004). Both McClure, Ericson, Laibson, Loewenstein, and Cohen (2007) and Sellitto, Ciaramelli, and Pellegrino (2010) have also shown that the neural response to immediate gift certificates is the same as that to immediate primary rewards.

6. Coding switching behavior

Theories of hyperbolic discounting predict that preferences will shift from *LL* to *SS* as the passage of time reduces the front-end delay. In the analyses of experiments, we report two different indices of this tendency: (1) The *SS ratio*, the fraction of respondents who choose *SS* when it is immediately available relative to the fraction who do so when it is delayed, and (2) The *switch-proportion* (SWP), the proportion of impatient shifts to all shifts, which excludes consistent responders, thereby focusing the metric exclusively on switching behavior. To illustrate the two metrics, consider the choice pattern below:

		Immediate choice	
		SS_I	LL_I
Distant choices	SS_D	100	1
	LL_D	10	100

The *SS* ratio is close to 1 (specifically, 110:101 ≅ 1.1), which accurately reflects the predominance of consistent choices—all but 11 of the 211 respondents made the same choice both times; they were consistently patient or impatient. Yet the SWP is .91 (i.e., 10:11), which reflects the fact that the inconsistencies which do occur are overwhelmingly likely to be impatient shifts. Hyperbolic discounting predicts that SWP will be greater than .5, whereas the reverse time inconsistency reported by Sayman and Onculer means an SWP of less than .5. The calculations for these indices are given in Table 1.

7. Experiment 1

7.1. Method

The respondents were 187 people, drawn from two UK universities (London School of Economics and Leeds University Business School) and our own online database, which was being formed during this study. Because of attrition over the course of the experiment, we report the results from 128 respondents who faithfully responded every Tuesday.

Table 2 depicts the design of the experiment and the results. Over four consecutive Tuesdays, respondents made a total of 10 choices between smaller–sooner (*SS*) and larger–later (*LL*) rewards. On the Tuesday of Week 1, they made all four choices (choosing between £20 "within one day" or £21 in one week, between £21 in one week or £22 in two weeks, and so on). On each successive Tuesday, they chose again between remaining options with the delay correspondingly reduced. For example, on Week 2, one of their three choices was between £21 within a day or £22 in one week.[3] Respondents were paid using a random-lottery incentive system (Starmer & Sugden, 1991). Each week, one in fifteen participants was selected to be paid 'for real' for one of their choices, and received the chosen amount on the specified date. This selection applied to every respondent every week.

[3] Pilot tests confirmed that if the difference between *SS* and *LL* was less than $1 (or £1), people overwhelmingly preferred *SS* in the Distant perspective. Conversely, if substantially larger than $1, they substantially preferred *LL*. Neither of these extremes would be desired, since it would permit the expression of only one type of reversal. These findings depart from the results of Ainslie and Haendel (1983), who found that even in the distant condition, a large proportion of respondents were unwilling to wait 3 days for a reward which was 25% greater.

Table 1
Computation of switching statistics.

		Immediate choice		Total	SS ratio	Switch proportion SWP
		SS	*LL*			
Distant choice	*SS*	Always impatient (*ii*)	Patient switch (*ip*)	SS_D	$\frac{SS_I}{SS_D}=\frac{pi+ii}{ip+ii}$	$\frac{pi}{ip+pi}$
	LL	Impatient switch (*pi*)	Always patient (*pp*)	LL_D		
	Total	SS_I	LL_I			

7.2. Results

Table 2 shows the proportion of *SS* choices, for each onset time. The usual *cross-sectional* time inconsistency (with impatient shifts) predicts that the proportion choosing *SS* will decline moving down each column. This shows how different choices made at the same moment in time are affected by the delay to the earlier of the two outcomes. Cross sectional time inconsistency is observed when the top number in the column exceeds the numbers below it, and this is true for all columns. This is a conservative test of cross-sectional inconsistency, because while the difference between *LL* and *SS* remained constant at £1, the proportional difference declined slightly each week, which should have made *SS* increasingly attractive. Despite this, the preference for *SS* actually decreased slightly over time.

The *longitudinal* inconsistency predicted by hyperbolic discounting would be shown if the proportion choosing *SS* increased moving left to right within a row, or if the numbers increased moving Southeast along any diagonal. That is, if people became more likely to choose *SS* as it became closer in time, when the calendar date was held constant. Neither of these patterns occurred. The data reported in Table 3 focus on the three comparisons that should show the greatest evidence of hyperbolic discounting—the Immediate vs. the most Distant choice for the three choices that were assessed from both perspectives. Of the 86 switches observed, 44 were impatient shifts and 42 were patient shifts. The average *SS* ratio was 1.01, and SWP was 51. Thus, the data reveal no evidence of hyperbolic discounting, by either of the diagnostic indices.

The data from the three related studies described earlier (Ainslie & Haendel, 1983; Read & van Leeuwen, 1998; Sayman & Onculer, 2009) are also shown in Table 3. A more formal statistical analysis of all data is provided after the description of Experiment 2.

8. Experiment 2

8.1. Method

In Experiment 2, we modified some features of Experiment 1 that may have suppressed the emergence of hyperbolic discounting. We reduced the payment lag from approximately one day to less than one hour to increase the immediacy of the "immediate" payment. We also simplified the task, obtaining only a single choice between *SS* and *LL* from the two different temporal perspectives (*Distant* and *Immediate*). We also asked respondents to later explain their choices, which provided us with another measure of preference, and some insights into the reasons for their preference.

Participants were 201 US residents who had not participated in Experiment 1 and who responded to an emailed invitation to participate. The invitation gave no hint of the questions to be asked. Participants were randomly assigned to one of three incentive conditions: (1) *Hypothetical*—choices were not consequential; (2) *Probabilistic*, as in our first experiment, and (3) *Certain*—every respondent received the option they preferred in *Immediate* choice. The three payment conditions were described as follows:

> [*Hypothetical*:] This choice is hypothetical, but please choose the same thing you would if you were making it "for real"—i.e., imagine that you will actually receive the gift certificate you choose at the specified time.
>
> [*Probabilistic*:] One in every ten participants will be randomly selected. If you are selected, you will actually receive the gift certificate you choose at the specified time.
>
> [*Certain:*] The choice is for real, and you will actually receive the gift certificate you choose at the specified time.

For the *Distant* choice, respondents chose between an Amazon gift certificate for $20 on the Tuesday "three weeks from today," or a certificate for $21 "five weeks from today." Three weeks later, in the *Immediate* condition, they had an unanticipated opportunity to revise their choice—they chose between a certificate for $20 "delivered by email immediately (within an hour)" and a certificate for $21 available "two weeks from today." To make good on our promise to provide the *SS* certificates immediately, we took turns sleeping and answering emails so that respondents would receive the reward whenever they happened to be on email. Respondents who chose *SS* always received their certificate within an hour, and usually within a few minutes.

8.2. Analysis of choices

The results shown in Table 3 confirm the findings of Experiment 1. We again found no evidence for hyperbolic discounting. If the three

Table 2
Design of Experiment 1 and proportion choosing *SS*.

Choice in week 1		Week in which choice was made				
SS	*LL*	1	2	3	4	Mean
£20 in 0 weeks	£21 in 1 week	.47[a]	–	–	–	.47
£21 in 1 week	£22 in 2 weeks	.38	.41[a]	–	–	.40
£22 in 3 weeks	£23 in 4 weeks	.39	.36	.37[a]	–	.37
£23 in 5 weeks	£24 in 6 weeks	.38	.37	.34	.39[a]	.37
	Mean	.41	.38	.36	.39	.39

[a] Immediate choices. All others are Distant choices for the options specified on the row.

Table 3
Results of Experiments 1 and 2, compared with benchmark results from Ainslie and Haendel (1983), Read and van Leeuwen (1998), and Sayman and Onculer (2009).

Condition	Always patient	Impatient switch	Always impatient	Patient switch	n	SS ratio	SWP
	pp	*pi*	*ii*	*ip*			
Experiment 1							
Week 1 ➔ 2	66	14	38	10	128	1.08	42
Week 1 ➔ 3	64	14	33	17	128	.94	.455
Week 1 ➔ 4	63	16	34	15	128	1.02	51
Combined[a]	193	44	105	42	384	1.01	.51
Experiment 2							
Hypothetical	21	4	33	7	65	.93	36
Probabilistic	10	9	36	5	60	1.10	64
Certain	16	6	46	8	76		43
Combined[a]	*47*	*19*	*115*	*20*	201	.99	49
Ainslie and Haendel (1983)							
Combined[a]	18	26	23	4	66*	1.81	.87
Sayman and Onculer (2009)							
Combined[a]	40	29	93	66	228[a]	.81	.31
Read and van Leeuwen (1998)							
HH[b]	2	9	37	2	50	1.18	.82
SH[b]	4	19	25	2	50	1.63	.90
HS[b]	9	19	22	0	50	1.86	1.00
SS[b]	14	23	12	1	50	2.69	.96

[a] Combined over all experimental conditions with some respondents appearing more than once.
[b] HH: Hungry during immediate and distant choice; SS: satiated during immediate and distant choice, and so on.

incentive conditions were pooled, *SS* was actually chosen slightly *less* often in Immediate than in the Distant choice.

8.3. Statistical tests: A Bayesian analysis

Our results show no mean tendency to make impatient rather than patient shifts. The significance of this finding depends on the degree of confidence with which we can rule out alternative hypotheses. We addressed this question by conducting a Bayesian analysis that compared our results with earlier studies to establish how certain we can be that the respondents in our studies had little or no tendency to make impatient shifts, and whether the results of our study differ from those of earlier ones.

To conduct the analysis we first assume the population of respondents has an unknown tendency to show impatient shifts, what we call the *population SWP*. We then compute a posterior distribution for this SWP from the observed data from our own studies and those summarized in Table 4. We treat switching as a binomial process, and assume a uniform prior for the switch rate over the range [0,1], meaning a Beta distribution with parameters a = 1 and b = 1. As shown by Edwards, Lindman, and Savage (1963) the choice of a prior makes little difference if (a) the data are highly diagnostic, and (b) the prior would be "smooth" over the range of possible values in any case. For each data set, we computed the posterior beta distribution, which has the following mean (μ) and variance (σ^2; for details, see Iverson, 1984, p. 31–33):

$$\mu = \frac{a + pi}{a + b + pi + ip}, \quad (3)$$

$$\sigma^2 = \frac{\mu(1-\mu)}{a + b + pi + ip + 1} \quad (4)$$

In these formulas, *pi* is the number of impatient shifts (i.e., from *p*atient to *i*mpatient), and *ip* the number of patient ones (from *p*atient to *i*mpatient), and *a* and *b* are the parameters of the Beta distribution—we assumed both are 1. The posterior distribution over possible population values of *SWP* can then be computed directly from these values, and the 95% credible interval (or Bayesian confidence interval) for this population value can obtained in the usual way as $\mu \pm 2\sigma$ (Fig. 4).

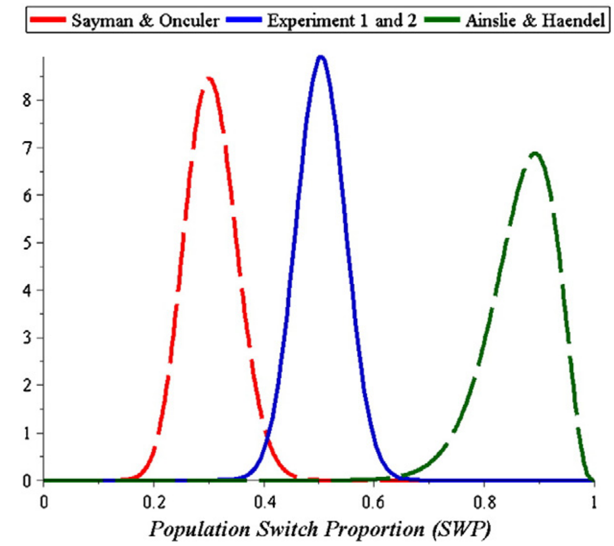

Fig. 4. Posterior distributions for switch-proportion for three papers adopting a longitudinal design involving monetary amounts: Ainslie and Haendel (1983), Sayman and Onculer (2009) and our Experiments 1 and 2.

Our studies provide no evidence for a bias in favor of patient versus impatient switches. The posterior distribution is tightly centered around a mean (μ) of .50: the variance (σ^2) is .0013 and the 95% credible interval over population switching proportions is from.43 to.58. The posterior distributions from the previous studies diverged from our own studies and with each other. Ainslie & Haendel's data produce a posterior distribution with very much higher SWP values than ours (μ= .86,.75 to .97), while Sayman and Onculer's data produced distribution with much lower values for SWP (μ= .31, .24 to .38). None of the credible intervals overlap. It is clear that the three data sets are highly unlikely to come from populations having the same underlying population switching rate. We conjecture that the primary cause of the differences across studies are the presence of social factors, which are absent from our study and which push in opposite directions in the former two studies.

An analysis of the data from Read and van Leeuwen's snack study shows a result similar to Ainslie and Haendel's yet even more extreme (μ= .94, .88 to .99). We suggest that both studies create circumstances that are conducive to impatient shifts. In Ainslie and Haendel's study the social pressures for resources to fund a good weekend were likely to be greatest on Friday, while in Read and van Leeuwen's study the visceral arousal associated with "junk food" is likely to be greatest when there is an opportunity to consume it immediately.

8.4. Analysis of explanations

One week after respondents' made their second (Immediate) choice, we asked them to provide reasons for both choices, stressing that 'if there was something different about the first situation than the second, we would like to know about that.' Nearly all respondents (96%) provided an explanation. The great majority of explanations (73%) contained no suggestion that temporal perspective changed preference intensity. For example, respondent #10, who was consistently patient, explained their first choice of LL, as follows: "There was nothing I wanted from Amazon that couldn't wait another two weeks or more. In that case, waiting and choosing the extra dollar seemed prudent." When explaining their subsequent choice, #10 merely reiterated his prior viewpoint, remarking "This was based on the same consideration as before. There was no urgency in my desire to acquire the gift certificate; therefore why not wait and perhaps receive a gift certificate of greater value?"

However, among the 155 respondents who chose consistently, 27 noted some change in the strength of preference between *SS* and *LL*. For instance, respondent #301 chose *SS* both times, but reported that *SS* was even more attractive in the immediate choice. When recalling the first (Distant) choice, she explained: *I'm always in need of money and I didn't want to wait the extra two weeks for 1 dollar.* A week later, she expressed the same view, but much more strongly: "…wow $20 in less than an hour, I would never have chosen LL and waited two weeks for 1 extra dollar. There is a big difference with the second question, 1 hour and two weeks."

Some explanations recapitulated the "psychophysical" theories that several researchers have proposed (e.g., Leland, 2002; Loewenstein & Thaler, 1989; Rubinstein, 2003; Zauberman, Kim, Malkoc, & Bettmann, 2009), by suggesting the perceived magnitude of a given temporal interval increased as onset time diminished.[4] Respondent #84 remarked: "Waiting an additional two weeks, when it has already been three weeks doesn't seem so bad. Waiting

[4] Psychophysical explanations can, however, go the other way and four respondents who explained their patient shift offered what might be called an 'antihyperbolic' psychophysical explanation. For example, Respondent #26 reported: " …in the first circumstance [the Distant choice] you were waiting a total of five weeks as opposed to the second circumstance [the Immediate choice] being only two weeks. Five weeks seemed a long time to wait for only an extra dollar, whereas it only being two weeks total on the second seemed reasonable."

two weeks, when the other option is an hour seems like a lot. You're waiting 66% longer for the first question. For the second question you're waiting 336,000% longer, if my math is right."

Many respondents who exhibited impatient shifts appealed to unanticipated changes in needs or circumstances. Respondent #85 explained her shift from *LL* to *SS* as follows: *I was feeling down that week, I had just given 2 weeks notice for my job and felt pinched for money. I thought that it would be a nice pick-me-up to have a gift certificate immediately to spend.* Similarly, respondent #82 (who was in the probabilistic condition) reports "[initially] I was not in a hurry to spend any money and I felt like the wait was worth it." [but later] *I realized that I had my husband's birthday coming up soon, and if I had gotten the $20 gift certificate that day, I could have used it towards his present*.

In contrast with the way temporal inconsistency is usually conceptualized (as changes in the weight placed on the utility of imminent consumption) these comments suggest instead unanticipated changes in the quality of imminent consumption opportunities. Since specific immediate needs can be conjured much more readily than specific future needs, allocating resources to *identified* needs favors the present over the future. This account has an obvious kinship with temporal construal theory (Trope & Liberman, 2003), and with Zauberman and Lynch's (2005) findings that people imagine greater slack in their future monetary and time budgets than actually prevails when the amorphous future needs (for time and money) crystallize into concrete current needs. The response of #82 illustrates this perfectly, as she failed to consider her husband's impending birthday until the Immediate choice was upon her.

9. Discussion

Inconsistent planning is the central prediction (and *raison d'etre*) of hyperbolic discounting. As opportunities for consumption become imminent, prior decisions are assumed to be revisited and revised in favor of options offering more immediate rewards. This notion will be intuitively compelling to anyone who has opted for fifteen more minutes of sleep when it would mean being late to an event that mattered, or watched a mediocre TV program rather than working on a project critical for future career success.

The intuitive appeal of hyperbolic discounting undoubtedly helps explain its warm reception and rapid adoption in economics, psychology, and philosophy. As Prelec (2004) notes, it "now functions almost as a default option for analyzing the misbehavior of economic agents." In light of this, it is surprising how little direct evidence exists for its central prediction. Most studies use a theoretically inappropriate cross sectional design or stimuli that cannot reliably be described as 'smaller–sooner' and 'larger–later,' and even these studies are not unequivocal in their support.

When we conducted two experiments designed to reveal the systematic inconsistencies predicted by hyperbolic discounting, we failed to find any evidence for them. Although many people changed their mind with the passage of time, the smaller–sooner reward was not chosen more often when it was immediately available. Though these data surprised us (and we *were* surprised), we accept them as evidence against hyperbolic discounting, as it is usually conceived.

We have presented our data to many proponents of hyperbolic discounting, who have responded in different ways. One response is that our results "merely" show a desire for consistency—that our respondents remembered their Distant choices, and chose the same thing in their Immediate choices. This argument fails in two ways: (1) We did *not* observe universal consistency. Many respondents did make inconsistent choices, but patient shifts were as common as impatient shifts; (2) Except in response to our data, we have never before seen memory offered as a solution to the problem of inconsistent planning. No one, for instance, has questioned why Odysseus' bothers to tie himself to the mast rather than simply tying a string around his finger to remind himself not to steer his ship into the rocks when the sirens beckon.

Another objection is that the theory of hyperbolic discounting does not apply to the circumstances of our experiment, which gives people too great an opportunity to 'think about' their decisions. This view was proposed by Strotz (1955), who argued that people can transform their innate hyperbolic function into an exponential one through education, and by Ainslie (2001, p. 32) who suggests that rewards which lend themselves to mental arithmetic may not reveal our "natural spontaneous preferences," but only those we have been educated to express. In this view, consistent planning is a special type of achievement which conceals the "true" underlying discount function that we allegedly share with lower animals, and our results reflect "only" this educated response and not the basic underlying desires. Though we accept the metaphor of conflicting selves concurrently dwelling in human heads expressing different discount functions at different times, we reject the idea that impatience is somehow more fundamental than patience. Dismissing the relevance of consistent behavior by positing the emergence of an "educated" self is no more satisfying than invoking an ephemeral "uneducated" self to explain away inconsistent behavior.

Although our results offer a challenge to hyperbolic discounting as a psychological theory, we do not propose that impulsivity or time inconsistent choices do not occur. It is obvious that they do and that they are common. William Burroughs failed in his battle with heroin; many have unprotected sex with condoms nearby; sleep in after resolving not to, and make futile vows to skip dessert. We do suggest, however, that alternative accounts of inconsistency be given more attention. We will examine two such explanations: Loewenstein's (1996) visceral arousal theory, which does not identify time as the causal mechanism, and Trope and Liberman's (2003) temporal construal theory, which does not see the effect of time as involving discounting.

Loewenstein's theory begins with the observation that most 'real world' behaviors attributed to hyperbolic discounting fit a familiar pattern: the agent is exposed to stimuli which trigger primary drives, and increase the desire to perform behaviors that will satisfy those drives. The odor of frying bacon, for example, might induce a strong desire to quickly locate the source and share in the feast. But this desire is evoked by the exposure to the olfactory cue, and not the (likely) temporal proximity of the bacon. Someone in an odorless room might choose fruit over bacon even if both could be had immediately, but change his mind if the scent of sizzling bacon were vented into the room, even if he was told the bacon would take longer to prepare. The powerful effect of the stimulus trigger in these situations can be mistakenly attributed to time because, as Herman and Polivy (2003) have observed, temporal availability and physical presence are almost perfectly confounded in nature—when we smell bacon it can usually be quickly acquired for consumption.

Loewenstein's model leads to a specific prediction. If Distant choices are made when in a state of desire, brought on by the presence of a triggering stimulus, then people will choose in line with their current arousal state. For example, if we can smell bacon frying when writing our grocery list, bacon will appear on that list. This phenomenon was illustrated in a study conducted by Van Boven and Loewenstein (2003), in which respondents who imagined being stranded in the wilderness indicated whether it would be worse to be hungry or thirsty. Although this was a prediction of a (hypothetical) *future* situation, their current situation mattered: after exercising, respondents were much more likely to predict that thirst would be the more pressing future problem. This reversal occurred because the 10 min of exercise made respondents thirstier, and not because it brought them 10 min closer to the choice of whether to pack food or water. Though the draw of visceral factors may be enhanced by the opportunity for immediate consumption, visceral arousal is the *primary* determinant of impulsive preference reversals. Such arousal is only evoked under some circumstances—and evidently not by the circumstances prevailing in our experiments

Temporal construal theory (Trope & Liberman, 2003) maintains that temporal perspective influences *which* features we attend to and the way we interpret them (but not the value placed on current versus future satisfaction). According to this theory, distant events are represented abstractly, in terms of a few essential features, and evaluated in terms of superordinate goals; whereas proximate events tend to be represented concretely, in specific detail, and are evaluated with reference to a variety of subordinate goals.

Since temporal distance can either accentuate or attenuate the significance of various attributes, and choice is based on options *as they are currently (mentally) represented*, options whose features satisfy lower level concrete goals will tend to be favoured in the short term, whereas options whose features satisfy higher order, more abstract goals will look more attractive from a more distant perspective. Changes in construal brought about by the passage of time can lead to inconsistent planning. For example, in Study 5 of Trope and Liberman (2000), respondents primed with a cognitive goal ("learning about a topic") chose an informative dry film over an uninformative funny one when both films were in the distant future, but chose the funny film when both would be viewed immediately (see also, Read, Loewenstein, & Kalyanaraman, 1999). If one assumes the funny film has higher short term utility but lower long term utility, this effect mimics hyperbolic discounting, and could be explained in these terms. Importantly, however, if respondents were primed with an affective goal ("getting oneself in a good mood") they were more likely to choose the funny film when choosing for the future than when choosing for the present. This contradicts hyperbolic discounting, but is consistent with temporal construal theory, which assumes that higher order goals are given more weight for the more distant future than for the more immediate future.

Both visceral factors theory and temporal construal theory differ from hyperbolic discounting—and related "discount function" explanations for discounting *behaviour*—in that they locate motivation in the value function and not in a discount function. To clarify this, we will use a bit of notation and a simple time discounting model. We assume that the current value V of an outcome ($\mathbf{x}$) received at time t is discounted by both a hazard function $p(\mathbf{x},t)$, which registers the probability that x will be received at time t, and a discount function $D(t)$ which registers the current weight given to the value that an outcome $\mathbf{x}$ will have when it is experienced at time t, $v(\mathbf{x},t)$. These sources can be jointly captured in the expression below:

$$V(\mathbf{x},t,p) = D(t)p(\mathbf{x},t)v(\mathbf{x},t)$$

The theory of hyperbolic discounting locates the source of valuation changes (and inconsistent planning) in the discount function $D(t)$, and, specifically, in the assumption that $-D'(t)/D(t)$ is decreasing in t. For the Mazur (1987) function, for instance, this is equal to $k/(1+kt)^2$. The assumption is therefore that the causal factor underlying changes in preference is *time*.

Alternative accounts of inconsistent planning can locate valuation changes in either the hazard function $p(\mathbf{x},t)$ (as already discussed, see Azfar, 1999 and Sozou, 1998), or the value function $v(\mathbf{x},t)$. In the equation above, we denoted the outcome $\mathbf{x}$ as a *vector*, to indicate that the outcome can often be decomposed into more elementary attributes, each of which can be affected differently by contextual or situational factors, including the passage of time. It is here that both visceral factors theory and temporal construal theory locate the incidental or direct effects of time.

According to visceral factors theory, the ability of an outcome to satisfy a particular desire receives greater weight when an environmental trigger for that desire is present, and presence or absence of these cues may be correlated with time. According to temporal construal theory "higher level" features get relatively more weight as outcomes are increasingly delayed. Neither theory requires that the overall value of an outcome is reduced if it is delayed, which renders unnecessary the discount function $D(t)$. In its place, inconsistent planning is explained in terms of temporal variation in attentional focus, which may depend on the passage of time (as in temporal construal theory), or merely be correlated with it (as in visceral factors theory). An explicit account of this approach is given in Read, Frederick & Scholten (In press).

10. Afterword

We find no evidence for systematic inconsistencies in planning that could motivate an assumption of hyperbolic discounting, and we question whether a hyperbolic discount function is necessarily the best account for such inconsistencies even when they do occur. More broadly, we also question whether people's lives are generally compatible with the constant operation of a hyperbolic discount function. A hyperbolic discounter, given continuous or frequent opportunities to indulge the present self will do so, repeatedly impoverishing his future (as is shown, in Fig. 1, by ongoing decline in long-delayed consumption from c_0 to c_1 to c_2). Such examples can, of course, be found (the smoker whose repeated gratification of a current craving for nicotine causes lung cancer). But counterexamples may be more abundant. Indeed, at least among those still alive to participate in surveys, the dominant regret is not excessive indulgence, but failures to indulge (Gilovich & Medvec, 1994; Hattiangadi, Medvec, & Gilovich, 1995; Kivetz & Keinan, 2006). When reflecting upon his life, even Burroughs remarked:

> I have never regretted my experience with drugs. I think I am in better health now as a result of using junk at intervals than I would be if I had never been an addict. When you stop growing you start dying. An addict never stops growing" (Burroughs, 1953/2003, p. 13).

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