Cognitive Limits, Apparent Impatience, and Monthly Consumption Cycles: Theory and Evidence from the South African Pension

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Abstract

Larger reactions to earlier incentives are usually attributed to time preference. However, cognitive limits could also generate behavior that appears impatient. We present a simple model illustrating "local" intertemporal decisions, then apply this interpretation to the puzzle of monthly consumption increases upon receiving predictable income: limited cognition explains stylized facts that preferences cannot. A survey experiment among South African pension recipients verifies novel predictions. Consumption cycling was concentrated among participants with low cognitive resources. This effect was greatest for participants with variable spending needs. Simulations explore heterogeneous effects of changing policy towards more frequent benefit payments, which could increase cycling.

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1 Introduction

When people are more responsive to earlier costs and benefits than to delayed incentives, economists, policy-makers, and common sense all ordinarily attribute such behavior to time preference. However, this paper proposes that many instances of behavior that responds most to present or sooner incentives could in fact be due to cognitive limits to intertemporal decision-making. Choice technology that finds it easier to optimize over temporally nearer consequences may encourage behavior that seems to reflect impatient preferences.

First, a simple model demonstrates that impatient-seeming behavior can be the result of cognitive limits to decision-making — even without any time preference, and especially when deliberation costs are high or the future is very uncertain. The rest of the paper applies these ideas to the intra-monthly consumption puzzle: the widespread tendency to consume more at the beginning than the end of even a short, predictable pay period, even in the absence of credit constraint. Agents' use of "local," rather than "global," intertemporal decision-making explains stylized facts about consumption and apparently impatient choice that models of time preference cannot.

Next, a survey experiment among state old age pension recipients in Cape Town, South Africa verifies novel predictions of the model. In door-to-door interviews, surveyors offered a discounted product for sale to participants who were randomly assigned to be interviewed either the week before or after their pension payday. In the experiment, the intra-monthly difference in consumption proved to be concentrated primarily among participants with low cognitive resources. Moreover, consumption cycling was especially likely among those with low cognitive resources and highly variable spending needs.

Finally, we present an applied model of intra-monthly consumption of a pension. The model elaborates on the principles behind the simple model. By explaining the findings of the survey experiment in a richer theoretical context, the model demonstrates how concepts of local intertemporal decision-making under cognitive limits can be applied to economic issues. This model is used to simulate the effects of a policy change: unlike in models of time preference, here modifying the benefit program to make smaller payments more frequently could decrease *or increase* monthly cycling.

The remainder of this section presents the simple model in the context of prior theoretical literature. Section 2 describes the intra-monthly consumption puzzle and the stylized facts to which the theory will be applied. Section 3 reports the survey experiment. Section 4 then presents an applied model, tailored to the experiment. Section 5 considers policy implications for the benefit program, and section 6 concludes.

1.1 Local intertemporal decisions

Behavior that responds most to immediate or present-time costs and benefits is often interpreted by economists as evidence of impatience, a preference for earlier rewards. This definition of impatience follows Elster (2007) – "preference for early reward over later reward" (154) – and, like Elster's, is intended to distinguish impatience from other factors in intertemporal decision-making besides preference over the timing of outcomes.

In response to time-inconsistent behavior that cannot be interpreted as a result of exponential discounting, economists have complicated models of time preference to include "present-biased preferences" (O'Donoghue and Rabin, 1999) or "hyperbolic discounting" (Laibson, 1997). These approaches modify the utility functions that agents intertemporally optimize. However, as this paper suggests, special responsiveness to more immediate or present benefits and costs is not always sufficient evidence for time *preference*, in particular.

Psychologists often differentiate between two systems of processing, one "local" and one "global" (Navon, 1977; Fiske and Taylor, 1991; Kahneman, 2003). Local decision-making is less taxing of limited cognitive resources. This paper explores the consequences of the premise that immediate, specific, present, or "local" consequences may be easier to understand or optimize than remote, overall, future, or "global" consequences. If cognitive limits take this form, then what appears to be impatience may not reflect time preference at all. Without denying that impatience can be very important, we will suggest that local intertemporal decision-making can explain some cases that time preference cannot.[1]

Whether, in any particular case, apparently impatient behaviors indeed reflect preferences matters not only for prediction but also for welfare and for policy design. As Beshears et al. (2007) and others have noted, time-inconsistent preferences pose a special problem for welfare economics: which time period's preferences count? Thus, for example, while many economists evaluate time-inconsistent welfare from a "long-run" perspective, Bernheim and Rangel (2009) propose a normative approach that recommends policy respect agents' first-period choices. However, if behavior is actually caused by costly intertemporal decision-making, the it is unnecessary to resolve disagreement among multiple temporal selves: there is only one preference ranking.

Our model of endogenously local decision-making belongs to a growing literature documenting different effects of differently cognitively salient, but otherwise theoretically equivalent, policy options (*eg* Chetty et al., 2009; Jones, 2008; Sahm et al., 2010; Tufano, 2010). As section 5 explores, bounded intertemporal rationality could have complex consequences for a policy change often proposed in the literature: shortening benefit pay periods with smaller payments. With cognitive limits, this policy change would have a different incidence of benefits than in the case where cycling is only caused by time preference. Indeed, cycling may increase for some people.

1.2 A simple model

The central ideas of this paper can be demonstrated with a simple, abstract model, outlined in Table 1 and inspired by the psychology of "local" decision-making. The agent must choose between two options: option A or option B. The model has three periods, 1, 2, and 3. She chooses A or B in the first period. The agent will receive a payoff in each of the first two

[1]To be clear, our approach also assumes a "present bias" in agents' understanding and optimization technology. However, we will follow the convention of reserving the term *present bias* for present-biased preferences.

Table 1: Three periods, two options

option	period 1	period 2	period 3
A	x_{1A}	x_{2A}	p chance of e
B	x_{1B}	x_{2B}	p chance of e

periods, and these payoffs depend on which option she chooses; thus she will receive either x_{1A} and x_{2A} or x_{1B} and x_{2B}.

Her utility is additive and does not discount across periods; she enjoys $x_1 + x_2$. Thus, there is no time preference, and she has no utility-based reason to prefer receiving more earlier. There is, however, a probability p of a shock to the payoff structure in the third period. If the shock occurs, her utility is not $x_1 + x_2$ but instead is e, no matter whether she chose A or B, where e is the expected payoff under the changed payoff structure. For the purposes of this illustration, the shock could be a disaster, with $e = 0$, or a benefit, with e large. The point is that the shock is outside of her control; p is the same whichever she chooses. All payoffs x are independently and identically uniformly distributed on the unit interval $[0, 1]$.

The key premise is that the agent's cognitive resources are limited, and more so about the future.[2] In particular, she easily understands immediate payoffs: in period 1, she knows x_{1A} and x_{1B}. However, understanding the future requires costly contemplation: she may pay a deliberation utility cost c to figure out period 2 payoffs x_{2A} and x_{2B}. If she pays c she learns x_{2A} and x_{2B}, otherwise she knows only that they are iid uniform. So, she is choosing from {deliberate, do not deliberate} then $\{A, B\}$ to maximize in expectation

$$(x_1 + x_2)(1 - p) - c\mathbf{1}_{\text{deliberate}}.$$

[2] Burks et al. (2009) offer a very similar suggestion in their discussion and interpretation of their important empirical results. Their account differs from ours, in that they propose an interaction between affect or preferences and cognition: "We assume that subjects dislike what they do not perceive precisely: an option that is perceived more noisily is, everything else equal, less likely to be chosen than one perceived more precisely." In this paper's simple model, the agent understands the earlier period better than she does the later period, similarly for both options; paying the deliberation cost equally clarifies them both.

To an economist or other observer who does not know about her deliberation costs, she would appear to be choosing impatiently when she chooses the option with more immediate benefits, the option with the greater x_1. She would seem especially impatient when she chooses that option even when the overall utility offered by the other option is greater. So, to ask when she will appear impatient is to ask when she will choose the option with more immediate benefits.

Proposition. *The probability of choosing the option that offers the higher period 1 payoff is (weakly):*

- *increasing in cognitive limits or costs c, even if $p = 0$,*
- *increasing in uncertainty p, and*
- *increasing in c more quickly for greater p.*

Figure 1 plots this result with the model taken literally and computed numerically. The result is probabilistic because payoffs are random variables: behavior depends on the realized draws of x_{1A} and x_{1B}. The probability is "weakly" increasing only because once c or p is large enough, the probability of an apparently impatient choice is 1. A proof is in the appendix. As the plot clarifies, the threat of the shock is not necessary for the relationship between choice and cognition; the probability is increasing in c even when $p = 0$. However, increasing p increases the slope, that is, the effect of c.

The intuition is that the agent chooses the option with a lower payoff in period 1 only if she pays the deliberation cost and thinks. Otherwise the two options match in expectation in period 2, so she chooses the one that offers more in period 1. Therefore, whether she chooses the apparently patient option depends on the costs and benefits of thinking. Clearly increasing c increases the cost, and makes thinking less likely. Perhaps less obviously, increasing p decreases the benefits of thinking: why bother to plan if there is a high likelihood that the shock will wipe out the difference so it will not have mattered what was chosen? Why invest in planning for a future that may not occur?

Both of these predictions differentiate the model from a standard explanation of choice based on impatient or present-biased preferences. In this model, an agent with high deliberation costs, unpredictable futures, or both will choose in a way that will appear impatient — opting for immediate benefits but a lower overall reward — even though she has no time preference over when she receives payoffs.

1.3 Related theoretical literature

Earlier theoretical papers offer antecedents for the argument of this essay: certain forms of bounded rationality can lead to behavior that may be mistaken for a manifestation of impatient preferences. Rubinstein (2003) suggests that laboratory findings of hyperbolic discounting could actually result from a form of bounded rationality in which participants only notice 'dissimilar' properties of alternatives: eleven and twelve years from now are similar while tomorrow is different from today. Other approaches, like this one, model behavior as the interaction of two mental systems (Rustichini, 2008), such as impatient affect and forward-looking deliberation (Loewenstein and O'Donoghue, 2007), or automatic spending and control (Benhabib and Bisin, 2005). Dasgupta and Maskin (2005) also suggest that certain types of uncertainty could encourage apparent hyperbolic discounting: as time goes on, the likelihood of getting a big, ordinarily delayed payoff improbably early decreases, so one might switch to a lottery offering a smaller but likely sooner payoff. Finally, Spears (2011) offers an axiomized representation of intertemporal choice (that is, choice of future choice sets) when bounded rationality causes the agent to only consider a sub-set of her options.

In macroeconomic theory, Sims (2003) proposes rationally inattentive agents who are limited in their ability to reduce the entropy in their understanding of the economic environment. In this spirit, Reis (2006) models consumers who only periodically gather information and plan, and rationally choose when to do so. These papers are anticipated by Akerlof and Yellen's (1985) observation that relatively large behavioral deviations can have small profit or utility costs to the agent near the optimum.

Perhaps the nearest paper to this one is by Karlan et al. (2010). They model consumers who may ignore opportunities for lumpy future spending, so "phenomena attributed to unstable time preference may in fact be due to limited attention." In field experiments in the Philippines and Peru, they find that sending reminders to save to account holders increases treated participants' savings, evidence that limited attention is a constraint on saving. However, unlike this paper, which endogenously accounts for variation in deliberation, in their model, attention and inattention (operationalized as forgetting a future spending opportunity, for which one might want to save) are exogenous conditions for comparative statics.

Finally, while not about intertemporal choice, this paper belongs to a growing recent literature about the implications of contemplation costs for economic choice (Ergin, 2003; Ergin and Sarver, 2010). Chetty et al. (2009) find that cognitive costs shape the relative salience of different forms of taxation. Chetty (2011) applies a conceptually similar model to labor supply elasticities. Similarly, Spears (2009) predicts theoretically and finds in an experiment that deliberation costs influence the price elasticity of demand for an inexpensive investment in health among poor women in rural India.

2 The intra-monthly consumption puzzle

The rest of this paper applies these ideas to the intra-monthly consumption puzzle: people spend more at the beginning of a pay period than at the end, a behavior we will call "cycling." To be clear, intra-monthly cycling is surely contributed to by many mechanisms, such as intra-household competition for resources. We abstract from these to offer a new explanation, which the data will show explains part of the variation in cycling.

Stylised Fact 1. *People exhibit substantial intra-pay-period consumption "cycling" (spending and consuming more at the beginning than the end). This is especially well documented among government benefit recipients, and is seen even among people who are not credit* *constrained.*

Stylised Fact 2. *Cognitive resources (both properties of a person such as ability and properties of a situation such as manipulated cognitive load) are correlated with apparently "patient" behavior that chooses early costs or late benefits, both in the lab and in the field.*

2.1 Intra-monthly consumption cycling

A large and growing set of studies document steeply declining consumption over the month or other pay period. For example, Stephens (2003) finds that US Social Security recipients' spending on instantaneous consumption is not smoothed across paycheck receipt. Mastrobuoni and Weinberg (2009) show that recipients without savings consume 25 percent fewer calories the week before payday than the week after. Similarly, Stephens and Unayama (2010) find consumption cycles among Japanese public pension recipients.

Cycling is not confined to the elderly. Shapiro (2005) documents a 15 percent decline in calorie intake over the food stamp month. Hastings and Washington (2008), using grocery store scanner data, find a similar decline in food stamp expenditures. Dobkin and Puller (2007) find a monthly effect of a California cash payment program on drug related hospitalization and crime. Huffman and Barenstein (2005) and Stephens (2006) use financial diaries to document a decline in consumption spending from paycheck to paycheck among UK households.

The typical conclusion of these papers is that cycling is driven by time-inconsistent, present-biased preferences. Calibrations reject standard exponential discounting, and many authors conclude that "the quasi-hyperbolic model is consistent with" their findings. However, almost none of these papers directly measure time preference to demonstrate that variation in time preference explains variation in cycling behavior.[3]

[3]Shapiro does report some related evidence: food stamp recipients who would accept less than $50 today in exchange for $50 in four weeks are more likely to have skipped a meal last month; however, as Shapiro admits, if this question is a measure of preference, it does not distinguish between time-consistent and time-inconsistent impatience.

Stephens and Unayama (2010) and Huffman and Barenstein (2005) document cycling among households known not to be credit constrained, for example, households with assets and who have and use credit cards. Explaining cycling with time preference alone also requires credit constraint: why would an extremely impatient household not simply borrow into the next month's money at the end of the month? Cycling among non-credit constrained households suggests that present biased preferences cannot be the only explanation.

2.2 Cognitive resources and apparent patience

Lab and field evidence agree that "patient" behavior is associated with the availability of cognitive resources, both due to people's cognitive ability and as manipulated by experimental situations. For example, Frederick (2005) finds and Oechssler et al. (2009) confirm that higher scores on the Cognitive Reflection Test are correlated with selecting larger, delayed rewards, both among students and the general population. In a door-to-door sample of German adults, Dohmen et al. (2007) find that those with higher cognitive ability in IQ-like tests are more willing to wait for more money.

Lab experiments find similar results. Ballinger et al. (2008) show that higher scores on a visual cognitive ability test and more working memory are both correlated with more saving in a lab consumption game. Getz et al. (2009) experimentally manipulate cognitive load to show that a higher load increases impulsive decision-making.

This result extends to non-abstract choices. Burks et al. (2009) find that in addition to choosing larger, later payments in the lab, truck drivers with higher cognitive skill are more likely to keep their job long enough to avoid incurring a costly debt for training. Benjamin et al. (2006) document similar results among Chilean high school students and in a range of behaviors in the US. In a classic experiment, Shiv and Fedorikhin (1999) show that participants asked to remember longer numbers are more likely to choose chocolate cake rather than fruit salad when surprised by the choice when walking down the hall.

2.3 Uncertainty and apparent impatience

While perhaps not yet a sufficiently consolidated literature to constitute a stylized fact of its own, there is some evidence that uncertainty about the future promotes impatient-seeming behavior. Milkman (2009) experimentally finds that "uncertainty about what the future may bring increases individuals' tendency to favor *want* options over *should* options," where "want" options include tempting snacks and entertaining movies and "should" options are healthy foods and educational films. Similarly, Smith et al. (2009) suggest that "the poor tend to be fat not because they have low income, but because they are at a greater risk of becoming destitute:" they propose that obesity is caused by "economic insecurity—defined, roughly speaking, as the risk of catastrophic income loss."[4]

In the lab, Keren and Roelofsma (1995) find that when prizes are probabilistic rather than certain, participants prefer a fancy French dinner sooner.[5] Anderson and Stafford (2009), using real money payments and time delays, present participants with a choice between earlier and delayed money payments, with different experimental treatments imposing different probabilities of actually receiving payments. When both options were risky, participants were more likely to choose the apparently impatient option. Sun and Li (2010), using a choice titration procedure, similarly find less "patience" when both options only have a 50 percent chance of being paid than in a condition with certainty.[6]

3 Experiment

Cognitive limits might explain consumption cycling if these limits encourage local decision-making that emphasizes immediate resources and consumption opportunities, instead of a

[4]Using data on U.S. men, they argue that, controlling for income levels, "a one percentage point increase in the probability of becoming unemployed causes weight gain … to increase by about 0.6 pounds."

[5]This result is from their experiment 4. In experiment 1 they find that risk increases patience. However, other studies attempt and fail to replicate that result, *cf.* Weber and Chapman (2005).

[6]They also find a "magnitude effect," that scaling up rewards increases apparent patience, an implication of the simple model in section 1.2.

full, "global" dynamic optimization. Section 4, below, presents a theoretical application of the concepts behind the simple model to intra-monthly cycling. For now, we can see from the simple model that explaining cycling with cognitive limits implies predictions reflecting the Proposition above. Cycling should be decreasing in cognitive resources, increasing in the unpredictability of the future, and most concentrated among those with low cognitive resources and highly unpredictable futures. Moreover, these effects can be independent of time preference, and indeed could operate in the absence of any time preference, as in the simple model.

In order to test these predictions, we conducted a survey experiment from December 2009 to February 2010, with a team of research assistants, in the Cape Flats of Cape Town, South Africa among recipients of the state old age pension. The experiment explored what explains different depths of intra-monthly consumption cycling among pension recipients.

Participants were randomly assigned to be interviewed either just before or just after receiving their monthly pension payment. At the beginning of each interview, after a short set of introductory demographic questions, participants were offered a product for sale, and decided whether or not to buy it. The interview then asked a set of survey questions, first about their household, then eliciting a canonical measure of time preference, and finally about their household finances. The interview ended with three complementary tests of cognitive resources.

There were several motivations for studying cycling in Cape Town. First, as the substantial prior literature from the first stylized fact attests, consumption cycling among government benefit recipients is important for the design and impact of pension programs, and because "behavioral" biases could be particularly costly to the poor. Bounded rationality may be especially important in policies designed around the choices of the elderly (Abaluck and Gruber, 2009). Second, the South African pension is an economically and socially large institution, interesting in its own right and big enough to create statistically powerful effects (Case and Deaton, 1998). Third, pragmatically, we were able to build upon the Cape Area

Panel Study (CAPS), which had already collected data and made a frame of clusters from which to sample (Lam et al., 2008).[7]

3.1 Procedure

3.1.1 Participants, pensions, and product

The participants were 384 "coloured," female pension recipients, interviewed by a socially similar (although younger) team of eight female surveyors. There was no direct screening by population group, but the experiment script was only in Afrikaans and surveying was done door-to-door in historically "coloured" neighborhoods.[8] Pension recipients were required to be at least 60 years old at this time, and most of the sample was between 60 and 70.

At the beginning of each month, pensioners receive 1010 rand from the government. For 89 percent of participants, the pension was the only source of income in her household. At market exchange rates of 7.4 ZAR to a USD, the pension would be about $130 a month, or about $200 at purchasing power parity.

At the beginning of the interview, participants were offered for sale a single four-bar package of white Lux soap for 12 rand.[9] The experiment's dependent variable is binary: did the participant buy the soap? This price was a 25 to 30 percent discount off of prices seen at area stores; the purpose of the discount was to generate enough sales for statistical differentiation, but the package was not large enough for important long-term stockpiling or resale (surveyors did not visit houses with a window shop). While soap is practical, white

[7] "The Cape Area Panel Study Waves 1-2-3 were collected between 2002 and 2005 by the University of Cape Town and the University of Michigan, with funding provided by the US National Institute for Child Health and Human Development and the Andrew W. Mellon Foundation. Wave 4 was collected in 2006 by the University of Cape Town, University of Michigan and Princeton University. Major funding for Wave 4 was provided by the National Institute on Aging through a grant to Princeton University, in addition to funding provided by NICHD through the University of Michigan."

[8] The other major population group of the Cape Flats is Xhosa speakers. For statistical power and practical reasons we decided to conduct the experiment in only one language; many Xhosa speakers would have been away from home for the summer.

[9] Soap was chosen not only because it is compact and logistically practical for the experiment and desirable to the participants, but also because it is an important but understudied health investment in poor countries (Zwane and Kremer, 2007).

Lux is an exciting brand for this population (Burke, 1996); although this interpretation is not crucial to the findings, if anything it potentially biases results towards time preference, the leading alternative to our explanation.

3.1.2 Randomizing timing of interview

Participants were randomly assigned to be interviewed either in the week before or the week after a pension payment, so either at the beginning or the end of their monthly cash-on-hand cycle. A participant would decide whether to buy the soap by comparing the utility gained from having the soap to the marginal utility of money lost by paying the price. Among participants making global intertemporal decisions out of permanent income and lifetime wealth, there is no reason for this disutility to be different, on average, before and after being paid. Among participants making local intertemporal decisions out of easily mentally accessible resources, this disutility will be higher at the end of the month, when cash on hand is lower. The model is section 4 makes this intuition more precise.

Within the Cape Flats, different communities receive their pension payments on different days at the beginning of the month. Randomization was done at the cluster level, where clusters were small residential areas of about three blocks defined by CAPS. The experiment was conducted in 50 CAPS clusters, arranged into 25 pairs. Each pair was formed within a larger neighborhood, a named area such as Athlone, Mannenberg, or Mitchell's Plain, the level at which paydays tended to vary. Within large neighborhoods pairs were matched to be similar using prior CAPS data. Once all pairs were made, the clusters in each were assigned to be interviewed before and after payday using a computer pseudo-random number generator.

Within each cluster were a few participants who had previously been interviewed by CAPS. We matched 56 participants to CAPS records. The remaining 85 percent of the sample was found by knocking door to door along the roads in and around the CAPS cluster. All interviews were surprise visits.

3.1.3 Observing other covariates

The experiment measured two key properties of participants in order to test whether the effect of the time of the pension month varies along the predicted dimensions: cognitive resources and unpredictability of the participants' spending needs.

The central prediction of the theory concerns cognitive resources. Cognitive resources were measured with three complementary tests at the end of the interview. Most importantly, participants were given a working memory test. Variation in working memory is highly correlated with individual differences in cognitive abilities and executive control (Conway et al., 2008).[10] The surveyor read a list of ten words and asked the participant to recall as many as she could. Then the surveyor asked some irrelevant questions, and afterwards the participant was again given a minute to recall as many words as she could. Because of the intervening questions, this is an example of a *complex working memory span task*, a highly predictive measure in which "subjects remember a short stimulus list for later recall, and must simultaneously engage in a secondary 'processing' task" (Chein et al., 2011). The median participant remembered two words the second time, three words at the 81st percentile and 4 at the 94th.

The experiment also included two simpler and more transparent measures of cognitive resources. Perhaps most relevant to the pension cycle, participants were asked the date and day of the week. About three-fourths knew the day of the week, date, month, and year. They were also asked a simple math question: "If you buy two packages of food for seven rand each and pay with twenty rand, how much change will you get?" Again, about three fourths answered correctly, generally but not exactly the same participants who knew what day it was.

The primary goal of this paper is to document a relationship between consumption cycling

[10] A growing and recent literature in cognitive psychology documents correlation between individual differences in working memory and apparent patience. For example, Hinson et al. (2003) experimentally demonstrate that occupying participants' working memory promotes impulsive behavior. Shamosh et al. (2008) find that lower working memory test scores (as well as general intelligence test scores) predict more delay discounting in choices between money now or later.

and cognitive resources. However, the theory makes a secondary prediction of an effect of unpredictability, and the survey additionally measured the variability of participants' spending needs by asking about them. While this measure is subjective, it is exactly an agent's subjective assessment that the model predicts would shape her decision to invest in deliberation. Any readers who are skeptical about the value of such a subjective report can concentrate on the main effect of cognitive resources, which itself differentiates this paper's theory from a time preference-based account.

Participants were asked: "Do you usually need to spend about the same amount of money each month, or do your needs change a little from month to month, or do your needs change a lot from month to month?" Among participants, 55 percent reported needs that change a little and 21 percent reported needs that change a lot. Endogeneity of such a measure is always a concern, but regressed on assets, age, schooling, and household characteristics, none of these predict needs that "change a lot." Moreover, the results below are similar with or without a broad range of controls. As further validation of the measure, participants reporting needs that change a lot are 8.4 percentage points more likely to report sometimes having to skip a meal at the end of the month (two-sided $p = 0.045$), a coefficient that falls only to 8.2 percentage points controlling for an asset index (as a quadratic polynomial), participant age (as a cubic polynomial), household size, having children in the house, and an indicator for having ever been to school.

Finally, wealth and poverty was measured with an asset index, counting how many of eight goods anyone in the participant's household owns: a radio, a television, a house phone, a cellular phone, a washing machine, a car, more than five books, and a refrigerator. The mean participant had between five and six of these. Almost everybody had a radio; few had a car.

3.2 Econometric strategy & validity

The two main regression specifications derive from questions posed by the Proposition. First, does buying at the beginning of the month exceed buying at the end of the month by more for participants with lower cognitive resources than for participants with higher cognitive resources? If randomization was successful, the groups assigned to be offered soap before or after the pension payment are counterfactuals for one another, and the difference between them reflects the effect of this timing. Is this difference greater for participants with lower cognitive resources? This question is answered by interacting cognitive resources with an indicator for being interviewed after, rather than before, the payment:

$$buy_{ij} = \beta_0 + \beta_1 after_i + \beta_2 cognition_{ij} + \beta_3 after_i \times cognition_{ij} + \varepsilon_{ij},$$

where i indexes individuals and j indexes CAPS clusters. The model predicts that $\beta_1 > 0$, $\beta_2 > 0$ (because spending by participants with higher cognitive resources will not drop so far at the end of the month), and $\beta_3 < 0$ (because deliberation dampens the intra-monthly cycle). Relative to participants with lower cognitive resources, those with more resources spend less at the beginning at the month and more at the end.

Second, is this effect of cognitive resources larger for participants with more variable spending needs? This is equivalent to asking whether β_3 in the equation above is greater for participants whose needs change much. Therefore, the relevant regression is the triple interaction of *after*, *cognition*, and *change*, (where *change* is reporting that needs change a lot from month to month) and the key prediction is that the coefficient on the triple difference is negative: the positive effect on purchasing of being interviewed after payday is concentrated on those with high change but low cognitive resources.

To minimize omitted variable bias, we present estimates of the interaction both with and without observed controls. In particular, we control for age (as a cubic polynomial), education, household size and the count of children in the household, wealth, a canonical measure of time preference (explained in appendix section A), and indicators for the participant's household already owning any soap and owning more than three bars of soap. These controls have essentially no effect on the main regression coefficients, suggesting that cognitive resources are not merely reflecting an endogenous correlation with some other difference among participants.

3.2.1 Randomization & balance

Table 2 reports summary statistics for covariates and verifies that, in this finite sample, randomization did not produce any statistically observable differences. Each column is a regression of a covariate on a dummy indicator for being assigned to be interviewed after payday. The only difference between participants interviewed before and after payday is that people interviewed after payday are eleven percentage points more likely than those interviewed before to have soap in their house; this is not an imbalance but another effect of payday (people go shopping) that, if anything, biases against our finding of intra-monthly cycling.

In the interviews, 8.3 percent of participants report that randomization failed: those assigned to the before group had been paid, or vice versa. Because randomization was at the cluster level and neighborhoods were paid together, we believe many instances of this are measurement error. Yet, some participants may, for example, have moved neighborhoods and not updated records. Randomization was not systematically wrong: regressing an indicator that the randomly assigned week was not the actual week on assets, education, age, and household size, none of these has a t-statistic greater than 0.69. While we will concentrate on intent-to-treat estimates below, we will also report treatment-on-the-treated estimates, instrumenting for the reported time relative to payday with the random assignment.

3.2.2 Measurement error

"True" cognitive resources are, of course, unable to be observed directly; they are measured with error in three indirect ways. Results using a single measure of cognitive ability may be subject to attenuation bias. Lubotsky and Wittenberg (2006) present a method for optimally combining multiple proxies for a single, unobserved regressor into a linear index. Their result weights the proxies according to their scaled coefficients when all are included and is optimal in the sense of minimizing attenuation bias.[11] The estimate is a lower bound (in absolute value) on the true effect of the underlying unobserved variable. We will present results estimating the effect of cognitive resources using a single (transparent but probably attenuated) proxy and using a Lubotsky-Wittenberg index, and the reader may decide which is the main result and which is a robustness check.

3.3 Results

The main empirical result of the experiment confirms the main prediction of the model:

Result 1. *Intra-monthly cycling is lower among participants with higher cognitive ability, who buy less at the beginning of the month and more at the end.*

Figure 2 plots the fraction of participants who bought the soap, splitting the sample between those interviewed before and after payday, and between those who answered the date question correctly and incorrectly, the simplest and most transparent of the cognition indicators. As the figure shows, 25 percent of participants who answer the date question incorrectly buy the soap the week before payday, but 48 percent buy it afterwards, almost doubling take-up; yet, among those who answered correctly, 27 percent buy the soap before payday while 34 percent buy it afterwards, only a 25 percent increase. Cognitive resources have opposite effects at the beginning and the end of the month because the marginal disu-

[11] The index is $x^{LW} = \frac{1}{\beta^{LW}} \sum_j x_j \hat{\beta}_j$, where $\hat{\beta}_j$ is the coefficient on each of the j proxies when included together and β^{LW} scales them by their combined coefficient.

tility of spending out of local resources increases throughout the month, while the disutility of spending out of global resources remains constant.

Table 3 presents regression results that verify the statistical robustness of this result. In the first panel, cognitive resources are operationalized with a Lubotsky-Wittenberg index that optimally combines the three measures to minimize measurement error and, in column 1, provides a lower bound of the effect. In the second panel, reporting the date and day correctly is instead used; while these results are attenuated as expected, they are nevertheless statistically significant and perhaps more transparently understandable. Results are also similar and statistically significant if we instead construct a cognitive resources index from the first principal component of the three measures.

In both panels, the table confirms the robustness of this finding to two alternative specifications. First, the set of control variables is added in columns 2 and 5. There is no evidence that the effect of cognitive resources reflects omitted variable bias: including the covariates has little effect, indeed the estimates of the interaction increase in absolute value. Second, columns 3 and 6 present treatment-on-the-treated estimates, instrumenting for the interview's reported position in the monthly calendar with its randomly assigned position in the monthly calendar. The first stage has an F-statistic of 884, easily passing weak instrument tests. This instrumentation further increases the point estimates.

Monte Carlo simulations by Cameron et al. (2008) demonstrate that 50 clusters are enough to reliably use asymptotically valid cluster-robust standard errors, which are included in table 3. However, Lubotsky and Wittenberg give no guidance for inference about an estimate using their procedure. Modifying a Wild cluster bootstrap for their procedure produced a p-value of 0.07.[12]

[12]Simulations by Cameron et al. (2008) show that Wild cluster bootstraps allow reliable inference with interacted dummies in finite samples with a low number of clusters. We first used the Lubotsky and Wittenberg procedure to find weights for a cognitive resources index, then estimated the regression with this index to find residuals. We then independently gave each cluster a 0.5 chance of multiplying all residuals in that cluster by -1, formed new "outcomes," and repeated the entire Lubotsky and Wittenberg procedure, getting a new $\hat{\beta}^{LW}$. We repeated this process 10,000 times to find an "empirical" distribution of $\hat{\beta}^{LW}$ against which our estimate could be compared.

The theory secondarily predicts that consumption cycling would be increasing in uncertainty, and that the effect of cognitive resources is greatest among those with the least predictable futures. Unpredictability decreases the benefit of planning for a future that may never come. Was the interaction between time of the month and cognitive resources indeed greatest for those with unpredictable needs?

Result 2. *Intra-monthly consumption cycling is concentrated among participants with low cognitive resources and variable needs.*

Figure 3 verifies this second prediction of the Proposition. Outside of the group of participants with low cognitive resources and highly variable needs, cycling is low. As table 4 documents, this triple interaction is statistically significant and robust to the inclusion of control variables. Again, the first two columns use a Lubotsky-Wittenberg index to measure cognitive resources; the second two report attenuated but transparent results of using the date question. Columns 2 and 4 include the same set of covariates, which change the other estimates only a little.

4 Applied model

The experiment found, primarily, that cycling is greatest among participants with lower cognitive resources, and secondarily, that this effect is greatest among those with the most unpredictable monthly needs. These results are qualitatively consistent with the simple model: increasing cognitive costs increases the costs of global intertemporal decision-making, while increasing uncertainty lowers the benefits; when people instead make local decisions, they emphasize more immediate resources and needs. Could an applied model, based on the same principles, account more directly for these results?

In the simple model of 1.2, the agent chose between two options. Agents in a monthly pension cycle allocate their spending throughout each month. This section presents an applied model, in which an agent faces a random distribution of needs throughout the month.

Like in the survey experiment, those with the highest contemplation costs and most variable distributions of monthly needs will cycle the most.

4.1 Problem

An agent lives for three periods: the first two form a *month* with a beginning and an end, and the third is the rest of her life. The agent receives income y at the beginning of the month, receives Y in period three and has no savings or borrowing constraints. She selects a quantity of consumption x_t each period.

Each period, the agent receives utility according to an increasing and concave felicity function $u(x)$ with a period-specific multiplier λ. Multipliers λ represent the unpredictability of a monthly profile of spending needs; they are drawn iid in the first and second periods from a finite set Λ according to a probability distribution $\phi : \Lambda \to [0, 1]$. Utility is intertemporally additive with no discounting or other time preference. In period three, the agent enjoys V, also increasing and concave, representing the value of wealth carried into the future, after this month. Put together, she seeks to maximize

$$U(x_1, x_2) = \lambda_1 u(x_1) + \lambda_2 u(x_2) + V\left(y + Y - (x_1 + x_2)\right).$$

The month's profile of utility multipliers is described by a *state*. A state, s, is an ordered pair from Λ, and S is the set of all states; $S = \{s\} = \{(\lambda_1, \lambda_2)\}$. Because multipliers are random variables, states are random vectors, and $f : S \to [0, 1]$ is the distribution of states, where $f(s) = \phi(\lambda_1) \times \phi(\lambda_2)$. Clearly this distribution is symmetric, so any rearrangement of multipliers is equally likely.

4.2 Two decision procedures

The agent's deliberation technology allows her to use one of two decision procedures in each state. "Global" optimization, economists' standard intertemporal utility maximization, simultaneously considers all three periods and saves and borrows among them. "Local" optimization focuses sequentially, period by period, on immediate needs and salient resources, in particular the current period's utility multiplier and cash on hand, respectively. Unlike local decision-making, global decisions are cognitively costly. Before the beginning of the month (or, in a 0th period), a cognitive algorithm $a : S \to \{G, L\}$ maps each state into the decision strategy selected for that state, were that state to occur. Therefore, the determination of the state s in period 1 also determines whether the agent will decide globally or locally.

Findings from psychology and economics inspire this setup. Berns et al. (2007) review neurological evidence that "time discounting in humans results from the interaction of two systems, one of which is capable of anticipating and caring about the distant future, and the other which is much more oriented toward the present." Behavioral studies observe choices consistent with the local model and its focus on mentally accessible assets, such cash on hand. Morewedge et al. (2007) demonstrate that consumption is increasing in the "cognitive accessibility" of resources: when prompted to think about their long-term assets rather than their wallets, people spend more. Card et al. (2007) show that variation in cash on hand due to unemployment insurance predicts job search behavior.

The global procedure solves the standard problem:

$$\max_{\{x_t\}} \sum_{t=1,2} \lambda_t u\left(x_t\right) + V\left(y + Y - \sum_{t=1,2} x_t\right).$$

Clearly, if it were costless, the agent would prefer to use the global procedure in every state. However, the agent must pay a utility deliberation cost of c for each state in which she would use the procedure. This cost is paid by the algorithm, in advance, as a cost of understanding the optimal behavior in s, whether or not state s occurs. Empirically, c is decreasing in overall cognitive resources available, including both properties of the person such as cognitive ability and properties of the situation such as cognitive load.

The local procedure sequentially chooses x period by period:

$$\max_{x_t} \lambda_t u(x_t) + v(b_t - x_t).$$

Periods are connected by b_t, interpreted as cash on hand (or a subjective balance of mentally accessible assets, that is increasing in cash on hand). This balance increases with income and decreases upon spending: $b_t = b_{t-1} + y_t - x_{t-1}$. Thus, the balance decreases throughout the month. The local procedure approximates the true value function with a local value function v, which is increasing and concave. It offers a heuristic value of ending the period with a current balance, but does not directly consider future utility multipliers or which period the agent is in.

The algorithm directs the agent to use global, rather than local, decision-making if the deliberation cost is less than the expected benefit:

$$a(s) = \text{global} \equiv \left[U^g(s) - U^\ell(s)\right] f(s) \geq c,$$

where $U^g(s)$ and $U^\ell(s)$ are the total utilities offered by global and local decision-making, respectively, in state s.[13] Clearly c increasing and $f(s)$ decreasing discourage being able to globally optimize in state s, all else equal.

4.3 Post-dictions for the experiment

This applied model accounts for the main finding of he experiment. Like in proposition 1.2 of the simple model, the agent will appear more impatient – cycling more – when deliberation is more costly and when circumstances are more unpredictable.

[13]This may suggest to some readers an infinite regress: how does the agent decide how to decide how to decide, and so on? Like other papers in this literature, this model stops at one level of bounded rationality (*e.g.* Chetty et al., 2009; Chetty, 2011). If the reader finds the boundedly rational algorithm's knowledge of U^g and U^ℓ unpalatable, it is not relevant for the comparative statics of c and f below, which would be qualitatively unaffected by replacing this difference, for example, with a constant expected gain of global decision-making across all states.

Figure 4 presents the result of simulating the effects of increasing deliberation costs c. The computation of the simulation is detailed in the appendix. As the deliberation cost increases, expected consumption across the month diverges from an even split across periods to a cycle that consumes more at the beginning than the end. This prediction matches the experiment's Result 1.

Corollary 1. *Effects of deliberation costs on cycling:*

1. *There exists* $\underline{c} > 0$ *such that for all* $c < \underline{c}$, $E[x_1 - x_2] = 0$.

2. *If* u *is homothetic, or if* $V(\cdot)$ *and* $v(\cdot)$ *are such that total spending within each month is equal under global or local decision-making, then* $c' > c''$ *implies that*

$$E\left[\frac{x_1'}{x_2'}\right] \geq E\left[\frac{x_1''}{x_2''}\right].$$

3. *There exists* $\bar{c}$ *such that for all* $c > \bar{c}$, $E[x_1] > E[x_2]$.

All proofs are in the appendix. Felicity, u, is "homothetic" when the share of spending is periods 1 and 2 is unchanged when the total amount spent in the month changes.

The experiment further found that cognitive resources had the greatest effect among participants with variable needs: can the theory also account for this? Unpredictability of s is operationalized as the entropy of f. Entropy is a measure of uncertainty, sometimes described as an analogue of variance for a distribution over a non-numerical set.[14] The entropy of f, defined as $H(f) = -\sum_S f(s) \ln f(s)$, is minimized at 0 when $f(s) = 1$ for some s and maximized by a uniform distribution.

Figure 5 presents similar simulation results of the effect on cycling of increasing the entropy of f at various levels of deliberation cost. The plotted lines are nonparametric regressions from simulated data where the ratio of consumption at the beginning of the

[14]However, the variance of ϕ would not be an appropriate measure because the key property from the perspective of the algorithm is the probability of a state, not where in Λ probability mass is situated.

month to consumption at the end of the month is found for many randomly generated distributions over Λ. Because the vertical axis is this ratio, 1 represents no cycling and higher numbers are more extreme cycling. At a low deliberation cost increasing entropy has little effect on cycling. Similarly, increasing deliberation costs has a small effect at low levels of entropy. It is where high unpredictability and high deliberation costs combine that cycling climbs quickly. This prediction matches empirical Result 2.[15]

Corollary 2. *Effect of H, the entropy of f:*

1. *For all c below a threshold c^*, as $H \to 0$, $E[x_1 - x_2] \to 0$.*
2. *For a large enough Λ, for all $c > 0$ there exists $H^*(c)$ such that for all $H > H^*$, $E[x_1] > E[x_2]$. $H^*(c)$ is decreasing in c.*

5 Heterogeneous effects of changing benefit policy

Some papers in the literature on the intra-monthly consumption cycle propose more frequent, smaller benefit payments as a tool governments can use to help households smooth consumption. For example, Stephens and Unayama (2010) find a decrease in cycling, on average, when the Japanese benefit period is shortened. In principle, both cognitive limits and time-inconsistent preferences could generate demand for a shorter pension period, but the behavioral effects and the incidence of who would benefit – among, for example, the impatient, the cognitively limited, and the credit constrained – would differ depending on the cause of cycling.

Ignoring transaction costs, paying the pension in half-size installments twice a month increases expected utility: it has no effect on global decision-makers, and helps smooth consumption of local decision makers. However, the effect on behavior is not so straightforward. Paradoxically, changing a benefit program such that benefits are paid twice a month

[15] Proposition 2 lacks the middle result of 1 because, at interior levels of entropy, transferring probability mass from a high probability state to a low probability state could cause the receiving state to be processed globally without causing the transferring state to be processed locally.

could *increase* consumption cycling for agents with moderate cognitive costs: agents with low cognitive costs are making global decisions and are unaffected by the change; agents with high cognitive costs always make local decisions, and now enjoy better smoothed consumption. Agents with moderate cognitive costs, however, may switch from global to local decision-making, once local decision-making has less imbalanced consequences, increasing their overall consumption cycling, particularly if they enter the month with cash on hand or also receive monthly income from a source other than the pension. The intuition is simple: global optimization is difficult, and shortening the pay period reduces the need for planning.

Figure 6 illustrates this possibility with a simulation computed from the applied model; the computation is detailed in the appendix. Here, paying the pension twice a month bounds consumption cycling at a lower maximum level, relative to paying the pension once a month, and this policy change has no effect on agents with low enough deliberation costs that they always globally optimize. However, the policy change increases cycling for agents with moderate deliberation costs. The average effect in a population would depend on the distribution of deliberation costs and unpredictability.[16]

The utility benefits of this policy change are also heterogeneous. The change has two effects on utility in the model: first, it decreases expected cycling under local decision-making, and second, in so doing, it could decrease the total deliberation costs paid by inducing some agents to switch from global optimization. Figure 7 plots the expected utility of an agent under both policies at different entropies and levels of cognitive limit. As the figure illustrates, the utility gain from this policy change is increasing in deliberation costs, and is generally larger under more entropic distributions. For agents with high enough cognitive costs or entropy, the gain can be greater than the utility benefit of a 5 percent increase in wealth. However, at high deliberation costs, the gain could be larger under lower entropy than higher: the intuition is that agents facing high entropy would make local decisions whether benefits

[16]The only empirical paper studying a policy change of this type – Stephens and Unayama's (2010) study of the Japanese pension – does not explore heterogeneity along these dimensions.

are paid once or twice, but agents facing lower entropy could be saved from making global decisions – and paying the deliberation cost – by being offered benefit payments twice a month.

In practice, which experiment participants would prefer this change? When asked, only three percent of participants replied that they would rather be paid twice a month than once a month. Certainly only some participants are susceptible to intra-monthly cycling; global decision-makers have no reason to prefer this change. Little econometric analysis is possible here, but those who reported changing needs were 2.7 times as likely to be among the small group who preferred to be paid twice a month (two-sided $p = 0.07$).[17]

Such low support for more frequent payments highlights the transaction costs of receiving a benefit payment, which may themselves be the first-order policy issue.[18] About 70% of recipients are paid at a government cash pay point, while the rest are paid by direct deposit into a bank account.[19] However, even those paid by direct deposit go to the ATM to collect their pension on payday (perhaps due to intrahousehold conflict or the social habits of a cash economy), so from the participants' point of view the difference is simply getting paid through the government's ATM or a private one. The elderly recipients typically wait in line for hours. They complained that at least at the government ATMs there used to be chairs. At the private ATMs to which they are increasing sent they must stand.

Additionally, participants may have overlooked externalities of cycling or other non-obvious costs. Dobkin and Puller (2007) study the monthly cycle of Supplementary Security Income in California and find cyclical effects on drug-related hospital admissions and mortality as well as arrests for drug-related crimes. Similarly, Evans and Moore (2009) identify

[17]Regressing the preference for being paid twice a month on both an indicator of changing needs and an indicator of remembering no words in the memory test (a 24th percentile score), both are positive and statistically significant (two-sided p-values of 0.04 and 0.08, respectively). Their interaction, if included, is positive but not statistically significant ($t = 0.7$).

[18]For a discussion of large transaction costs associated with collecting benefits from actual and hypothetical forms of India's Public Distribution System, see Khera (2011).

[19]This distinction had no detectable statistical interaction with the experiment results, primarily because deposit recipients are distributed throughout the survey area unpredictably, due to ongoing government efforts to convert the entire system to direct deposit.

short-term mortality effects upon receipt of income from a range of sources: Social Security, military wages, tax rebates, and payments from the Alaska Permanent Fund. Adams et al. (2003) and Polivy (1996) cite evidence that periodic calorie restriction may encourage obesity — widespread in this experiment's population — perhaps by undermining psychological or biological abilities to regulate food consumption. Such costs are important to policy makers, but may not have been considered by participants and, as externalities, were not included in the simulation of participants' utilities.

6 Conclusion

Bounded intertemporal rationality that more easily understands and optimizes over consequences that are nearer in time can be responsible for behavior that might ordinarily be interpreted as evidence for impatient preferences. Cognitive limits can explain stylized facts about the intra-monthly consumption puzzle and the relationship of cognitive ability to seemingly impatient choice that models of time preference cannot. This approach's novel prediction that intramonthly cycling will be concentrated among pension recipients with low cognitive resources is verified by a survey experiment in Cape Town. The experiment further verifies a secondary prediction, that this effect is greatest among participants with unpredictable needs. Further analysis of data from the survey reported in appendix section A finds no evidence that cycling is due to present biased time preferences.

To be clear: present-biased preferences are certainly important and often active. Cases in which people pre-commit their behavior in the face of temptation may indeed be likely to be best explained with preferences. However, behavior exhibiting an extreme depth of apparent impatience, while consistent with present-biased preferences, is not sufficient evidence for them.

If apparent impatience is actually due to cognitive limits, rather than time preference, it matters both for welfare economics and for policy design. Time-inconsistent preferences have complicated welfare economics precisely because agents are taken to rank options in more than one way. It is not then clear which ranking policy should respect. Whenever behavior is actually caused by costly intertemporal decision-making this debate is unnecessary: there is only one preference ranking.

Earlier papers have proposed paying benefits such as pensions in smaller installments, at more frequent intervals. While both cognitive limits and present bias offer rationales for this policy change, the particular behavioral effects and the incidence of benefits would be different if cycling is due to bounded intertemporal rationality. Cycling may even increase for some groups, potentially important given externalities of cycling. Finally, local intertemporal decision making that attends to salient resources underscores findings that the effects of fiscal policy could depend on the mechanism by which consumers are paid (Sahm et al., 2010).

In politics and popular media, poor people are often criticized for impatient, lazy, or myopic choices. To many opponents of benefit programs, this behavior reinforces doubt that the poor are disadvantaged and deserve support (*cf.* Gilens, 2000). Bounded intertemporal rationality offers another interpretation. In this experiment's sample, most participants are relatively poor. Yet, without taking a stand on whether heterogeneity in schools (Case and Deaton, 1999) or early life nutrition and health (Case and Paxson, 2009) might differentially shape subsequent cognitive resources, it seems modest to suggest that, in general, poorer people might face the sort of deep unpredictability that discourages investing in charting an optimal intertemporal path.

A Empirical extension: Time preference

If time preference, consistent or inconsistent, explains intra-monthly cycling then consumption cycling should be concentrated among the impatient or present biased, respectively. Time preference was measured with a standard pair of decisions between earlier and delayed payments, either now or in the future. Participants were asked to imagine they had won a prize and could choose how it would be paid. First, they were asked if they would prefer 500 rand now or 750 rand in a month. Then they were asked if they would prefer 500 rand in 12 months or 750 rand in 13 months. Shifting payments by a month and by a year controls for monthly and annual cycles in needs.

Although economists have objected to such 'money soon' vs. 'money later' questions on the grounds that participants could use external capital markets (Cubitt and Read, 2007), they remain a staple technique of this literature (*eg* Ashraf et al., 2006). Perhaps more importantly, these questions were asked hypothetically; they were not incentivized with real payments. However, Johnson and Bickel (2002) and Madden et al. (2003) have demonstrated that behavior is the same using real and hypothetical payments, and Bickel et al. (2009) has further shown similar neural imaging responses to real and hypothetical choices.

Table 5 presents the distribution of selections. We will label a participant "impatient" if she preferred 500 now and 500 in 12 months and "present biased" if she preferred 500 now and 750 in 13 months. Although these decisions were not incentivized with real-money payments, there is some reason to trust them: according to a different part of the survey, present-biased participants reported being 12 percentage points less likely to follow through on spending plans (p-value = 0.075), exactly what naïve present bias prevents (O'Donoghue and Rabin, 1999).

Using these data, figure 8 demonstrates that intra-monthly consumption cycling was not concentrated among the present-biased. Measurement error – only two survey questions are available to infer time preference – would predict attenuated results. However, if anything, those with present biased preferences cycle in the opposite direction, although because neither present bias nor its interaction is statistically significant, these point estimates of differences are best considered zeros.

$$\widehat{\text{buy}}_i = \underset{(0.031)}{0.254} + \underset{(0.045)}{0.136} \text{ after}_i + \underset{(0.100)}{0.094} \text{ pres. bias}_i - \underset{(0.135)}{0.215} \text{ after}_i \times \text{pres. bias}_i,$$

with clustered standard errors in parentheses. There is similarly no effect of time-consistent impatience, that is, of choosing the earlier reward in both questions.

As section 2.1 reviewed, credit constraints are necessary for a time preference-based explanation for intra-monthly cycling, but not for this bounded rationality account. Observing credit constraint is difficult because the key question is whether the participant *could* borrow, not if she does. We attempted to measure credit constraint with several survey questions: Could you borrow money from somebody if you needed to? Do you ever skip meals at the end of the month? Have you ever lost something on lay-buy because you could not make a payment? These did not work well as a measure of credit constraint; the asset index was negatively correlated with reporting being able to borrow money ($p = 0.057$) which may be because of social or religious pressure to disavow and disapprove of loans, especially among the many Muslim participants.

With these caveats, we restricted the time preference regression to participants in the upper half of a credit constraint index constructed from these questions. Could time preference have mattered among the credit constrained, the group for whom impatience is a more likely explanation? Even in this group, there is no evidence of an effect of time preference: the coefficient on the interaction between present bias and time of the month is essentially unchanged (-0.183), negative, and not statistically significant.[20]

B Proofs and computations

Proposition 0

The agent will only choose the option with the lower payoff in the first period if she deliberates, a choice she makes based on observing x_{1A} and x_{1B}. Let $d = |x_{1A} - x_{1B}|$. Because the second period payoffs are independent of the first, write x_{2H} and x_{2L} for the

[20]While credit constraint is not directly relevant to the effects of limited cognition, including answers to these questions or an index based on them (alone or interacted with *after*) to the main regressions in tables 3 and 4 does not change the results, and indeed increases the triple difference in absolute value.

second period payoffs for the options with the high and low first period payoffs, respectively.

The agent will deliberate only if $c \leq (1-p)E\left[\max\{x_{2L} - x_{2H} - d, 0\}\right]$, which simplifies to $d \leq 1 - \sqrt[3]{\frac{6c}{1-p}}$. Therefore, the probability of choosing the option that offers the higher initial value, conditional on the first period difference, is

$$Pr[H|d] = \begin{cases} 1 & d > 1 - \sqrt[3]{\frac{6c}{1-p}} \\ \frac{(1-d)^2}{2} & d \leq 1 - \sqrt[3]{\frac{6c}{1-p}} \end{cases}$$

Because $d \in (0,1)$, $\frac{(1-d)^2}{2} < 1$, so this is increasing in c and p for all d until the difference threshold is zero, at which point the probability is 1. Because this result holds for all d, it will hold integrating it over the distribution of d.

Corollary 1

a. The set of all states S is finite, so $\left[U^g(s) - U^\ell(s)\right]$ has a positive minimum. Let $\underline{c}$ be 95 percent of this positive minimum. If $c < \underline{c}$ then in all s the agent uses global optimization. Let $(x_1^g(s), x_2^g(s))$ be the global optimum consumption in each state. Utility weights λ are iid by period, so all permutations of $(x_1^g(s), x_2^g(s))$ are equally likely. Therefore the distribution of $x_t^g(s)$ is independent of t, so the expectation is as well.

b. If $c' > c''$ then either some states switch from global to local decision making or no states do, in which case nothing changes. For states that do not switch the ratio of x_1 to x_2 does not change.

For any state s that does switch, let $x^\ell(s) = x_1^\ell(s) + x_2^\ell(s)$. Then let $(x_1^{\ell g}(s), x_2^{\ell g}(s))$ maximize utility in state s such that exactly x^ℓ is spent in the month; therefore, this ordered pair is how the global process would allocate expenditure to periods if it spent the same amount as the local process. By the assumption that u is homothetic, $\frac{x_1^{\ell g}(s)}{x_2^{\ell g}(s)} = \frac{x_1^g(s)}{x_2^g(s)}$.

By the first order conditions for optimization, we know that, in any state,

$$\begin{aligned} \lambda_2 u'(x_2^\ell) &> \lambda_1 u'(x_1^\ell). \\ \lambda_2 u'(x_2^{\ell g}) &= \lambda_1 u'(x_1^{\ell g}). \end{aligned}$$

The first line holds because b decreases by x_1 at the end of period 1. Now, assume for indirect proof that $x_2^\ell \geq x_2^{\ell g}$. Then, by the concavity of u, $\lambda_2 u'(x_2^\ell) \leq \lambda_2 u'(x_2^{\ell g})$. Therefore $\lambda_1 u'(x_1^\ell) < \lambda_1 u'(x_1^{\ell g})$ so $x_1^\ell > x_1^{\ell g}$. But this contradicts the construction of $(x_1^{\ell g}, x_2^{\ell g})$ as summing to x^ℓ, so $x_2^\ell < x_2^{\ell g}$. Similarly, $x_1^\ell > x_1^{\ell g}$.

Therefore, in any s that switches, $\frac{x_1^{\ell g}(s)}{x_2^{\ell g}(s)} < \frac{x_1^\ell(s)}{x_2^\ell(s)}$. Expectation is, here, a finite weighted sum, so in states that switch $\frac{x_1^g(s)}{x_2^g(s)}$ is replaced by $\frac{x_1^\ell(s)}{x_2^\ell(s)}$, which is greater, so the sum is greater.

c. S is a finite set. Let $\bar{c} = \max_S \left\{U^g(s) - U^\ell(s) + 1\right\}$. Then, for all $c > \bar{c}$, the agent uses local decision-making. By the implicit function theorem, $\frac{\partial x^\ell(\lambda)}{\partial b}$ is increasing for all λ. After each period, b declines by x^l. Therefore, within a month, for all λ, x^ℓ is strictly greater in earlier periods. Again, the distribution of states is symmetric. Therefore $E[x_1] > E[x_2]$.

Corollary 2

a. As H becomes close to zero, f becomes close to putting all of the probability in one state, $\tilde{s}$. By the construction of f as the product of iid draws from ϕ, this state must be of the form (λ, λ) for some $\lambda \in \Lambda$. Let $c^* = \frac{(U^g(\tilde{s}) - U^\ell(\tilde{s}))f(\tilde{s})}{2}$. Then, for all $c < c^*$ the agent globally optimizes in $\tilde{s}$. By the form of $\tilde{s}$, $x_1^g(\tilde{s}) = x_2^g(\tilde{s})$. The expectation linearly mixes these quantities with the finite solutions in other states, which can be made of arbitrarily small probability as H approaches zero.

b. By the proof of part c of proposition 1, when the agent only uses local decision making $E[x_1] > E[x_2]$. Let $u_m = \max_S\{U^g(\tilde{s}) - U^\ell(\tilde{s})\}$. Let $n = |S|$; this proof only holds when $n > \frac{u_m}{c}$; intuitively, there is a limit on the uncertainty inherent in a small set of states, but as deliberation costs get high the agent will make local decision even in very small sets. H is maximized by a uniform distribution, in which $f(s) = \frac{1}{n}$ for all s and $H = \ln(n)$. By the condition on n, the agent will decide locally at the maximum H; by the continuity of entropy she will do so in a neighborhood of the maximum, until the probability on the u_m state rises to $\frac{c}{u_m}$. There, entropy is no greater than

$$H^*(c) = -\frac{c}{u_m} \ln\left(\frac{c}{u_m}\right) - \left(1 - \frac{c}{u_m}\right)\left[\ln\left(\frac{1 - \frac{c}{u_m}}{n-1}\right)\right],$$

which is decreasing in c.

Simulations

Simulations were done in Stata, and “do files” are available upon request. Period felicity functions and continuation value functions are natural logs, so utility and the global objective function is $\lambda_1 \ln(x_1) + \lambda_2 \ln(x_2) + V \times \ln(y + Y - (x_1 + x_2))$, where V is now a constant. The local objective function is $\lambda \ln(x) + v \times \ln(b - x)$, where v is a constant. The simulation uses $\Lambda = \{1, 2, \ldots, 10\}$, so $|S| = 100$, implying that entropy is maximized by a uniform distribution at approximately 4.6.

For figure 4, the comparative static with c, the parameters were set to $b_0 = 0, y = 1, Y = 0.6, v = 3$, and $V = 6$, and a uniform distribution of states was used. Consumption was calculated in each period, in each state, and averaged over states, at 500 evenly spaced levels of c from 0.01 to 5.00. The plots are local polynomial regressions of consumption on c.

For figure 5, the comparative static of h, the same parameter values were used. The low, medium, and high values of c are 0.01, 0.15, and 0.75. Stata's psuedo-random number generator was used to generate 40,000 distributions over Λ by assigning a random weight to each λ and setting $\phi(\lambda) = \frac{w_\lambda}{\sum_\Lambda w_\lambda}$; these generate $f(s)$, and H was calculated for each of these, giving 40,000 values of H. For each of these distributions, consumption was calculated for each level of c in each state, and the expected ratio of x_1 to x_2 was computed for each c. The plots are local polynomial regressions of 40,000 values of these expected ratios on H. It is not an accident that cycling appears bounded above: maximum expected cycling occurs when the agent decides locally in each state, a finite set.

For figure 6, the same functional form was used, with a uniform distribution over Λ. The parameters were set to $b_0 = 1.2, y = 1, Y = 0.6, v = 3$, and $V = 7$. For the policy change, y was split so the agent received 0.5 in each of periods 1 and 2. The ratio of the expectations of consumption was calculated at intervals of c of 0.000025, and the plots are local polynomial regressions.

For figure 7, the same procedure and parameter values were used as with figure 6, indeed the high entropy case uses the same data: the uniform distribution gives the maximum entropy at about 4.6. The lower entropy case was computed for 3,000 randomly drawn distributions, each with entropy about 4.3 and drawn according to the weighting procedure used for 5, with the weights the ten integers from 1 to 10. The utility increase is simply the difference in expected utilities. The global procedure does not care when income is received, so wealth was increased five percent from 2.8 by adding 0.14 to Y, to compute the effect of a 5 percent increase in wealth.

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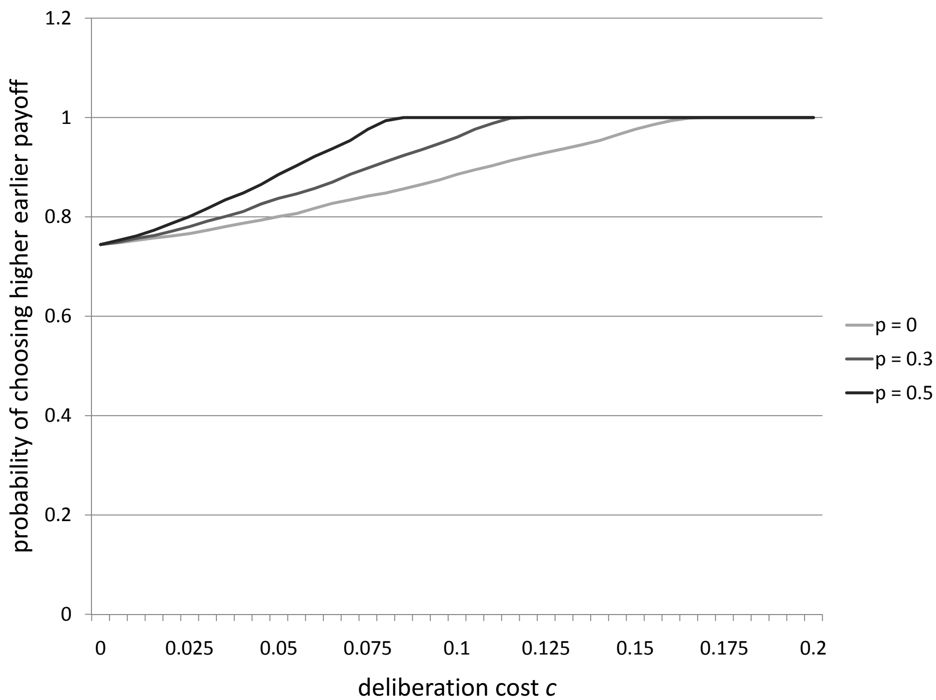

Figure 1: Simple model: Probability of choosing apparently “impatient” option

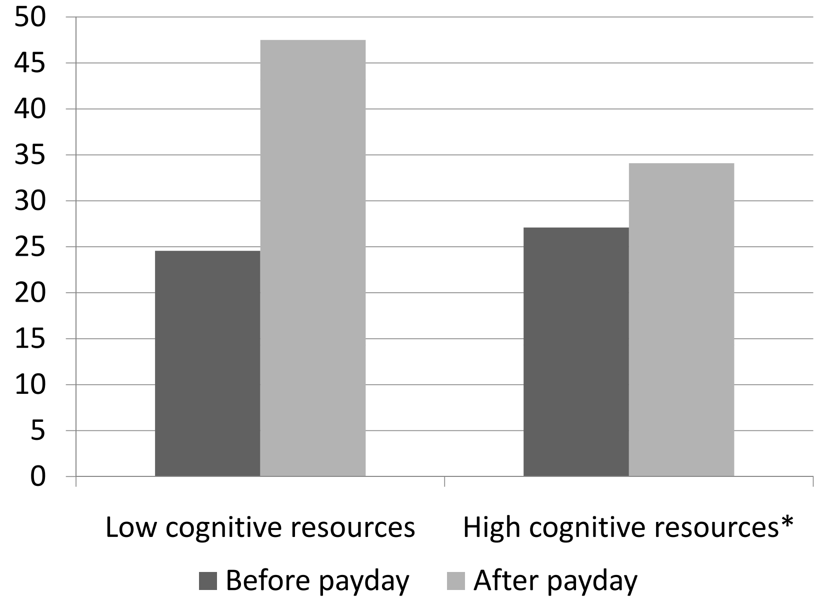

Figure 2: Survey: Percent buying soap by cognitive resources
* answered day correctly

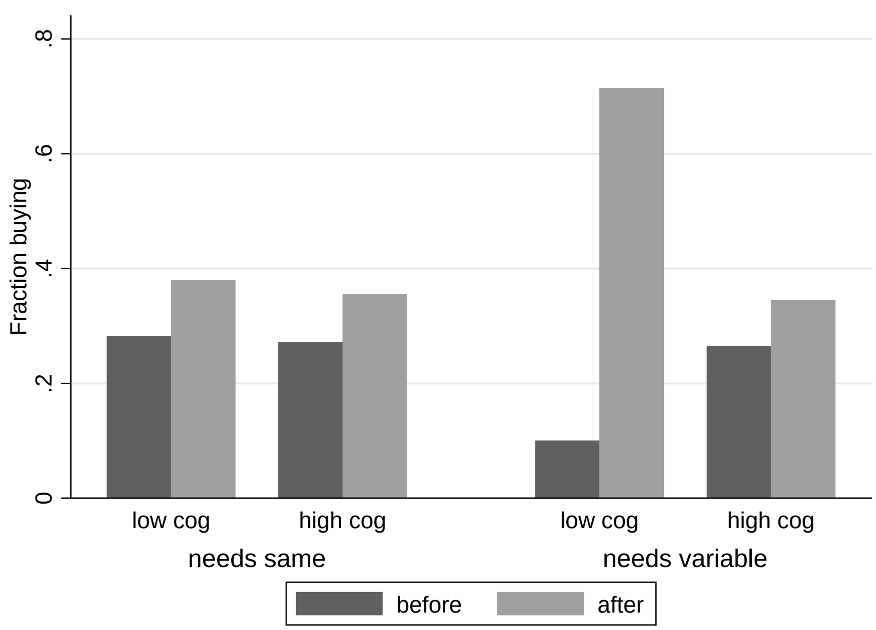

Figure 3: Survey: Cycling, cognitive resources, and unpredictability
"High cognitive resources" here indicate answered day correctly

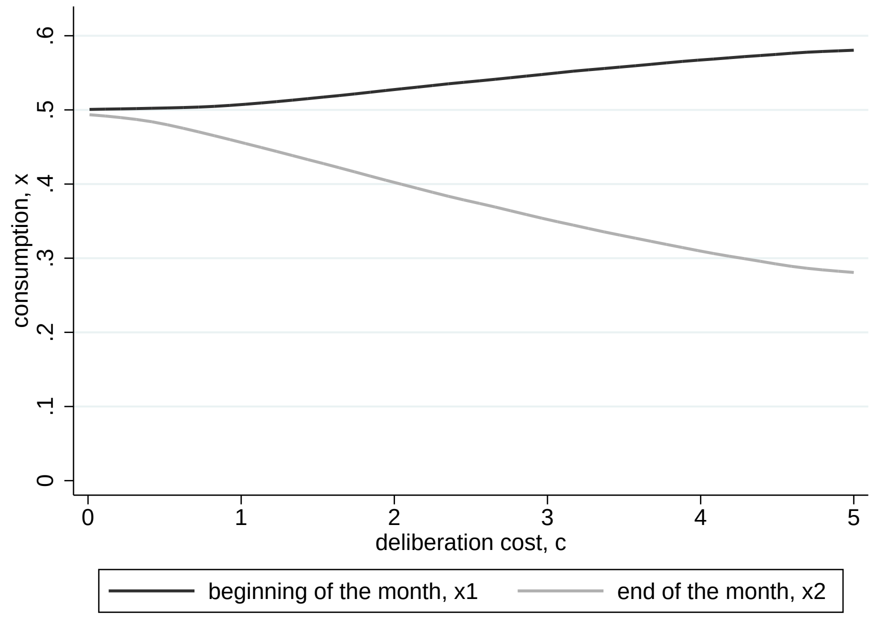

Figure 4: Simulation: Cycling and cognitive resources

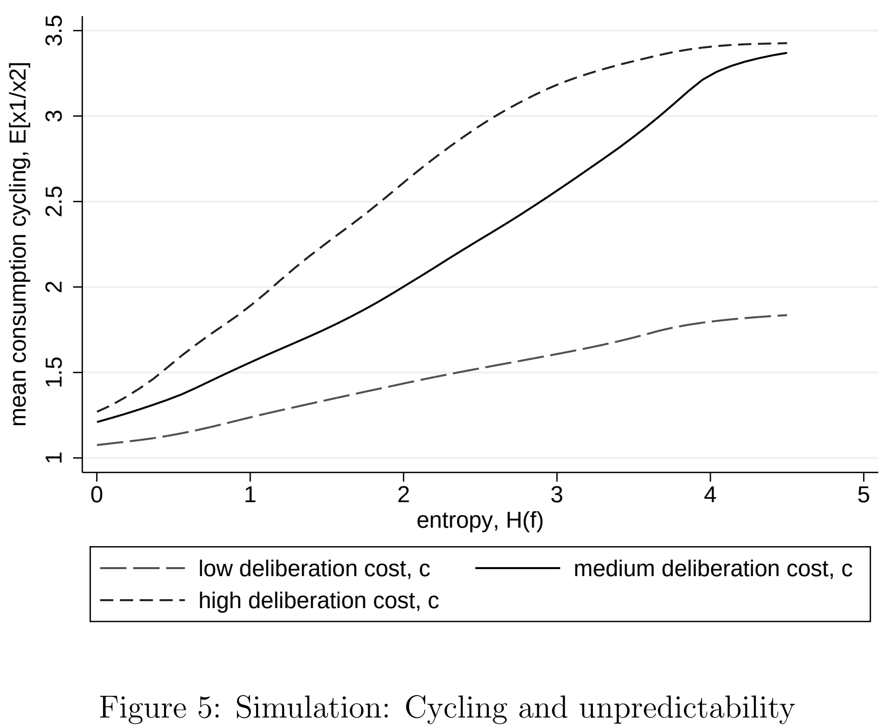

Figure 5: Simulation: Cycling and unpredictability

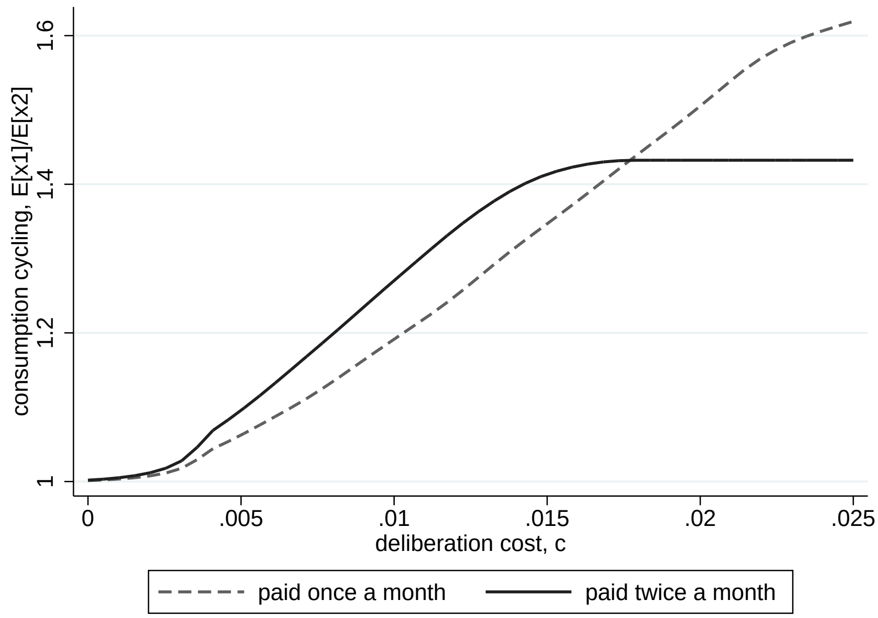

Figure 6: Simulation: Effects of reducing the pay period on cycling

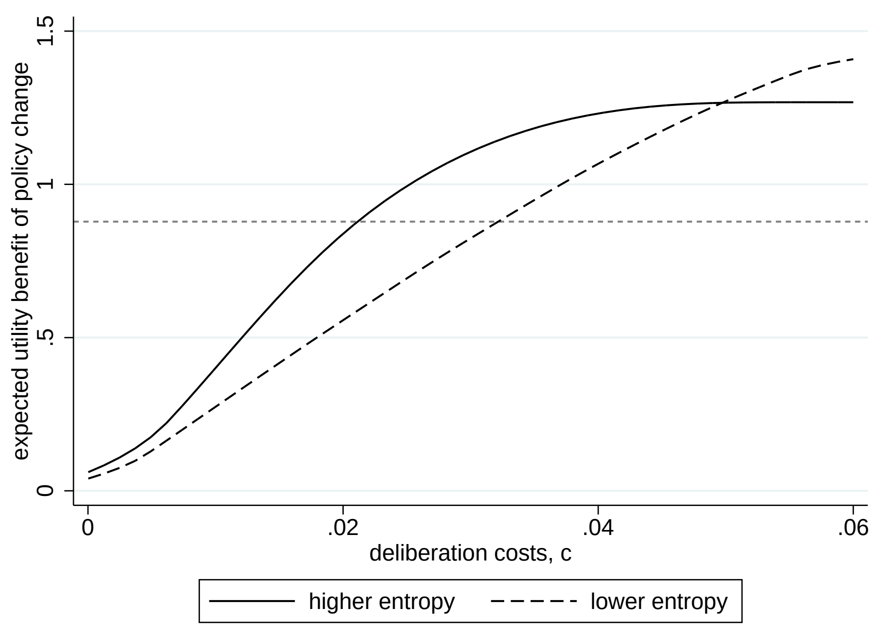

Figure 7: Simulation: Heterogeneity of benefits of reducing the pay period
The dotted line, included for reference, is the utility benefit of increasing the total wealth by 5 percent of an agent with $c = 0$ facing a uniform distribution of states.

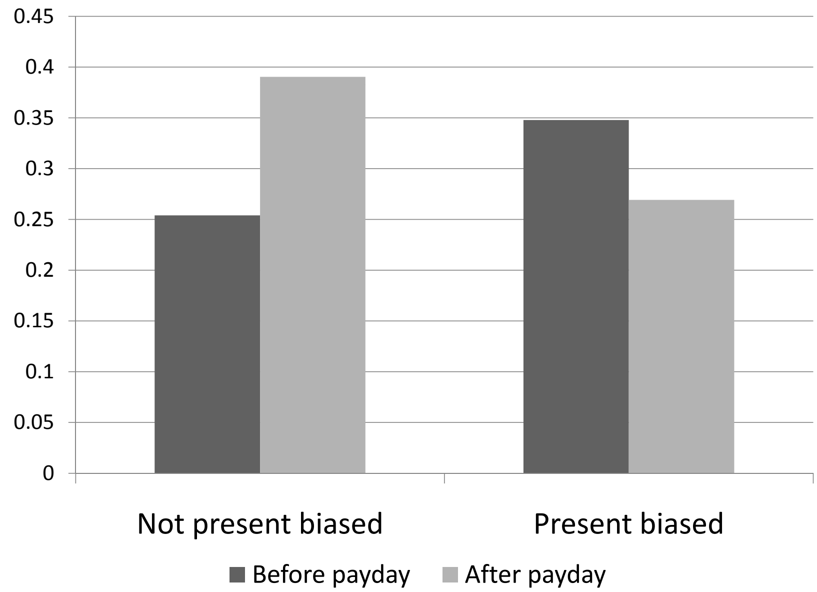

Figure 8: Appendix: Present bias does not predict cycling

Table 2: Summary statistics & experimental balance

	(1)	(2)	(3)	(4)
	age	ever school	has soap	asset count
after payday	-0.261	0.0112	0.107*	0.177
(assignment)	(0.652)	(0.0241)	(0.0414)	(0.198)
constant	69.20*	0.948*	0.811*	5.519*
	(0.465)	(0.0172)	(0.0319)	(0.149)
	(5)	(6)	(7)	(8)
	date correct	math correct	present biased	household size
after payday	0.0363	-0.0435	0.0427	0.369
(assignment)	(0.0501)	(0.0418)	(0.0379)	(0.321)
constant	0.731*	0.788*	0.108*	4.660*
	(0.0338)	(0.0316)	(0.0240)	(0.171)

Clustered standard errors in parentheses. *After* is random assignment to be interviewed after payday, at the beginning of the pension month, rather than before payday.

Table 3: Cycling and cognitive resources

	(1)	(2)	(3)	(4)	(5)	(6)
	Lubotsky & Wittenberg			Date correct		
	ITT	ITT	TOT	ITT	ITT	TOT
after	0.266**	0.263**	0.331**	0.229**	0.234**	0.290**
	(0.0937)	(0.0965)	(0.107)	(0.0812)	(0.0842)	(0.0966)
cognitive	0.125*	0.138*	0.152**	0.0254	0.0366	0.0433
resources	(0.0645)	(0.0710)	(0.0684)	(0.0476)	(0.0498)	(0.0494)
after × resources	-0.284*	-0.308*	-0.391**	-0.159*	-0.188*	-0.234**
	(0.157)	(0.162)	(0.181)	(0.0934)	(0.0975)	(0.111)
age, age^2, age^3		✓	✓		✓	✓
ever school		✓	✓		✓	✓
hh size, children		✓	✓		✓	✓
present bias		✓	✓		✓	✓
soap, much soap		✓	✓		✓	✓
n	384	381	381	384	381	381
clusters	50	50	50	50	50	50

Standard errors clustered by neighborhood in parentheses. The first panel uses a Lubotsky and Wittenberg (2006) index for *cognitive resources*, a weighted average of the working memory test score and correct answers to the math and date questions; the second panel uses the date question only. ITT results are "intent to treat," using random assignment to being interviewed after pension payment for *after*; TOT results are "treatment on the treated" instrumenting for participants' reported time in the monthly cycle with experimental assignment.

Table 4: Cycling, cognitive resources, and unpredictability

	(1) L-W	(2) L-W	(3) day correct	(4) day correct
after	0.138	0.107	0.124	0.0956
	(0.110)	(0.114)	(0.104)	(0.103)
needs change	-0.169	-0.0694	-0.192*	-0.136
	(0.144)	(0.142)	(0.106)	(0.108)
ability	0.0737	0.0384	-0.0121	-0.0320
	(0.0782)	(0.0903)	(0.0585)	(0.0606)
after × ability	-0.0925	-0.0605	-0.0480	-0.0274
	(0.180)	(0.189)	(0.121)	(0.120)
change × ability	0.230	0.0965	0.194	0.162
	(0.275)	(0.257)	(0.145)	(0.141)
change × after	0.601*	0.539*	0.535*	0.526*
	(0.218)	(0.224)	(0.190)	(0.200)
change × after × ability	-0.922**	-0.800*	-0.562**	-0.549*
	(0.400)	(0.401)	(0.260)	(0.263)
controls		✓		✓
constant	0.233*	-4.717	0.283*	-2.697
	(0.0404)	(11.97)	(0.0449)	(11.79)
n	384	376	384	376

Clustered standard errors in parentheses. *Change* is an indicator for reporting that needs change a lot from month to month; cognitive ability is as noted at the top of the panel. Controls include assets, age, age^2, household size, children, education, and indicators for having soap and having more than three bars of soap.

Table 5: Time preference: impatience & present bias

participant selected:	500 now	750 in one month
500 in 12 months	45%	14%
750 in 13 months	14%	27%