AN EXPERIMENTAL ANALYSIS OF TIME-INCONSISTENCY IN LONG-RUN PROJECTS

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ABSTRACT. In the first part of this paper, we elicit time preferences by using the experimental and econometric methods of Benhabib-Bisin-Schotter (2006). We follow the matching task procedure on money-time pairs with real rewards. Among the model specifications we use, the one with exponential discounting and quasi hyperbolic component of present bias appears to be the best model fitting the data. Unlike Benhabib et al., the present bias in the form of a fixed cost is not supported strongly by the data. In the second part of the paper, we test the theory of behavior of time-inconsistent agents in a long run project based on the quasi hyperbolic specification of O'donoghue and Rabin (2005) and Akin (2004). The preferences elicited in the first part are used to predict the behavior of agents in the long run project and categorize them based on their types. We find that the theory captures most of the subjects' observed behavior and helps understanding their types. We also find that some of the observations are compatible with alternative models, including sign effect, the preference for improving sequences, and anticipatory utility models.

KEY WORDS: eliciting time preferences, hyperbolic discounting, experiment, long run projects

JEL CLASSIFICATION CODES: C72, C91, D91

1. INTRODUCTION

Consider an agent who is engaged in a *long-run project* that pays off only if completed in a certain time interval. The agent's problem is to allocate the time needed to complete the project *efficiently*, i.e., to find the allocation that maximizes his payoff given his preferences and the time constraint. Examples include an architect working on a drawing, a professor writing a paper, working on a referee report, or preparing teaching materials, a student doing a homework, etc. The following outcomes (some of them overlap) may emerge out of these situations; last minute finish ups, scattered completion of parts, early completion, and incomplete projects for which some effort has already been expended.

Not all the outcomes above are efficient in terms of planning or implementation. It would not, for instance, be efficient to start a project, invest the time and effort into it, and then leave it unfinished. However, we regularly observe such outcomes around us and even in our personal lives. Are they simply mistakes? Or is there any rationale or explanation for such behavior? Behavioral economic research on *intertemporal decision making and self control* might offer us some clues to answer these questions. Time inconsistencies leading to inefficient outcomes can be observed if people have strong preferences for immediate gratification. These systematic biases appearing as reversal of preferences can be modeled by imposing declining discount rates on intertemporal valuations of future payoffs[1]. Among such models, hyperbolic and quasi hyperbolic discounting models are commonly utilized.

Given the difficulties of finding field data to test for agents' time preferences, estimating these models by using experimental methods emerges as a natural approach. Unlike the existing literature, which attempts to elicit the time preferences only, we take it one step further and investigate, both theoretically and experimentally, how players whose preferences have been elicited *behave* in a long run project. Therefore, there are two main objectives in this paper; to elicit preferences of the subjects, and to observe and explain their allocation patterns (investment schedules) in a multi period project.

There is a large literature on how to elicit preferences both in Psychology and Economics. Frederick-Loewenstein-O'Donoghue (2002) offers a review of a wide variety of research done in this area. In a recent paper, Benhabib-Bisin-Schotter, 2006, (from now on BBS) studies this problem by carefully taking into account the weaknesses of the existing literature. They estimate the parameters of the discount functions with a new econometric approach that follows a matching task procedure on money-time pairs with real rewards. Exponential, hyperbolic and quasi hyperbolic discounting frameworks are all embedded in this specification. In addition, they incorporate a present bias in the form of a fixed cost into their specification that turns out to be the best in terms of fitting their data. In the first part of our paper, we follow their methodology with a few small differences. We find that even though the data do not seem to support solely one model or the other, among the model specifications we use, the model with exponential discounting and quasi hyperbolic component of present bias appears to be the best one fitting the data. In contrast to BBS, our data does not support present bias in the form of a fixed cost. Overall, we find it difficult to reach general conclusions about which approach is the best in terms of compatibility with the observed choices. Subjects display diverse choices, and different models seem to fit the observed behavior of different subjects.

An incomplete project is an undesirable outcome but an incomplete project on which some effort has already been spent is even worse. There is a rapidly growing literature on individual decision making with time-inconsistent preferences and economic applications to understand this type of behavior[2]. In most of these studies, it is assumed that the tasks or projects that the agents are involved in have only one stage, i.e., they are one shot tasks or projects. However, time inconsistency may arise not only in cases where there is a one stage task to be completed in one of the $T > 1$ periods, but also in cases where the task includes $n > 1$ stages to be completed in $T > n$ periods[3]. This is the case in most of the real world tasks such as studying for an exam, finishing a paper, earning a certificate or a degree, and learning to play an instrument. These are all long-run projects that are fairly flexible in terms of allocating effort over multiple time periods, and they often have to be completed given the cost of not completing them. The real-life observations of such experiences as incomplete projects that seem contrary to the intuition and the theoretical interpretations make this issue worthwhile to investigate. The time-inconsistency literature may help us understand why these kinds of behavior may arise and develop new incentive mechanisms to deal with these inefficiencies.

There is a limited theoretical and experimental work examining behavior of economic agents engaging in a long run project[4]. In this paper, we design an experiment in which we first elicit subjects' preferences and then ask them to work on a long run project. Subjects determine the time allocation for a *two hour costly task* among three periods with a delayed payment scheme. We develop a theory that has a predictive power over the subjects' allocations based on their elicited preferences. Moreover, in addition to the quasi hyperbolic discounting, we find support for alternative approaches, namely *sign effect, the preference for improving sequences and anticipatory utility model.*

The rest of the paper is organized as follows. Section 2 discusses a discounting framework in general and offers a formal model of behavior in long run projects based on quasi hyperbolic discounting. Section 3 presents the experimental design in detail. The methodology used for the analysis of the data is discussed in section 4. Section 5 presents the results from the experiment. Section 6 discusses the limitations and alternative approaches. Section 7 concludes.

2. Discounting and Hyperbolic Discounters in Long-Run Projects

Economic decision makers are often faced with problems involving trade-offs between current and future payoffs. Discounted utility theory offers a formal analysis of these trade-offs. It postulates that the payoffs earned later in the future are less valued than the ones earned relatively early because of such reasons as the uncertainty about the availability and the magnitude of future payoffs, future payoffs being more abstract than the current or closer ones, and the possibility of dying before the realization of the payoff. It also suggests that the objective of the economic agents facing intertemporal decision problems is to maximize the sum of the discounted utilities over time. The current payoffs enter the utility function without any discounting while the future payoffs enter the utility function in a discounted manner. To evaluate the future payoff y, we use the discount function $d(t)$, hence the discounted utility of payoff y earned at time t would be $yd(t)$. Because of diminishing values of future payoffs, the discount function is assumed to be decreasing in time, $d'(t) < 0$.

In this paper, we will be interested in monetary payoffs. Money-time pairs are represented as (y, t) where y is the amount of money in dollar terms and t is the date at which y is earned (t days from now on.) The discount function that is commonly used is the exponential discounting where $d(t) = e^{-rt}$ and it is usually written as $d(t) = \delta^t$ where $\delta = e^{-r}$ is the discount factor and r is the discount rate.

In general, the discount rate is given by rate of change of the discount function:

$$-\frac{\frac{d(d(t))}{dt}}{d(t)} = -\frac{d'(t)}{d(t)}$$

where $\frac{d(d(t))}{dt}$ is the derivative of $d(t)$ with respect to time t. For exponential discounting, the discount rate is constant and given by $-\frac{d'(t)}{d(t)} = r = -\ln(\delta)$. For hyperbolic discounting, $d(t) = \frac{1}{1+rt}$ and the discount rate is decreasing in time and given by $-\frac{d'(t)}{d(t)} = \frac{r}{1+rt}$.

Decreasing discount rate means that the discount function declines at a faster rate in the short run than in the long run. Quasi hyperbolic discounting due to Phelps and Pollak (1968) and Laibson (1997) is another kind of discounting that is non-exponential and exhibits decreasing discount rates. It is a discrete-time discount function represented as $\{1,\ \beta\delta,\ \beta\delta^2,\ \beta\delta^3, ...\}$. According to this specification, the discount rate between the current period and the next period is $\frac{1-\beta\delta}{\beta\delta}$. However, per period discount rate between any two future periods is $\frac{\beta\delta^t - \beta\delta^{t+1}}{\beta\delta^{t+1}} = \frac{1-\delta}{\delta}$ and is less than the former, $\frac{1-\delta}{\delta} < \frac{1-\beta\delta}{\beta\delta}$. It reflects a present bias for $\beta < 1$ because it has the feature that there is a sharp drop in valuation of all future payoffs in the sense that for even $\delta = 1$, any delayed payoff y is worth at most βy.

BBS introduces a new form of present bias called *fixed cost* in the sense that a fixed cost is attached to any delayed payoff independent of the amount. As a result, the discounted utility of payoff y earned at time t now would be $yd(t) - b$ where b is the fixed cost.

The systematic biases reflected as preference reversals (or dynamic inconsistency) documented by the experimental studies can be explained by decreasing discount rates. In this sense, quasi hyperbolic and hyperbolic discounting exhibiting decreasing discount rates are compatible with these biases. In this paper, we, first elicit the parameters of the discount function for each subject via experimental techniques and then assess the compatibility of the elicited preferences with the observed behavior of the subjects during a multi-period project.

The elicited preferences give us clues as to how each subject might behave in a multi-period project. In addition, depending on the types of the agents[5], the prediction for the subjects' behavior may change. The hyperbolic agents in long-run projects are investigated in a recent study by O'Donoghue and Rabin (2005). The authors examine procrastination on multi-stage projects. They show that procrastination can be observed not only at the beginning of projects but also in carrying on with the projects that have already been started. This may also lead to cases where naive procrastinators may start a project, put some effort into it, but never finish it. They also find that procrastination is more likely when the effort is allocated more unequally across periods and when the cost of effort is higher towards the end, in which case agents are more likely to start but not finish a project.

The paper by Akin (2004) examines the case where an agent plays a self investment game in which he has to complete a long run project or task. The paper generalizes the two period model of O'Donoghue and Rabin (2005) to any finite period case under the assumption of homogeneous costs across periods. Under this assumption, Akin (2004) shows that the exponential type completes the investment stage immediately, the sophisticated type has a cyclical completion behavior and the naive type either invests immediately or postpones until the deadline. It is also shown that when a bonus scheme is added, naive procrastinators have to be compensated in an increasing manner to continue to invest and a higher compensation is needed for the agents with a higher degree of present bias.

Ariely and Wertenbroch (2002) offer experimental evidence on the interaction among procrastination, deadlines and performance of people when they face a sequence of tasks. They find that people are willing to self-impose deadlines, and this enhances their performance but not up to the optimal level. They also find some evidence for partial awareness of self-control problems. Fischer (2001) takes a similar approach to ours and explains how time-inconsistency problems induce severe procrastination. Considering a classical intertemporal utility maximization model with work and leisure as the arguments, Fischer examines a model where the agent has to allocate effort when a fixed amount of work has to be completed by a deadline. She shows that procrastination can arise from a utility maximizing behavior in a dynamically consistent way. However, it requires very high discount rates to generate serious procrastination and it cannot explain undesired procrastination.

The model that we present here is similar to the one in O'Donoghue and Rabin (2005) and Akin (2004). We generalize the analysis of O'Donoghue and Rabin (2005) to include *three* periods. Unlike Akin (2004), we do not assume homogeneous costs across periods. The model we develop here will form the basis of the game that the subjects played in our experiment.

2.1. Model. An agent has a costly project to complete within a certain period of time. The agent has the choice of when and how to complete, or not to complete the project. The project is a long term project in the sense that the agent has to invest in at least two different periods to complete it. The project cannot be completed in only one period because of the time and effort constraints. Completion of the project results in a fixed payoff. The payoff, v, is earned one period after the completion period.

For simplicity, we assume that the project must be completed in at most three periods. The agent has to distribute the required time to complete the project among these three periods to maximize his net payoff given his preferences.

Players' preferences are as follows: the player may be time-consistent exponential agent having the sequence of discount factors: $\{1,\ \delta,\ \delta^2,\ \delta^3, ...\}$ or he may be naive or sophisticated hyperbolic both having the following sequence of discount factors: $\{1,\ \beta\delta,\ \beta\delta^2,\ \beta\delta^3, ...\}$. Here, δ is the standard time-consistent impatience factor where $\delta \in (0,1)$ and β is the time-inconsistent preference for immediate gratification or the self-control problem of the agent where $\beta \in (0,1)$. Let $\widehat{\beta}$ be the agent's belief about his future self-control problems- his beliefs about what his taste for immediate gratification, β, will be in all future periods. A sophisticated person knows exactly what his future self-control problems will be, therefore has perceptions $\widehat{\beta} = \beta$. A naive person believes he will not have any self-control problems in the future, therefore has perceptions $\widehat{\beta} = 1$. In this part, we will be referring to quasi hyperbolic discounting whenever we use the term hyperbolic discounting.

Let C represent the total cost that needs to be incurred in order to complete the project[6] and let $\overline{c}$ denote the maximum cost that can be incurred in a given period. We will assume $C \in (\overline{c},\ 2\overline{c}]$. If we call c_1, c_2 and c_3 as the cost incurred in periods 1, 2 and 3, respectively, then $c_1 \leq \overline{c}$, $c_2 \leq \overline{c}$, $c_3 \leq \overline{c}$ and $c_1 + c_2 + c_3 \leq C$. If $c_1 + c_2 + c_3 = C$, a fixed payoff v is earned, if $c_1 + c_2 + c_3 < C$, the project fails to be completed generating a zero payoff.

2.2. Timing of The Game. In period 0, the agent learns about the project, the allocation restrictions of the cost and the payoff. He then plans how much cost to incur in the following periods. This planning of the project is important because depending on the preferences of the agent, the plan may turn out to be time-consistent, i.e., the plan and the actual investment behavior are the same, or it may turn out to be time-inconsistent, i.e., the plan and the actual investment behavior are not the same.

In period 1, the agent has two choices. One is to do nothing because either postponing is optimal or the project is not worth starting. The other is to choose $0 < c_1 \leq \overline{c}$ and incur this cost with the expectation of finishing the project in the future.

In period 2, the agent has two choices again. If he incurred c_1 in the last period, he can finish the project by investing the rest $C - c_1$ (if $c_1 \geq C - \overline{c}$). Alternatively, he can do nothing (if a project is not worth starting in period 1, it is not worth starting in period 2 either). The agent may also want to invest some, but not all of the remaining cost $C - c_1$. If he did not invest in the previous period, he either invests $C - \overline{c} \leq c_1 \leq \overline{c}$ or gives up on the project completely (given that the agent did not invest in the first period, if he does not invest in period 2 either, he will not be able to finish the project.)

In period 3, if the agent finished the project in the previous period, he gets the payoff. If he incurred the cost c_1 and c_2 ($C - \overline{c} \leq c_1 + c_2 < C$) in the previous periods, he can either invest the rest in period 3, finish the project and get the payoff in the following period, or he may choose not to finish the project even though he has already incurred $c_1 + c_2$. We will examine the convex cost case later but for now, we assume the cost is linear in time and the following remark states that under the linear cost, for all parameter values, the set of optimal allocations is very small.

Remark 1. *In period 1, for the agent with hyperbolic ($\beta \in (0, 1)$) or exponential discounting ($\beta = 1$), it is optimal to incur the maximum cost, $\overline{c}$, at the finishing stage. To see this, consider the fact that the agent tries to maximize the following discounted utility by choosing c_1 and c_2,*

$$P^*(c_1,\ c_2) = \max_{c_1, c_2} P(c_1,\ c_2) = \max\{0, -c_1 - \beta\delta c_2 - \beta\delta^2(C - c_1 - c_2) + \beta\delta^3 v\} \text{ if } c_1 + c_2 \neq C$$

$$P^*(c_1,\ c_2) = \max_{c_1, c_2} P(c_1,\ c_2) = \max\{0, -c_1 - \beta\delta c_2 + \beta\delta^2 v\} \text{ if } c_1 + c_2 = C$$

It is clear that for any given $\beta,\ \delta,\ C$ *and* v *values, if* $c_2 \neq C - c_1,$ *then since* $P(c_1,\ c_2)$ *is decreasing both in* c_1 *and* c_2*, the following are true*

$$-c_1 - \beta\delta c_2 - \beta\delta^2(C - c_1 - c_2) + \beta\delta^3 v \overset{c_1 \to 0}{<} -\beta\delta c_2 - \beta\delta^2(C - c_2) + \beta\delta^3 v < -\beta\delta(C - \overline{c}) - \beta\delta^2\overline{c} + \beta\delta^3 v$$

$$-c_1 - \beta\delta c_2 - \beta\delta^2(C - c_1 - c_2) + \beta\delta^3 v \overset{c_2 \to 0}{<} -c_1 - \beta\delta^2(C - c_1) + \beta\delta^3 v < -(C - \overline{c}) - \beta\delta^2\overline{c} + \beta\delta^3 v$$

however,

$$-\beta\delta(C - \overline{c}) - \beta\delta^2\overline{c} + \beta\delta^3 v > -(C - \overline{c}) - \beta\delta^2\overline{c} + \beta\delta^3 v$$

On the other hand, if $c_2 = C - c_1,$ *then by the same reasoning above, the agent should choose* $c_1 = C - \overline{c}$*. Then the above problem can be written as follows:*

$$P^*(c_1,\ c_2) = \max\{0,\ \ -(C - \overline{c}) - \beta\delta\overline{c} + \beta\delta^2 v,\ \ -\beta\delta(C - \overline{c}) - \beta\delta^2\overline{c} + \beta\delta^3 v\}$$

Depending on the parameter values (as long as both expressions are greater than zero), one of them will give us the maximizing allocation as either $c_1 = 0$ *and* $c_2 = C - \overline{c}$ *or* $c_1 = C - \overline{c}$ *and* $c_2 = \overline{c}$*.*

2.3. Formal Analysis. The investment schedule $(c_1,\ c_2,\ c_3;\ t)$ means that the agent invests c_1 in period 1, c_2 in period 2, c_3 in period 3 and gets the payoff at time t. For example, $(c_1,\ C - c_1,\ 0;\ 3)$ means that the agent invests c_1 at $t = 1$, invests the rest at $t = 2$ and gets the payoff at $t = 3$.

$$c_1 + c_2 + c_3 \leq C$$

$$\begin{aligned} If\ c_1 + c_2 + c_3 &= C, \text{ then } t = \begin{cases} 3, \text{ if } c_1 + c_2 = C \\ 4, \text{ if } c_1 + c_3 = C,\ c_2 + c_3 = C \text{ or } c_i \neq 0,\ i = 1,2,3 \end{cases} \\ If\ c_1 + c_2 + c_3 &< C, \text{ then we write } (c_1,\ c_2,\ c_3; -) \end{aligned}$$

Exponential Agent. The exponential agent is time-consistent in the sense that he plans to follow an investment schedule and he follows it as such. His plan of finishing the project or not doing it depends on whether the project is worth doing regardless of the period from which he looks ahead. If condition 1 below is satisfied, then the exponential agent investment schedule will be $(C - \overline{c},\ \overline{c},\ 0; 3)$:

$$-(C - \overline{c}) - \delta\overline{c} + \delta^2 v \geq 0 \tag{1}$$

If the above condition is not satisfied, then the exponential agent will not start the project. So, since for the exponential agent $\beta = 1$, postponing is not optimal.

Naive Hyperbolic Agent. The naive hyperbolic agent may not be able to follow his original plan in the future because of unawareness of his own preference for immediate gratification. In period 0, if the condition 1 is satisfied, then he plans to finish the project in the future. In period 1, he will compare the expressions in condition 2 below:

$$\underbrace{-(C - \overline{c}) - \beta\delta\overline{c} + \beta\delta^2 v}_{(C - \overline{c},\ \overline{c},\ 0;3)} \geq \underbrace{-\beta\delta(C - \overline{c}) - \beta\delta^2\overline{c} + \beta\delta^3 v}_{(0, C - \overline{c},\ \overline{c};4)} \geq 0 \tag{2}$$

If condition 2 is satisfied, then the agent starts doing the project. If condition 3 below is also satisfied, then the naive agent finishes the project in the second period and gets the payoff in period 3 $(C-\bar{c},\ \bar{c},\ 0;3)$:

$$\beta\delta v-\bar{c}\geq\beta\delta^2 v-\beta\delta\bar{c}\geq 0 \tag{3}$$

However, if $\beta\delta^2 v-\beta\delta\bar{c}\geq\beta\delta v-\bar{c}\geq 0$, then the agent follows the investment schedule $(C-\bar{c},\ 0,\ \bar{c};4)$. In addition, if $\beta\delta v-\bar{c}\leq 0\leq\delta v-\bar{c}$, then he does not finish the project, $(C-\bar{c},\ 0,\ 0;-)$.

If condition 2 is not satisfied,

$$0\leq\underbrace{-(C-\bar{c})-\beta\delta\bar{c}+\beta\delta^2 v}_{(C-\bar{c},\ \bar{c},\ 0;3)}\leq\underbrace{-\beta\delta(C-\bar{c})-\beta\delta^2\bar{c}+\beta\delta^3 v}_{(0,C-\bar{c},\ \bar{c};4)} \tag{4}$$

then he postpones the project to period 2. In period 2, he starts. In period 3, if $\beta\delta v-\bar{c}\geq 0$, then $(0,\ C-\bar{c},\ \bar{c};4)$. If $\beta\delta v-\bar{c}\leq 0\leq\delta v-\bar{c}$, then $(0,\ C-\bar{c},\ 0;-)$.

If the following is satisfied, then he never starts, $(0,\ 0,\ 0;\ -)$;

$$\underbrace{-(C-\bar{c})-\beta\delta\bar{c}+\beta\delta^2 v}_{(C-\bar{c},\ \bar{c},\ 0;3)}\leq\underbrace{-\beta\delta(C-\bar{c})-\beta\delta^2\bar{c}+\beta\delta^3 v}_{(0,C-\bar{c},\ \bar{c};4)}<0$$

Sophisticated Hyperbolic Agent. The sophisticated agent thinks ahead and perceives what he will do in the future. He then works backwards and decides what to do now. If conditions 2 and 3 are satisfied, then he follows $(C-\bar{c},\ \bar{c},\ 0;3)$. If 3 and 4 are satisfied, then, he follows $(0,\ C-\bar{c},\ \bar{c};4)$. A sophisticated agent will never incur any cost without getting any payoff i.e., he never starts a project that he will not finish (he never follows $(C-\bar{c},\ 0,\ 0;-)$ or $(0,\ C-\bar{c},\ 0;-)$). This happens because he knows how he will behave in the future. On the other hand, since naive agent misperceives his future actions, he may start projects that he will not finish.

We can also observe an outcome where the cost incurred is not equal to $\bar{c}$. This is because the agent knows how he will actually evaluate payoffs in the future, thus he can arrange the cost to make each stage worth investing. If condition 2 is satisfied, but condition 3 is not, then he knows that he cannot implement $(C-\bar{c},\ \bar{c},\ 0;3)$. Instead, he will figure out the least costly implementable strategy and compare it with $(0,\ C-\bar{c},\ \bar{c};4)$ because this is surely implementable by his future self. The least costly implementable strategy is the one that makes the second period self indifferent between postponing the remaining time to the last period and finishing it in the second period. It is given by the following equation:

$$\beta\delta v-c^*=\beta\delta^2 v-\beta\delta c^*$$

where c^* is the maximum amount of cost/time that sophisticated agent can allocate for the second period because any $c>c^*$ will make him postpone the completion of the project to the third period. Then, he will choose and implement $\max\{(0,\ C-\bar{c},\ \bar{c};4),\ (C-c^{**},\ c^{**},\ 0;3)\}$ strategy where $c^{**}=\max\{C-\bar{c},c^*\}$ and $c^{**}=c^*$ (note that by definition, $c^*<\bar{c}$.) If $c^{**}=C-\bar{c}$, then least costly implementable strategy is $(C-\bar{c},\ c^*,\ \bar{c}-c^*;4)$ and net payoff of this is obviously lower than that of $(0,\ C-\bar{c},\ \bar{c};4)$.

2.4. Convex Cost Specification. Until now, we have assumed that the cost is linear in time, $C(t) = t$. In this section, we generalize the analysis to the convex cost case. The problem of the agent is now as follows:

$$\max_{\{t_1,t_2\}}\{-\underbrace{c(\frac{t_1}{T})^\alpha}_{c_1} - \beta e^{-rl_1}\underbrace{c(\frac{t_2}{T})^\alpha}_{c_2} - \beta e^{-rl_2}\underbrace{c(\frac{T-t_1-t_2}{T})^\alpha}_{C-c_1-c_2} + \beta e^{-rl_3}v\}$$

where T is the total time to be allocated, c is the total cost[7] for T, t_i is the time allocated to the period i and $\alpha > 1$. Taking the first order conditions and doing the necessary calculations, we find that

$$\begin{aligned} t_1^* &= t_2^*(\beta e^{-rl_1})^{\frac{1}{\alpha-1}} = \frac{T(\beta e^{-rl_1})^{\frac{1}{\alpha-1}}}{1+e^{\frac{-r(l_1-l_2)}{\alpha-1}} + (\beta e^{-rl_1})^{\frac{1}{\alpha-1}}} \\ t_2^* &= \frac{T}{1+e^{\frac{-r(l_1-l_2)}{\alpha-1}} + (\beta e^{-rl_1})^{\frac{1}{\alpha-1}}} \\ T - t_1^* - t_2^* &= \frac{Te^{\frac{-r(l_1-l_2)}{\alpha-1}}}{1+e^{\frac{-r(l_1-l_2)}{\alpha-1}} + (\beta e^{-rl_1})^{\frac{1}{\alpha-1}}} \end{aligned}$$

Note that $t_1^* \to \frac{T}{3}$; $t_2^* \to \frac{T}{3}$ and $T - t_1^* - t_2^* \to \frac{T}{3}$ as $\alpha \to \infty$. In the experiment, we use $T = 120$, $l_1 = \frac{3}{365}$, $l_2 = \frac{7}{365}$, $l_3 = \frac{11}{365}$, β and r are subject specific and convergence is achieved after $\alpha = 3$. Thus, non linear costs might offer a better explanation of more even allocation of costs.

One challenge with our experiment data is that we might observe similar behavior from subjects with different preferences. This problem can be solved by eliciting subjects' preferences. However, for some quasi hyperbolic agents, we may not be able to distinguish whether they are sophisticated or naive by simply looking at their elicited preferences and the behavior. On the other hand, if they do not invest consecutively, they are automatically naive unless there is an exogenous shock that the subject did not take into account initially. If they do not follow the specified cost distribution (first invest $C-\bar{c}$ and then $\bar{c}$), then they are automatically sophisticated unless they have other behavioral characteristics that will be mentioned shortly. Although we will discuss different approaches that may lead to different allocation patterns in the discussion section, we will mention some of them[8] here as they will be helpful in assessing the results of the experiment. One obvious factor is *exogenous cost shocks* that can explain almost any type of distribution of cost behavior observed. *Concave cost function specification* is another alternative. Different cost allocation patterns may arise from this specification. Another possible approach is, the so called *sign effect,* according to which gains are discounted at a higher rate than losses. Another reasonable approach is *the preference for improving sequences* suggesting that people prefer improving sequences to declining ones. Finally, *the models of anticipatory utility* argue that if people derive utility from both current consumption and the anticipated future consumption, then the instantaneous utility function should involve both. We will provide a more detailed discussion of these models later in the paper.

3. Experimental Design

We recruited a total of 29 Pennsylvania State University (PSU), University Park Campus, students (both undergraduate and graduate as subjects for the experiment.) The experiment took place in the Laboratory for Economics Management and Auctions (LEMA) at PSU. The experiment included four sessions and two parts. The first part included the first session while the second, third and fourth sessions constituted the second part. The first session included the explanation of the structure of the entire experiment and a set of questions that were designed to elicit time preferences of the subjects. The sessions in the second part were called "task sessions" in which the subjects were asked to complete a long-run task. In the recruiting process, we emphasized that participants had to be *available* for all of the four sessions even though they did not have to stay in the lab throughout each session. The purpose of imposing this availability requirement is to eliminate any exogenous factors that may prevent subjects from coming to any of the sessions. As will be explained later, this requirement is particularly important for the second part of the experiment. The instructions used in the experiment are in the appendix.

The first part of the experiment was similar to BBS. In this session, subjects were asked thirty questions that are of the following form:

"What amount of money, $x, if paid to you today would make you indifferent to $y paid to you in t days?" $____

In the thirty questions given to the subjects, we specified the values of (y, t). A typical question was as follows:

"What amount of money, $x, if paid to you today would make you indifferent to $50 paid to you in 30 days?" $____

The values of t included 5, 10, 15, 20, 25 and 30 days while the values of y included 10, 20, 30, 40 and 50, giving a total of thirty combinations.

As in BBS, we utilized the Becker-DeGroot-Marschak incentive mechanism to determine what amount and when the subjects would be paid. After the subjects answered all of the thirty questions, one of the questions was randomly drawn using dice rolls. Drawing was done for each subject separately and in private. Suppose, for example, that the question with values $y = 50$ and $t = 30$ is drawn for subject #1 where the subject is asked what amount she would require today to make her indifferent between that amount today and $50 to be paid in one month. Suppose her answer is $40. Then, a random number is drawn between 0 and 50 where all the numbers between 0 and 50 have equal probability of being drawn. This number is drawn separately and privately for each of the participants in the experiment. If the number drawn is smaller than the indifference amount the subject stated (i.e., if the number drawn is smaller than 40), she would have to wait for one month at which time she will be paid $50. If the number drawn is greater than the indifference amount she stated (i.e., if the number drawn is greater than 40), then the amount drawn is paid to her immediately. The purpose of this lottery is to attach monetary incentives to subjects' answers to these thirty questions, hence to prevent random responses from the subjects. Under the risk neutrality assumption, it is a dominant strategy to report the true indifference amount in this mechanism[9].

At the end of the session, the amount the subjects earned was deposited into their Penn State ID Card accounts at the date determined by the lottery. Payments were deposited to the subjects' ID card accounts, as opposed to paying the subjects in cash, due to its convenience and to eliminate uncertainties regarding the ability of the subjects to show up for payments in future periods as well as eliminating differences in traveling time and cost to the payment site across subjects[10].

The second part of the experiment was designed to observe the behavior of the subjects facing a long-run project. In the task sessions, the subjects were asked to complete a two-hour task. Our choice of task for the subjects needs to satisfy the following constraints: 1. It has to be costly. That is, the task should yield disutility, not utility, for the subjects, 2. It has to be perfectly divisible in the sense that the subjects should be able to leave it whenever they wish and return to it at a later session, 3. It has to be long enough to keep them busy for two hours, 4. It should not require any subject specific knowledge, age, experience, etc. Under these constraints, we decided to ask the subjects to "fill out surveys" for two hours. These surveys were obtained from various online resources and included simple multiple choice questions about the subjects' internet usage, shopping behavior, choice of movie and restaurants, etc. A sample survey is included in the Appendix. Subjects had the flexibility to allocate the two-hour task time among the three task sessions scheduled for April 20, April 24 and April 27, 2006. We required them to come to each of the three task sessions and to sign a sign up sheet[11]. In addition to what they earned from the first part, subjects were also promised to be paid a fixed amount, $35, only if they complete this two-hour task and sign the sign up sheet at each of the three task sessions. Subjects were allowed to work on the task up to 90 minutes (1.5 hours) in any given session. Thus, they had to work on the task in at least two of the three task sessions to complete the task. This makes the task a long-run task in the sense that they could not finish it in one period. We asked the subjects for their plans (nonbinding) regarding the task before giving out the questions in the first session and at the beginning and end of each of the task sessions. We collected this information to observe possible inconsistencies in their plans and actual allocations.

The payment schedule for the second part of the experiment was as follows: if the task was completed on April 27, then the $35 payoff would be deposited to the subject's ID account on May 1. If it was completed on April 24, then the $35 payoff would be deposited on April 27. This is an example of a delayed reward where subjects are paid later than the time they finish the task. This is consistent with the theory we have in the previous section.

Except the second session (first task session), the subjects were free to choose the date at which they come to the Lab to work on the task (between 1.00-3.00 pm at the specified dates). We required all subjects to show up for the beginning of the second session to participate in an auction. In this second price auction, our aim was to learn about their cost of the two hour task. The auction was as follows: first, the subjects were asked to fill out a form to indicate their plan regarding the completion of the task. We then asked each of them to fill out a bid form. This bid was for the right to be waived from the requirement of completing the two-hour task. A subject's bid indicated how much money that subject was willing to give up out of his/her $35 fixed earnings. The highest bidder paid the second highest bid; hence his earnings was $35 minus the second highest bid. The winner was exempted from completing the two-hour task and was paid according to his/her indicated plan.

The maximum bid at the auction was $25, with a minimum bid of $0 and the second highest bid of $18[12]. The average bid was $6 with zero bids, $8.3 without zero bids. Actual allocations and bids are provided in Table 1. Two of the subjects started but did not finish the second part of the experiment, seven of the subjects allocated the task equally between the first two periods, three of the subjects took a break in the second period, five of them allocated the task in all the three periods, four of them finished the task in the first two periods, three of them worked only in the last two periods, one of them did not come to the second part of the experiment at all and four of them spent the maximum time in the first period and finished it in the second period.

After going over the instructions in the first session, the subjects were given a quiz involving questions about the experiment and more than 90% of the questions were answered correctly. This indicates that subjects had a good understanding of the structure and the rules of the experiment.

4. Methodology

The econometric method we used to elicit the preferences is very similar to that of Benhabib et al. The method involves a four-parameter discounting model as follows:

$$D(y,\ t;\ \theta,\ r,\ \beta,\ b) = \beta d(t;\ \theta,\ r) - \frac{b}{y}$$

$$\text{where } d(t;\ \theta,\ r) = (1-(1-\theta)rt)^{\frac{1}{1-\theta}}$$

Here, (y,t) is the money-time pair, θ is the curvature of the discount function, β is the quasi hyperbolic component of present bias, b is the fixed cost component of the present bias and r is the discount rate when the discounting is exponential though in general it is a component of discount rate that is independent of time. Exponential, hyperbolic and quasi-hyperbolic approaches are all embedded in this one specification. Without the present bias components and for some specific curvature of the discount function, the discount function becomes:

$$D(y,\ t;\ \theta,\ r) = (1-(1-\theta)rt)^{\frac{1}{1-\theta}}y$$

When $\theta = 1$, this turns into the exponential discounting:

$$D(y,\ t;\ \theta = 1,\ r) = e^{-rt}$$

When $\theta = 2$, discount function turns into the hyperbolic discounting:

$$D(y,\ t;\ \theta = 2,\ r) = \frac{1}{1 + rt}$$

In the first part of the experiment, we obtain the indifference points of each subject on money-time pairs as mentioned earlier. We did this by asking the subjects for the indifference amount to be earned today, \$$x$, to a specified late payment (\$$y,\ t$) for different combinations of \$ amounts and time horizons. As a result, we have 30 observations[13] for each subject $i = 1, 2, ..., 29$ for x where $x = yD(y,t)$ under the risk neutrality assumption.

In the most general form, we assume that the data generating process for each subject i is:

$$x = y^i(x,t)D(y^i(x,t),\ t;\ \theta^i,\ r^i,\ \beta^i,\ b^i)\varepsilon^i(x,t)$$

where $\varepsilon^i(x,t)$ is assumed to be lognormally distributed[14] and i.i.d. with respect to subjects and questions. The estimation method we used is the non-linear least squares[15].

For the second part of the experiment, we used different statistical approaches to compare the actual data and the theoretical predictions. Recall that we assigned the subjects a project to be completed in two hours and we restricted the maximum amount of work for a given period to 1.5 hours. This means that

$$\max_{\{t_1,t_2\}} \{-\underbrace{c(\frac{t_1}{120})^\alpha}_{c_1} - \beta e^{-r\frac{3}{365}} \underbrace{c(\frac{t_2}{120})^\alpha}_{c_2} - \beta e^{-r\frac{7}{365}} \underbrace{c(\frac{120 - t_1 - t_2}{120})^\alpha}_{C - c_1 - c_2} + \beta e^{-r\frac{11}{365}} v\}$$

subject to

$$t_1 + t_2 + t_3 = 120;\ t_1 \leq 90,\ t_2 \leq 90;\ \alpha \geq 1$$

If $t_1 + t_2 = 120$ above, then the problem would be as follows:

$$\max_{\{t_1,t_2\}} \{-\underbrace{c(\frac{t_1}{120})^\alpha}_{c_1} - \beta e^{-r\frac{3}{365}} \underbrace{c(\frac{t_2}{120})^\alpha}_{c_2} - \beta e^{-r\frac{7}{365}} v\}$$

subject to

$$t_1 + t_2 = 120;\ t_1 \leq 90,\ t_2 \leq 90;\ \alpha \geq 1$$

From the second part of the experiment, we obtained (the actual data) $(t_j^i)^*$ for all subjects $i = 1, 2, ...29$ and for all periods $j = 1, 2, 3$. From the theory, we calculated predicted values $\widehat{t_j^i}$ for all $i = 1, 2, ...29$ and for all $j = 1, 2, 3$. The statistical approach that we use to compare the actual data and the theoretical predictions is as follows:

1. We first look at the ratio of the sum of errors to the maximum error. We look at both the sum of absolute errors and sum of squared errors.

   (a) For the absolute errors case, the statistic we study is

   $$S_{1a} = \frac{\sum_i \sum_j |\widehat{t^i_j} - (t^i_j)^*|}{180 * N}$$

   where N is the number of subjects. The numerator first takes a subject, calculates the absolute error we made for that subject and then adds these errors across subjects. This number alone does not mean anything unless we compare it to what the maximum possible error is. The denominator is the maximum possible error one can make in predicting the allocations[16].

   (b) For the squared errors case, the statistic we look at is

   $$S_{1b} = \frac{\sum_i \sum_j (\widehat{t^i_j} - (t^i_j)^*)^2}{140 * 90 * N}$$

   For both of these values, a closer statistic to *zero* represents a better prediction. These statistics are similar to $R - Square$ (to be more precise, they are similar to $1 - (R - Square)$).

2. Then, we look at the correlation coefficient indicating the strength and direction of a linear relationship between two random variables[17]. Specifically, the statistics we look at is

   $$S_2 = correlation(\widehat{t^i_j},\ (t^i_j)^*)\ \forall\ j = 1,\ 2,\ 3,$$

   where a statistics closer to *plus one* represents a better prediction[18].

3. We then compare first two moments of the actual and predicted data. For this, we use following statistics

   $$S_{3a} = \frac{mean(\widehat{t^i_j})}{mean((t^i_j)^*)}\ and\ S_{3b} = \frac{variance(\widehat{t^i_j})}{variance((t^i_j)^*)}\ \forall\ j = 1,\ 2,\ 3.$$

   For both of the statistics, a value closer to *one* represents a better prediction.

4. We also look at a measure called effect size to measure the strength of the relationship between two variables. The most commonly used effect size measure is Cohen's d. It is defined as follows:

   $$d = \frac{mean_1 - mean_2}{\sqrt{\frac{(SD_1^2 + SD_2^2)}{2}}}$$

where $mean_i$ and SD_i are the mean and standard deviation for group i, for $i = 1, 2$. The most accepted opinion about the interpretation of the resultant effect size is that 0.2 is indicative of a small effect, 0.5 a medium and 0.8 a large effect size. A larger measure means that there is a consistent difference between the two series.

Although S_{1a}, S_{1b}, S_{3a} and d carry some valuable information about the predictions, it would be more meaningful if we compare our statistics with the statistics obtained by a random allocation (we will refer to them as SR_{1a}, SR_{1b}, SR_{3a} and d_r). If $S_{1a} < SR_{1a}$, $S_{1b} < SR_{1b}$, $S_{3a} > SR_{3a}$ and $d < d_r$, then we conclude that our prediction does better than the one with random allocation. In other words, it has more predictive power than the one with random allocations. Note that this approach is appropriate for S_{1a}, S_{1b} and S_{3a}, but not for S_2 and S_{3b}.

5. Results

In this section, we report the results from the econometric examination of the data. First, we discuss the results from the elicitation of the preferences, first part of the experiment. Then, we report the results from the second part of the experiment, behavior of the players in the long-run project.

5.1. Preference Elicitation. We examined the data from the first part of the experiment by using different model specifications mentioned in the methodology section. There are five different model specifications and we will report results from each of them in the order that they were mentioned in the methodology section. The first three estimation methods are identical to those of BBS and we will compare our results with theirs. The last two estimation methods are different in the sense that the curvature of the discount function is restricted to 1 and present bias is included both in the form of a variable and a fixed cost.

In the first estimation, we specify the discount function as follows:

$$d(t;\theta,\ r,\ \beta,\ b) = d(t;\theta,\ r,\ \beta = 1,\ b = 0)$$

The values for the parameters θ and r are significant for 11 and 12 out of 25 subjects, respectively. They are jointly significant in only 5 cases. The exponential specification, $\theta = 1$, is rejected for 12 subjects. The values for r are pretty high such that in 18 cases, it is more than 100% and for 10 subjects, it is in the order of thousands. On the other hand, for 5 subjects, it is less than 100% and its average is 55%. This specification does not seem to be an appropriate model because of the high values for r and the insignificance of the parameters in more than half of the cases. Table 2 shows the results for all the subjects.

In the second estimation, the following discount function is used:

$$d(t;\theta,\ r,\ \beta,\ b) = d(t;\theta,\ r,\ \beta = 1,\ b).$$

Here, we basically added the present bias parameter in the form of a fixed cost, b. As opposed to what BBS found in their data, we could not find a significant support for the present bias in the form of a fixed cost. For only half of the subjects, the fixed cost b is estimated significantly different than 0, in 5 of these cases, it is less than zero and the average is approximately \$1.3 (minimum is $\$-4.7$ and maximum is \$12.) Moreover, this specification does not allow us to get more plausible estimates for r either. The numbers we obtained in the first estimation are very similar to the ones in this specification. Only half of the values for r are significant and the point estimates are almost the same as above. Both the hypothesis of exponential discounting, $\theta = 1$, and hyperbolic discounting, $\theta = 2$, are not rejected at the 95% confidence interval for half of the subjects (for two of the subjects, they are not rejected at the 90% confidence interval). The range of the values of θ is from -18 to $+97$ (in one case it is in the order of negative thousands.) As in BBS, we are not able to distinguish the exponential discounting from hyperbolic discounting. The results are reported in Table 3.

In the third model specification, we allow all parameters to vary (there are no restrictions on the parameters.) The present bias in the form of variable cost (it is variable in the sense that the cost of earning y at a future date, $(1-\beta)y$, increases linearly with y), β, for 19 subjects is greater than 1. The number of significant β values are 19 out of 24 subjects. For 7 of these 19 subjects, we could not reject the hypothesis that $\beta = 1$. Among these 12 subjects, only 5 are significantly smaller than 1. These results are similar to the results of BBS. The θ and r parameters do not seem to be significant at all and for 19 of the 24 subjects both the hypothesis of exponential and hyperbolic discounting could not be rejected. For 16 subjects, the fixed cost b is estimated significantly different than 0, in 4 of these cases, it is less than zero and the average is approximately \$1.9 (minimum is $\$-4.26$ and maximum is \$17.) As a result, the estimates for the fixed cost b are not very much different than the previous case. The results are reported in Table 4.

Now we turn to the next two specifications where we fix the curvature of the discount function to unity, $\theta = 1$. In other words, we assume an exponential specification and we added the quasi hyperbolic component, β , and then the fixed cost component, b.

In the fourth specification, we used the following discount function:

$$d(t;\theta,\ r,\ \beta,\ b) = d(t;\theta = 1,\ r,\ \beta,\ b = 0)$$

This means that discounting is exponential and there is no present bias in the form of a fixed cost but there is a quasi hyperbolic component. In this specification, all the $\beta's$ are significant and for 22 out of 25 subjects, $r's$ are also significant (two of these are significant at the 90% confidence interval, one is at 95%, one is at 97% and others are significant at the 99% confidence interval.) Now only 9 out of 25 β values are greater than 1 and for 4 of these, the hypothesis of $\beta = 1$ cannot be rejected. The values for β range from 0.64 to 1.19. The average of $\beta's$ is 0.92 (Excluding the ones that are not rejected to be 1, the average becomes 0.9). Moreover, the values of r are more reasonable in the sense that for half of the subjects it is less than 100% (average is around 45%), for only one subject, it is in the order of thousands and the average is 1.9 (1.45 without the highest one.) The results are reported in Table 5.

In the last specification, we used the following discount function:

$$d(t;\theta,\ r,\ \beta,\ b) = d(t;\theta = 1,\ r,\ \beta,\ b)$$

where we allow both present bias components, fixed and variable. The estimates we obtained for β and r in this specification are very similar to the ones we obtained in the previous specification. All $\beta's$ and all but 5 r's are significant. Now 12 out of 25 β's are greater than 1 and for 4 of these, the hypothesis of $\beta = 1$ cannot be rejected. The values for β range from 0.64 to 1.22. For 16 of the subjects, the fixed cost b is estimated to be significantly different than 0, in 5 of these cases, it is less than zero and the average is approximately \$1.6 (minimum is $\$-4.43$ and maximum is \$17.6.) The results are reported in Table 6.

In summary, the last two specifications seem to be more reasonable in explaining the data, especially the fourth one. As a result, the present bias in the form of a fixed cost does not receive as strong support as in the BBS paper. The data tends to be in support of exponential specification along with the quasi hyperbolic component with an average of 0.92, which is still higher than the one reported by Laibson-Repetto-Tobacman (2004). Since the variable cost is found to be significantly less than 1, using it in the economics applications remains meaningful. As mentioned in BBS, these results are obtained with the data including small rewards and the short time-horizons, thus, we have to be very cautious in generalizing our results.

5.2. Long-Run Project. We now report the results from the second part of the experiment. We report the values of statistics for different specifications. For the case of linear cost, we obtain the following results:

S_{1a}= 0.37	S_{1b}= 0.19	S_2= 0.37, 0.32, 0.49	S_{3a}= 0.72, 1.18, 1.71	S_{3b}= 1.5, 1.18, 1.71
SR_{1a}= 0.46	SR_{1b}= 0.18	S_2=	SR_{3a}= 0.76, 0.82, 2.47	S_{3b}=

d = 0.23, 0.57, 0.13
d_r= 0.97, 0.35, 2.53

The first row represents the values of statistics that we defined in the methodology section. It roughly means that the model explained %63 and %81 of the data in absolute and squared error terms, respectively. The correlation terms, S_2, are all positive meaning that the data series are positively correlated and correlation is medium in two of the series and large in the last one. The ratios of means and variances are fairly close to one, which implies a good fit between the observed behavior and the theoretical prediction. The values of Cohen's d are fairly small implying that there is no significant difference between the two series.

When we compare our statistics with the statistics that are obtained by even allocations (for every agent, the time is allocated equally) presented in the second row, we conclude that our predictions actually perform weakly better in all statistics than even allocations statistics.

For convex cost with $C(t) = t^2$, we have,

S_{1a}= 0.47	S_{1b}= 0.18	S_2= 0.2, −0.14, 0.37	S_{3a}= 0.72, 0.84, 2.58	S_{3b}= 0.02, 0.007, 0.005
SR_{1a}= 0.46	SR_{1b}= 0.18	S_2=	SR_{3a}= 0.76, 0.82, 2.47	S_{3b}=

$d = 0.55, 0.08, 0.81$
d_r= 0.97, 0.35, 2.53

Although the convex cost specification predicts allocations well for some agents, overall, it does not offer better results than the linear cost approach.

By looking at the subjects' allocation pattern and based on the theory, we can say something about the types of the subjects. Observationally, to distinguish the types of the agents, the following point is important. Among those subjects for whom it is not optimal to postpone at $t = 1$, naive types will spend the minimum time at $t = 1$. However, sophisticated types will check whether or not this is an implementable plan by verifying the feasibility of finishing the rest of the task at $t = 2$. If it is feasible, then they start with $C-\overline{c}$ at $t = 1$ and finish with $\overline{c}$ at $t = 2$. If not, then they figure out c^* that is the maximum tolerable amount of time leading them not to postpone at $t = 2$. They take $c^{**} = \max\{C-\overline{c},\ c^*\}$ and then they compare spending $C-c^{**}$ at $t = 1$ and c^{**} at $t = 2$ with postponing the task. Based on their elicited preferences, we calculate c^{**} values at which it is not optimal for some subjects to postpone at $t = 1$ but it is optimal for them to postpone at $t = 2$. For *three* subjects who are in this category, c^{**} is $65,\ 70$ and 80. For these subjects, it is optimal to incur $C-c^{**}$ at $t = 1$ and c^{**} at $t = 2$ rather than postponing. Only for these subjects, the theory is able to make a prediction as to whether they are sophisticated or naive. However, the sophisticated approach predicts these subjects' behavior better. There are *six* more agents for whom it is optimal to postpone in the first period. Unfortunately, we cannot identify the types of these subjects because based on their elicited preferences, naive and sophisticated types behave in the same way. For the rest of the subjects, the theory again suggests the same pattern of allocation (incurring $C-\overline{c}$ at $t = 1$ and $\overline{c}$ at $t = 2$) for both types.

As a result, when the theoretical predictions are compared with the actual data obtained from the experiment, we find that the theory overall is capable of predicting the allocation pattern to some extent. Although most of the subjects' allocation is not predicted perfectly, it is fairly evident that our analysis has some predictive power. In terms of type categorization, in most of the cases, the theory is not able to make distinction between the sophisticated and naive hyperbolic types. This is because the theory predicts the same pattern for both types, based on their elicited preferences. However, if other modelling approaches are also taken into account, the agents can be categorized based on their types[19]. We briefly elaborate on the categorization we made based on the choices of the subjects in the next section.

6. Discussion

We observed some noisy behavior both in the preference elicitation and the elicitation of individual task costs. Firstly, some subjects showed no discounting at all in the first part of the experiment. Fortunately, we gave all subjects a set of hypothetical questions as a part of the costly task. These questions were in the same format as the questions in the first part where we used different time horizons and payoffs. More specifically, we asked four set of questions: 1. High rewards (ten times higher, \$100-\$500) with same time horizons, 2. Same rewards with long time horizons (0.25, 0.5, 1, 3, 6, 12 months), 3. High rewards with long time horizons, and 4. The same questions in BBS (y: 10, 20, 30, 50, 100; t: 3 days, 1 week, 2 weeks, 1 month, 3 months, 6 months). Half of the agents who did not show any discounting with real rewards did not show any discounting with hypothetical rewards either[20]. We cannot infer the discount functions of these agents. One of the subjects reported meaningless \$x values, so we excluded him.

Secondly, we designed a second price auction to learn about the subjects' valuations of the task cost. This is explained in section 3. Although it is a weakly dominant strategy to reveal the true valuation, some subjects reported a zero valuation and some reported very low valuations. We redid the analysis by using the bids of \$7 and \$14 (average rate is \$7 per hour in the jobs on campus) for these subjects, but obtained no significant difference in the results.

In the second part, we performed our analysis based on the best fitting model to the data from the first part, namely the exponential discounting model with a quasi hyperbolic component. Even though the predicted pattern is not exactly observed for most of the subjects, this model had some predictive power.

The results suggest that there are various potential factors that have not been captured in the models or the experimental design. An *exogenous cost shock,* for instance, can explain almost any type of observed behavior (including not finishing the task.) *Concave specification of cost function* may be another alternative.

The issue of the cost function being convex or concave is related to the efficiency issues. If there are decreasing returns to effort, then the cost function should be convex. If the cost function is convex, then it induces the subjects to allocate the task among periods more equally. However, if there are increasing returns to effort (one interpretation is that as you work, it becomes easier to finish an additional unit of the task), then the cost function should be concave. In that case, there are two competing factors in allocating the task. Since it is more efficient to work more at a given period, you are willing to spend more hours at the beginning. On the other hand, since you discount the future, it is less costly to bear the cost in the future and this makes you postpone working. These factors work in opposite directions[21] and the subject's allocation would be skewed towards the dominant factor.

Another possible explanation is the so called *sign effect,* which argues that gains are discounted at a higher rate than losses. Many studies showed that people prefer to incur a loss immediately rather than delay it, which in our case implies working more in earlier periods (see Benzion, Rapoport, Yagil, 1989; Loewenstein, 1987 for some examples.) Another reasonable behavioral specification is *the preference for improving sequences.* Many studies dealing with the preferences over the sequences of outcomes found that people prefer improving sequences to declining ones (see Frederick-Loewenstein, 2002 for an overview.) This may also explain why people invest earlier in our case. Last but not least is *the models of anticipatory utility.* It posits that if people derive utility from both current consumption and the anticipated future consumption, then the instantaneous utility function should involve these too. Loewenstein (1987) has a formal model of this kind and gives a possible explanation for preferring improving sequences and for handling undesirable tasks promptly instead of postponing them. We refer the reader to Frederick-Loewenstein-O'Donoghue, 2002, to see more detailed discussion of the most of the issues mentioned in this section.

The last three approaches above are partially supported by the behavior we observed. For example, the average time spent in the first period is more than fifty minutes while it is predicted to be less than thirty minutes because, if all costs and rewards are discounted at the same rate, then it becomes optimal to postpone the costs towards the end. This observation signals that these three approaches play a role in agents' allocation decisions. However, we cannot separate these three approaches because all imply a similar behavior pattern in our framework.

We also find that more than half of the subjects allocated more than half of the task to the first period. This behavior may be attributed to the last three models discussed earlier. Three of these subjects invest less in the second period than in the third period. This may be attributed to these agents being naive in their beliefs. Four of these subjects who finished the task in the second period invested much more in the first period than the second period, and this may be attributed to these subjects being sophisticated in their beliefs. Seven of the agents invested equally in first two periods and finished the task in the second period. This may be attributed again to the three models and to subjects having convex cost. Two of the agents can be identified as naive hyperbolic (because one started the task but did not finish and the other allocated the cost to all three periods in a naive way) and two of them as sophisticated hyperbolic. Three of them could not be identified as exponential, naive or sophisticated. Two of them may be identified as sophisticated with a concave cost. Table 7 displays the categorization we made based on different models in Table 7. Our results indicate that agents display diverse time preferences and follow diverse time allocation in multi-period investments. The models we studied in the paper explain the observed behavior of some but not all of the subjects..

7. Conclusion

In this paper, we elicit time preferences by using the experimental and econometric methods of Benhabib-Bisin-Schotter (2006). Then, we test the theory of behavior of possibly time-inconsistent agents in a long run project based on O'Donoghue and Rabin(2005) by using the quasi hyperbolic specification. In the first part of the experiment, we found that quasi hyperbolic discounting model is supported more by the data compared to the other specifications. As opposed to Benhabib et al., we do not find support for a fixed cost form of present bias. Since we obtain our results with the data that do not include high rewards and long time-horizons, we have to be very careful in generalizing our results. However, with the overall results we have at hand, we conclude that it is difficult to make generalizations as to which discounted utility model performs better in explaining observed choices.

After eliciting time preferences of the subjects, we observed the behavior of the subjects in a multi-period project. We used the estimated preferences to predict the allocation patterns. We find that the predictions of the theory capture most of the subjects' observed behavior and the theory has some predictive power. Since the theory's prediction based on the elicited parameters is not able to make distinction between most of the agents' types, we use different models, namely, *sign effect, the preference for improving sequences, anticipatory utility models,* to help us understand the observed behavior, and found support for these models in our data.

The results suggest that a subject specific approach is more useful to employ. Rather than picking up a specific model and following a uniform prediction for all of the subjects (e.g., assuming all agents have a linear or convex cost), it is more productive to recognize heterogeneity among the subjects and employ alternative models to understand the behavior of different groups of subjects. This also suggests that, given that we observed very different behavior patterns even in our small sample, we should view different intertemporal choice models as being complementary rather than conflicting or competing with each other.

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NOTES

1. See Ainslie, 1992, Ainslie-Herrnstein, 1981, Laibson, 1997, 2003, Loewenstein-Prelec, 1992, O'Donoghue T., Rabin M., 1999a.
2. See, for example, Akerlof (1991), Dellavigna-Malmendier (2006), and O'Donoghue-Rabin (1999b, 2001).
3. The simplest case is where $n = 2$ and $T = 3$, and this is what we will examine in this paper, both theoretically and experimentally.
4. Examples include Akin (2004), Ariely-Wertenbroch (2002), Fischer (2001) and O'Donoghue-Rabin (2005).
5. The possible types are exponential, naive hyperbolic and sophisticated hyperbolic types. We do not allow partially naive types in this paper. All types will be explained in the model explicitly.

6. The cost is most likely a function of time and effort, $c(t,e)$. We will assume that it is only a function of time and satisfies $c(t) \geq 0,\ c'(t) \geq 0$ and $c''(t) \geq 0$, for all $t \geq 0$. The case of concave cost function will be discussed later in the paper.

7. In linear cost case, $\alpha = 1$, c_i represents the monetary cost of spending t_i minutes in period i and $c_i = c\frac{t_i}{T}$ where c is the cost of spending T minutes on the project.

8. For the last three alternative specifications, see Frederick, Loewenstein, and O'Donoghue (2002).

9. Some of the participants reported the same amount \$x for all \$y values. This suggests that they do not discount the future at all and they wanted to guarantee earning \$y.

10. Student ID cards can be used to make purchases at any on campus and many of the off campus establishments (cafetarias, restaurants, bookstores, coffe shops, etc.).

11. This requirement is part of our effort to eliminate the impact of traveling time and cost to the experimental site (otherwise, subjects with higher traveling costs would be more likely to opt to complete the task in two, rather than three, sessions). This makes the subjects focus only on the task, not on other transaction costs. A similar method is used in Mukherji-Villaverde, 2002.

12. 8 out of 24 subjects submitted a \$0 bid. We did our analysis by using \$7 (the average bid) and \$14 (the average wage for a two-hour job on campus) as the cost of two-hour task for these subjects, but the results did not change significantly.

13. Recall that values of t include 5, 10, 15, 20, 25 and 30 days while the values of y include 10, 20, 30, 40 and 50, thus giving a total of thirty combinations.

14. We also estimated the parameters under the assumption that

$$x = y^i(x,t)D(y^i(x,t),\ t;\ \theta^i,\ r^i,\ \beta^i,\ b^i) + \varepsilon^i(x,t)$$

where errors, $\varepsilon^i(x,t)$, are assumed to be normally distributed and i.i.d. with respect to subjects and questions. The results did not change significantly.

15. The estimations are performed both in EViews and Matlab. We are grateful to Prof. Benhabib for providing the Matlab code.

16. The maximum possible error in predicting the allocations is 180. This can be seen from, for example,

$$(t_j^i)^* = ((t_1^i)^*,\ (t_2^i)^*,\ (t_3^i)^*) = (0,\ 30,\ 90)\ and\ \widehat{t_j^i} = (\widehat{t_1^i},\ \widehat{t_2^i},\ \widehat{t_3^i}) = (30,\ 90,\ 0)\ OR$$

$$(t_j^i)^* = ((t_1^i)^*,\ (t_2^i)^*,\ (t_3^i)^*) = (60,\ 60,\ 0)\ and\ \widehat{t_j^i} = (\widehat{t_1^i},\ \widehat{t_2^i},\ \widehat{t_3^i}) = (0,\ 30,\ 90)$$

If you add these across the subjects, you get $180*29$. The denominator in part b is $140*90*29$ because the maximum deviation for a subject is $(90)^2 + (60)^2 + (30)^2 = 140 * 90$.

17. Cohen (1988) has suggested the following interpretation for correlations in psychological research:

Correlation	Negative	Positive
Small	-0.29 to -0.10	0.10 to 0.29
Medium	-0.49 to -0.30	0.30 to 0.49
Large	-0.50 to -1.00	0.50 to 1.00

18. $correlation(\widehat{t_j^i},\ (t_j^i)^*) = \frac{Cov(\widehat{t_j^i},\ (t_j^i)^*)}{\sigma_{\widehat{t_j^i}}\ \sigma_{(t_j^i)^*}} = \frac{\frac{1}{N}\sum_{i=1}^{N}[(\widehat{t_j^i} - mean(\widehat{t_j^i})][(t_j^i)^* - mean((t_j^i)^*)]}{\sqrt{\frac{1}{N}\sum_{i=1}^{N}[(\widehat{t_j^i} - mean(\widehat{t_j^i})]^2}\sqrt{\frac{1}{N}\sum_{i=1}^{N}[(\ (t_j^i)^* - mean(\ (t_j^i)^*)]^2}}$

19. Here, *type* has a more general meaning than used in the paper and it covers all modeling approaches we mentioned throughout the paper.

20. Using hypothetical or real rewards is a choice of design and some studies showed that experiments with hypothetical rewards yield smaller discount rates than the ones with real rewards, although there is no consensus on this. For a detailed discussion of this, see Frederick-Loewenstein-O'Donoghue, 2002.

21. There is, most probably, a relationship between the concavity of the cost function and the parameters of the discount function.

REFERENCES

1. Ainslie, G.: (1992), *Picoeconomics*, Cambridge University Press.

2. Ainslie, G., Herrnstein R.J.: (1981), Preference Reversals and Delayed Enforcement, *Animal Learning and Behavior*, 9, 476-82.

3. Akerlof, G.: (1991), Procrastination and obedience, *American Economic Review*, 81, 1-19.

4. Akin Z.: (2004), The Role of Time-Inconsistent Preferences in Intertemporal Investment Decisions and Bargaining, Penn State University, mimeo.

5. Ariely, D. and Wertenbroch, K.: (2002), Procrastination, deadlines, and performance: self-control by precommitment, *Psychological Science,* 13, 219-224.

6. Benhabib J., Bisin A., Schotter A.: (2006), Present-Bias, Quasi-Hyperbolic Discounting and Fixed Costs, NYU, mimeo.

7. Benzion, U., Rapoport A., Yagil J.: (1989), Discount Rates Inferred from Decisions: An Experimental Study, *Management Science*, 35, 270-84.

8. Cohen, J.: (1988), *Statistical power analysis for the behavioral sciences*, (Second edition), Hillsdale, NJ: Erlbaum.

9. Cohen, J.: (1992), A power primer, *Psychological Bulletin*, 112, 155-159.

10. DellaVigna, S., Malmendier, U.: (2006), Paying not to go to the gym, *American Economic Review*, Vol. 96, 694-719.

11. Fischer, C.: (2001), Read this paper even later: procrastination with time-consistent preferences, *Journal of Economic Behavior and Organization*, 46, 249-69.

12. Frederick S., Loewenstein G., O'Donoghue T.: (2002), Time Discounting and Time Preference: A Critical Review, *Journal of Economic Literature*, 40, 351-401.

13. Frederick S., Loewenstein G.: (2002), The Psychology of Sequence Preferences, Working Paper, Sloan School, MIT.

14. Laibson, D.: (2003), *Intertemporal Decision Making*, Encyclopedia of Cognitive Science, Nature Publishing Group, London.

15. Laibson, D.: (1997), Golden Eggs and Hyperbolic Discounting, *Quarterly Journal of Economics*, 62, 443-77.

16. Laibson, D., Repetto A., Tobacman J.: (2004), Estimating Discount Functions from Lifecycle Consumption Choices, Harvard University.

17. Lowenstein, G., Prelec, D.: (1992), "Anomalies in intertemporal choice: Evidence and an interpretation, *Quarterly Journal of Economics*, 107, Pages 573-598.

18. Loewenstein, G.: (1987), Anticipation and Valuation of Delayed Consumption, *Economic Journal*, 97, 666-85

19. O'Donoghue, T. and Rabin M.: (1999a), Doing It Now or Later, *American Economic Review*, 89:1, 103-124.

20. O'Donoghue, T. and Rabin, M.: (1999b), Incentives for procrastinators, *Quarterly Journal of Economics* 114, 769-816.

21. O'Donoghue, T. and Rabin, M.: (2001), Choice and procrastination, *Quarterly Journal of Economics,* 116, 121-160.

22. O'Donoghue, T. and Rabin, M.: (2005), Procrastination on long-term projects, *Journal of Economic Behavior and Organization*, forthcoming

23. Phelps, ES., Pollak, RA.: (1968), On Second-best National Saving and Game-equilibrium Growth, *Review of Economic Studies*, 35, 185-199.

24. Villaverde, J.F., Mukherji A.: (2002), Can We Really Observe Hyperbolic Discounting?, PIER Working Paper, N0.02-008.

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TABLE -1	Period 1 (minutes)	Period 2 (minutes)	Period 3 (minutes)	Cost ($)
Subject 1	0	70	50	10.00
Subject 2	0	90	30	0.00
Subject 3	60	45	15	1.00
Subject 4	60	60	0	1.00
Subject 5	50	70	0	5.00
Subject 6	0	30	90	NA
Subject 7	60	60	0	10.02
Subject 8	45	75	0	15.00
Subject 9	90	0	30	0.00
Subject 10	65	25	30	5.01
Subject 11	80	40	0	5.00
Subject 12	0	30	90	25.00
Subject 13	60	60	0	0.00
Subject 14	60	60	0	0.00
Subject 15	30	75	15	NA
Subject 16	60	60	0	0.50
Subject 17	50	0	0	10.00
Subject 18	60	60	0	18.00
Subject 19*	90	30	0	10.00
Subject 20*	30	0	0	0.00
Subject 21	60	60	0	0.00
Subject 22*	90	30	0	0.00
Subject 23	60	45	15	5.00
Subject 24	90	30	0	5.00
Subject 25	70	50	0	5.00
Subject 26	20	90	10	4.25
Subject 27	90	30	0	15.00
Subject 28*	NA	NA	NA	NA
Subject 29	90	0	30	0.00

* These are excluded in the analysis because of invalid data.

TABLE 2	Teta	r
Subject 1	48.90***	36.27
Subject 2	-5.72	1.09***
Subject 3	36.95	9634948
Subject 4	32.52***	47.26
Subject 5	3.20	4.62***
Subject 6	8.06	162
Subject 7	-0.41	5.89***
Subject 8	22.64***	7.46***
Subject 9	11.10	443
Subject 10	-1.63***	3.77***
Subject 11	-7.43	0.82***
Subject 12	95.41*	1904
Subject 13	21.44***	2240
Subject 14	10.51	5.22
Subject 15	-5.41***	1.79***
Subject 16	26.51	12.60
Subject 17	1.95	3.65*
Subject 18	-14.38*	0.57***
Subject 19	-11.09***	0.06***
Subject 20	36.94*	8.68
Subject 21	554.17	0.01
Subject 22	22.24***	0.28***
Subject 23	5.48**	34.98
Subject 24	5.67***	0.78***
Subject 25	37.81	0.02***

* Significant at the 90% confidence interval
** Significant at the 95% confidence interval
*** Significant at the 99% confidence interval

TABLE 3	Teta	r	b
Subject 1	48.32***	97.96	-0.72**
Subject 2	-19.37**	0.53***	0.99***
Subject 3	44.21	27746392	1.15
Subject 4	32.04***	19.67**	0.84***
Subject 5	1.04	2.71**	1.50**
Subject 6	8.43	140.00	0.86
Subject 7	-0.17	6.69***	-1.02
Subject 8	22.79***	7.84***	-0.05
Subject 9	9.03*	1104	-4.27**
Subject 10	-0.54	5.50***	-2.47***
Subject 11	-9.72	0.72**	0.15
Subject 12	97.59***	166	0.92***
Subject 13	21.11***	2848	-0.43
Subject 14	9.32	2.85	1.18
Subject 15	-18.24**	0.63**	3.20***
Subject 16	-9.73	0.42	2.91***
Subject 17	4.38	8.11	-2.38*
Subject 18	-2.88	1.00***	-0.58**
Subject 19	-12.77***	0.05***	0.40
Subject 20	36.42*	14.50	-4.45
Subject 21	-16256	-5.01E+19	1.29***
Subject 22	21.50***	0.26***	0.38
Subject 23	-5.56	1.63*	12.83***
Subject 24	7.07***	1.14***	-4.70***
Subject 25	-12.64	0.01***	0.46***

* Significant at the 90% confidence interval
** Significant at the 95% confidence interval
*** Significant at the 99% confidence interval

TABLE 4	Teta	r	b	Beta
Subject 1	48.57	8431	-0.72**	1.10
Subject 2	-9.93	0.82**	1.50***	1.03***
Subject 3	34.55	1.06	1.13	0.68***
Subject 4	-16.66	0.47**	0.83***	0.93***
Subject 5	8.49**	93106	2.65***	3.60
Subject 6	7.93	227405	0.90	2.98
Subject 7	0.79	10.39***	0.92	1.20***
Subject 8	25.41***	23.12	-0.05	1.03***
Subject 9	9.00	144932	-4.27**	1.84
Subject 10	0.32	7.53***	-1.37**	1.11***
Subject 11	4.96	2.04	0.73**	1.05***
Subject 12	-72.48	0.14	0.92***	0.95***
Subject 13	-30.22	0.38	-0.43	0.71***
Subject 14	13.05	78100	1.91	2.26
Subject 15	-11.49***	0.96***	4.63***	1.07***
Subject 16	17.45	2.02	3.45***	1.05***
Subject 17	7.69	37949	-2.17	3.18
Subject 18	0.59	1.24*	-0.50*	1.01***
Subject 19	-6.67***	0.07***	1.44***	1.01***
Subject 20	-12.47	0.07	-4.35	0.92***
Subject 21	887	0.02	1.30***	1.00***
Subject 22	29.95***	0.63*	1.16*	1.02***
Subject 23	-2.49	2.52*	17.89***	1.16***
Subject 24	8.02***	1.46***	-4.43***	1.01***
Subject 25	77.20*	0.03**	0.86***	1.00***

* Significant at the 90% confidence interval
** Significant at the 95% confidence interval
*** Significant at the 99% confidence interval

TABLE 5	Beta	r
Subject 1	0.936***	0.499***
Subject 2	1.007***	1.627***
Subject 3	0.735***	0.530
Subject 4	0.913***	0.842***
Subject 5	1.003***	3.631***
Subject 6	0.614***	1.198
Subject 7	1.197***	11.859***
Subject 8	0.976***	0.987***
Subject 9	0.649***	1.750
Subject 10	1.190***	9.376***
Subject 11	1.025***	1.524***
Subject 12	0.923***	0.312**
Subject 13	0.744***	1.533***
Subject 14	0.972***	1.874*
Subject 15	1.025***	4.247***
Subject 16	0.940***	0.902*
Subject 17	1.016***	3.584***
Subject 18	1.022***	1.251***
Subject 19	1.006***	0.103***
Subject 20	0.937***	0.141**
Subject 21	0.999***	0.003
Subject 22	0.994***	0.095***
Subject 23	0.801***	4.809***
Subject 24	0.985***	0.450***
Subject 25	1.0004***	0.016***

* Significant at the 90% confidence interval
** Significant at the 95% confidence interval
*** Significant at the 99% confidence interval

TABLE 6	Beta	r	b
Subject 1	0.92***	0.51***	-0.72**
Subject 2	1.05***	1.56***	1.50***
Subject 3	0.67***	0.33	1.13
Subject 4	0.94***	0.82***	0.83***
Subject 5	1.07***	3.34***	2.64***
Subject 6	0.64***	1.14	0.96
Subject 7	1.22***	11.44***	0.95
Subject 8	0.95***	0.99***	-0.05
Subject 9	0.53***	2.21	-4.26**
Subject 10	1.16***	9.82***	-1.32*
Subject 11	1.04***	1.49***	0.73**
Subject 12	0.95***	0.30***	0.92***
Subject 13	0.73***	1.56***	-0.43
Subject 14	1.02***	1.77*	1.91
Subject 15	1.15***	3.71***	4.66
Subject 16	1.03***	0.82**	3.45***
Subject 17	0.96***	3.86***	-2.18
Subject 18	1.01***	1.27***	-0.50*
Subject 19	1.01***	0.10***	1.41***
Subject 20	0.92***	0.14**	-4.43
Subject 21	1.00***	0.00	1.30***
Subject 22	1.00***	0.10***	1.21*
Subject 23	1.22***	4.77***	17.68***
Subject 24	0.97***	0.36***	-4.33***
Subject 25	1.00***	0.02***	0.86***

* Significant at the 90% confidence interval
** Significant at the 95% confidence interval
*** Significant at the 99% confidence interval

	Actual Allocation			Prediction of Sophisticated Hyperbolic Model			
TABLE 7	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3	Model Prediction**
Subject 1	0	70	50	**0**	**30**	**90**	2, 4
Subject 2	0	90	30	**30**	**90**	**0**	2, 4
Subject 3*	60	45	15	**55**	**65**	**0**	4 or 5, 6, 7
Subject 4	60	60	0	**30**	**90**	**0**	3, 5, 6, 7
Subject 5	50	70	0	**30**	**90**	**0**	2
Subject 6	0	30	90	**0**	**30**	**90**	1 or 2
Subject 7	60	60	0	**90**	**30**	**0**	3, 5, 6, 7
Subject 8	45	75	0	**30**	**90**	**0**	2
Subject 9	90	0	30	**0**	**30**	**90**	1, 5, 6, 7
Subject 10	65	25	30	**90**	**30**	**0**	3, 5, 6, 7 or 1, 5, 6, 7
Subject 11	80	40	0	**90**	**30**	**0**	3, 5, 6, 7
Subject 12	0	30	90	**0**	**30**	**90**	1 or 2
Subject 13	60	60	0	**0**	**30**	**90**	3, 5, 6, 7
Subject 14	60	60	0	**30**	**90**	**0**	3, 5, 6, 7
Subject 15	30	75	15	**30**	**90**	**0**	1
Subject 16*	60	60	0	**40**	**80**	**0**	3, 5, 6, 7
Subject 17	50	0	0	**30**	**90**	**0**	1
Subject 18	60	60	0	**90**	**30**	**0**	3, 5, 6, 7
Subject 19	60	60	0	**90**	**30**	**0**	3, 5, 6, 7
Subject 20	60	45	15	**0**	**30**	**90**	5, 6, 7
Subject 21	90	30	0	**30**	**90**	**0**	2 or 5, 6, 7
Subject 22	70	50	0	**30**	**90**	**0**	2 or 5, 6, 7
Subject 23	20	90	10	**30**	**90**	**0**	1 or 2
Subject 24*	90	30	0	**50**	**70**	**0**	2 or 5, 6, 7
Subject 25	90	0	30	**90**	**30**	**0**	1, 5, 6, 7

**** Prediction of naive hyperbolic model for these agents is (30, 0, 90)***

***** 1. Naive Hyperbolic; 2. Sophisticated Hyperbolic; 3. Convex Cost; 4. Concave Cost; 5. Sign Effect; 6. Preference for Improving Sequences; 7. Anticipatory Utility***

APPENDIX A
INSTRUCTIONS
First Session

Thank you for coming. This is a study of individual decision making. The instructions are simple. If you follow them closely, you will make some amount of money. How much and when you get paid will be based on your decisions. All the money that you earn will be deposited to your Penn State ID Card accounts. The data collected in this experiment will be used in economic decision analysis and the identity and choices of participants will be kept confidential.

This is the first session of a sequence of 4 sessions. The remaining three sessions will be held on April 20 (Thursday) - April 24 (Monday) - April 27 (Thursday)). At the end of today's session, you will earn either some amount today or some other amount in the future depending on your decisions and a lottery process. In the remaining three sessions, your payoff will again depend on what you do in those sessions. The details will be explained shortly.

In this session, you will be asked thirty simple questions and your answers will determine when you will be paid. The payment amount will be determined by a lottery process and by your answers to these questions.

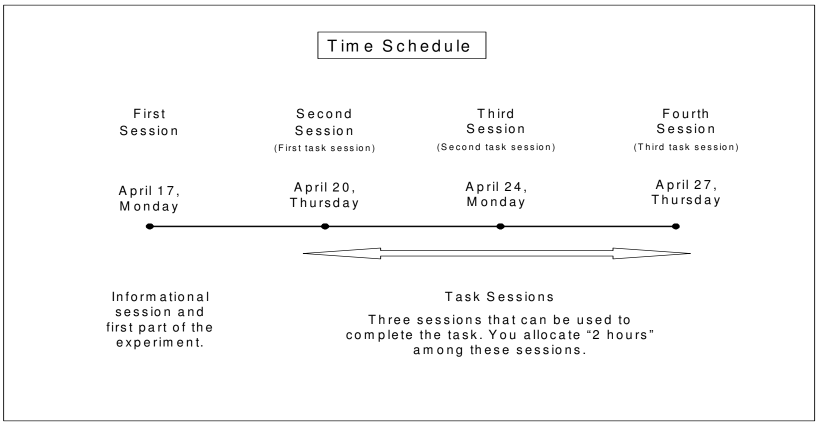
As an example, here are two of the thirty questions you will be asked to answer:

"What amount of money, if paid to you today would make you indifferent to $10 paid to you in 5 days?"

"What amount of money, if paid to you today would make you indifferent to $50 paid to you in 1 month?"

After you answer all of the thirty questions, one of the questions will be drawn randomly. Suppose, for example, that at the end of the experiment the second question above is drawn where you are asked what amount you would require today to make you indifferent between that amount today and $50 to be paid to you in one month. Suppose your answer is $40. Then, we will draw a random number between 0 and 50 where all the numbers between 0 and 50 have equal probability of being drawn. We will draw this number separately for each of the participants in the experiment. If the number drawn for you is smaller than the indifference amount you stated (i.e., if the number drawn is smaller than 40), you would have to wait for one month at which time you will be paid $50. If the number drawn is greater than the indifference amount you stated, then the amount drawn will be paid to you today. Note that the smaller the indifference amount you chose as your response to the question drawn, the higher the chances that you will be paid today and the smaller the expected amount that you will be paid today.

The following graph summarizes the schedule for the experiment:



In the three sessions that will follow today's session (we will refer to these sessions as "task sessions"), the main objective will be to complete a "two-hour task" that involves filling out some simple surveys. You have the flexibility to allocate the two-hour task time among the three task sessions scheduled for April 20 (Thursday), April 24 (Monday) and April 27 (Thursday). You have to come to each of the three task sessions and sign a sign up sheet. You will be paid a fixed amount, $35, only if you complete this two-hour task and sign the sign up sheet in each of the three task sessions. You can work on the task at most 90 minutes (1.5 hours) in a given session. This means that you will need to work on the task in at least two of the three task sessions to complete the task. Note that even if you complete the two-hour task in two of the three sessions, you still have to come and sign the sign up sheet in the other session. We will send you remainder emails one day before the task sessions.

If you complete the task on April 27, then the $35 payoff will be deposited to your ID account on May 1. Note again that even if you complete the task on April 24, you need to come to the third task session on April 27 and sign the sign up sheet. There is no session on May 1 and no need to show up on that date. It is a date of payment for those who choose to complete the two-hour task on April 27.

As mentioned earlier, you can divide the two-hour time period to complete the task in any way you like among the three task sessions. Please indicate your plan regarding the task by filling out the schedule below and crossing appropriate boxes. These plans are not binding. Changing your plans will not affect your payoff as long as you complete the task and sign the sign up sheet in all the three task sessions.

APRIL 20: ____ minutes;

APRIL 24: ■ ____ minutes, ■ Finish the task;

APRIL 27: ■ ____ minutes, ■ Finish the task;

Are there any questions?

We next ask you to answer the following thirty questions in the space provided:

QUESTIONS. . .

End of Session 1 Questionnaire

Please answer the following question (your answer will not impact your payoff or the plan you provided before for the remaining sessions):

Suppose we maintained the requirement of coming to all the three task sessions and signing a sign up sheet and gave you the choice between the following two options:

Option 1. You determine the allocation of the two-hour time as you wish, as you have now.

Option 2. Distribution of the two-hour time is determined by the experimenter as one hour on April 20 and one hour on April 24.

Please circle the option you would have chosen: Option 1 Option 2

Explain why you chose this option (Please be specific):

Second Session (First Task Session)

Thank you for coming back. Recall that the objective in the three task sessions (including today's session) is to complete a "two-hour task" that involves filling out some surveys. You have the flexibility to allocate the two-hour task time among the three task sessions scheduled for today, April 24 (Monday) and April 27 (Thursday). To get paid, you have to come back for each of the remaining two task sessions and sign a sign up sheet.

You will be paid a fixed amount, $35, only if you complete this two-hour task and sign the sign up sheet in all of the three task sessions. You can work on the task at most 90 minutes (1.5 hours) on a given task session. This means that you will need to work on the task in at least two of the three task sessions to complete the task. Note that even you allocate the two hours between two of the three sessions, you have to come and sign the sign up sheet in the other session.

Given that you cannot work on the task more than 90 minutes in any of the task sessions, the earliest session that you can complete the task is the next task session on April 24, Monday. You can also complete the task in the third task session on April 27, Thursday.

If you complete it on April 24, then the $35 payoff will be deposited to your ID account on April 27. Note that you still need to come to the third task session and sign the sign up sheet on April 27. If you complete it on April 27, then the $35 payoff will be deposited to your ID account on May 1.

Recall that you can allocate the two-hour task time however you like among the three task sessions. Now please indicate your plan regarding the task by filling out the schedule below and crossing appropriate boxes. These plans are not binding. Changing your plans will not affect your payoff as long as you complete the task and sign the sign up sheet in all the three task sessions.

Now, you have 2 minutes to fill out the schedule and answer the following question. Then we will collect this document.

Now please fill out the following schedule:

TODAY: ■ ____ minutes;

APRIL 24: ■ ____ minutes, ■ Finish the task;

APRIL 27: ■ ____ minutes, ■ Finish the task;

Please answer the following question:

Are your today's plan and the plan you submitted in the previous session different (circle your answer)? YES NO

If YES, please state the reason for the change in your plans?

Before we proceed to the "task" of filling out some surveys, we will conduct a simple auction.

You indicated your plan regarding the task. Now we will give you the following option: we ask each of you to fill out a "Bid form" that will be distributed to you momentarily. You will be bidding for the right to be exempted from the requirement of completing the two-hour task. Your bid is how much money you are willing to give up out your $35 fixed earnings in order to be exempted from the requirement of completing the two-hour task. The participant with the highest bid will win the auction and will not have to complete the two-hour task. The highest bidder will pay the second highest bid; hence his/her earnings will be $35 minus the second highest bid. You cannot bid more than $35.

Example: Suppose you bid $20 and turns out that the highest bid from the other participants is $17.5. You will win the auction and get paid $35-$17.5 = $17.5. Your payment date will be based on the plan that you submitted above. If, for instance, you indicated in your plan (the one you have filled today) that you would finish the task in the session on April 24, then $17.5 will be deposited to your ID account on April 27. If you indicated that you would finish the task in the session on April 27, then $17.5 will be deposited to your ID account on May 1. Note that even if you win the auction, you still have to come to the next two sessions and sign the sign up sheet. Otherwise, you will not be paid anything.

Now please indicate how much money you are willing to bid to be exempted from completing the two-hour task. Write your bid on the Bid form within the next two minutes. Do not show your bid to anybody. Your bids will be collected at the end of the two-minute period and the winner will be announced. In case of a tie for the highest bid, we will roll a dice to determine the winner.

(Bids are collected and the winner is determined. . .)

Now, the time is –:– PM, You can start filling out the surveys. You can spend up to 90 minutes on the surveys today. It is important that you do not engage in any activity (using the computer, listening to your ipod, reading newspapers, etc.) during the time you spend on the surveys.

Please take your time to fill out the surveys carefully. Note that you do not have to complete all the surveys by the end of the two-hour period.

SURVEYS. . . . .

After you are done with the surveys for the day, please fill out the questionnaire below, leave everything on your desk, then come and sign the sign up sheet. We will note that ending time on your forms.

End of Session 2 Questionnaire

Now, please answer the following questions before you leave:

1. Is the actual amount of time you have spent on the task today different than your planned allocation for today (the plan you submitted at the beginning of this session or the plan you submitted in the previous session)?

Please circle your answer: YES NO

If YES, please give a brief explanation.

Third Session (Second Task Session)

Given the number of minutes you spent on the task in the second session (first task session); please indicate your plan for the remaining minutes to complete the two-hour task by filling out the schedule below and crossing appropriate boxes. These plans are not binding. Changing your plans will not affect your payoff as long as you complete the task and sign the sign up sheet in all the three task sessions.

TODAY: ■ _ _ _ _ minutes, ■ Finish the task;

APRIL 17: ■ _ _ _ _ minutes, ■ Finish the task;

Now answer the following question:

QUESTION 1. Is your plan for today different than the plan you submitted for today in the previous session. Please circle your answer: YES NO

If YES, please state the reason for the change in your plans for today?

****

QUESTIONS & SURVEYS...

****

Please answer the following question after you are done with the questions & surveys for today and before you leave:

QUESTION 2. Is the actual amount of time you spent on the task today different than your planned allocation for today (the plan you submitted at the beginning of this session or the plan you submitted in the previous session). Please circle your answer: YES NO

If YES, please give a brief explanation.

Fourth Session (Third Task Session)

This is the final session. Today you will spend the remaining minutes, if any, to complete the two-hour requirement on the task.

****

IF YOU HAVE ANY REMAINING MINUTES, START ANSWERING THE QUESTIONS AND FILLING OUT THE SURVEYS NOW...

****

Please answer the following questions before you leave and be precise as much as you can. Your answers are very important for our analysis:

QUESTION 1: Your answer will not impact your payoffs. Suppose we maintained the requirement of coming to all the three task sessions and signing a sign up sheet. Suppose also that we now give you the same 2-hour task as we did at the beginning of the experiment. Now, how would have you allocated your time among the task sessions?

APRIL 20: ____ minutes;

APRIL 24: ■ ____ minutes, ■ Finish the task;

APRIL 27: ■ ____ minutes, ■ Finish the task;

If your plan now is different than what you did in the actual experiment, what is the reason for this difference? Please be specific.

QUESTION 2: Your answer will not impact your payoffs. Suppose we maintained the requirement of coming to all the three task sessions and signing a sign up sheet and gave you the choice between the following two options:

Option 1: You get to determine the allocation of the two-hour time as you wish (as has been the case for this experiment)

Option 2: Distribution of the two-hour time is determined by the experimenter as one hour on April 20 and one hour on April 24.

Please circle the option you would have chosen: Option 1 Option 2

Explain why you chose this option (Please be specific):

QUIZ

Please circle T for true and F for false.

1. I can finish the whole task in one day. T F (False)
2. I can finish the task either in the second task session (April 24, Monday) or in the third task session (April 27, Thursday). T F (True)
3. I will be paid as soon as I complete the task. T F (False)
4. My main decision is how to allocate the 2 hour task time among the three task sessions. T F (True)
5. I have to finish the task, once I started it. T F (False)
6. I can earn partial payoff by completing a portion of the task. T F (False)
7. I cannot work on the task more than 90 minutes (1.5 hour) in one task session. T F (True)
8. Although I come and sign the sign up sheet in all the three task sessions, I will not be paid $35 if I do not complete the task. T F (True)

9. Although I complete the two hour task, I will not be paid $35 if I do not come and sign the sign up sheet in all three task sessions. T F (True)

APPENDIX B
A SAMPLE SURVEY

In the past three months, have you purchased products or services through the Internet, for your personal use? __

• Yes • No

Please check the product or service category you most recently purchased.

• Books • Financial services • Computer equipment • CDs

• Other ______________________________________

When you began shopping on this occasion, were you: • Just surfing the net • Intending to make a purchase.

• Other ______________________________________

How much did you spend on this transaction? • Less than $25 • $26-$50 • $51-$75 • $76-$100

• Other ______________________________________

Did you return the merchandise or cancel the service after you received it? • Yes • No

Did you contact the customer service department of this Internet retailer with a complaint or problem? _• Yes • No

How much would you estimate you have spent with this Internet retailer in the past twelve months? • less than $50 • $51-$100 • $101-$150 • more than $150

How many transactions have you made with this Internet retailer over the past 12 months? • 1 • 2 • 3 • 4

• Other _____________________