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Lifecycle Consumption Plans, Social Learning and External Habits: Experimental Evidence*

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Abstract

We report results from a laboratory experiment exploring the extent to which individuals can solve a deterministic, intertemporal lifecycle consumption optimization problem and the effect of revealing social information on past average consumption amounts; as all individuals have identical induced preferences and lifetime incomes, such social information could be useful in solving for the optimal consumption path. Instead, we find that the provision of social information on past average levels of consumption results in a greater deviation of consumption from both the unconditional and the conditionally optimal paths. We find some improvement in consumption planning relative to the conditional optimum when social concerns (external habits) are explicitly incorporated into subject's period utility functions as in external habit formation preference specifications. Our results on the effects of social information on consumption behavior may help to explain the phenomenon of over-consumption and under-saving that has been observed in many developed countries in recent decades as social information on the behavior of others has become more readily available.

Keywords: Consumption, intertemporal optimization, social learning, lifecycle models, external habit formation, experimental economics.

JEL classification: C91, C92, D11, D91, E21.

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1 Introduction

In dynamic, intertemporal models of lifecycle consumption, it is standard to assume that agents can solve for the optimal consumption/savings plan over their expected lifetimes given all available information on income and prices. Indeed, this assumption underlies all modern micro-founded models of household behavior, beginning with Modigliani and Brumberg's (1954) lifecycle theory of consumption and Friedman's (1957) permanent income hypothesis. The possibility that individuals might condition their choices on the decisions made by other, similarly situated individuals is typically excluded (e.g., via the representative agent assumption) though there are specifications of preferences where *habit* levels of consumption as determined by the choices of other individuals do enter into agents' utility functions and therefore affect individuals' consumption choices. However, there is little doubt that individuals often look to their peers when deciding how much to consume or to save and indeed, the notion that individuals make such social comparisons was an important part of earlier theories of consumption behavior by Veblen (1899) and Duesenberry (1949). The idea that the utility derived from consumption depends on ones' own consumption relative to that of others has been formalized in models of external habit formation or "keeping up with the Joneses" preferences, e.g., by Abel (1990). Nevertheless, there is little in the way of micro-level evidence as to whether and how such social information on the consumption choices of others actually affects an individual's own consumption and savings choices. In this paper we take a first step toward understanding how social information on the consumption choices made by contemporary peers affects an individual's own lifecycle consumption decisions.

Specifically, we examine the impact of social information on consumption and savings decisions over the lifecycle by designing and analyzing data from a controlled laboratory experiment. The control of the laboratory provides us with several benefits that are not available to researchers working with non-experimental field data. In particular, since we can control endowments, interest rates and the utility derived from consumption, we are able to make sharp predictions as to the optimal path of consumption that individuals should follow. Further, the control of the laboratory allows us to manipulate the information that individuals have available to them when making decisions so that we can assess whether information about the decisions of others, i.e., "the Joneses," really matters. Finally, and perhaps most importantly, as we endow all agents with the *same* lifetime lengths and income process and we eliminate all uncertainty, we ensure that social comparisons with others are potentially useful, i.e., that individuals could find it relevant to consider the decisions made by their peers, “the Joneses”. By contrast, it is not possible ensure that the Joness are so similarly situated in studies involving field data. We note further that dynamic optimization problems are difficult to solve (the solution to the one we study in this paper is solved numerically) and so it seems entirely plausible that agents having difficulty solving such problems might reasonably look to the decisions of other, similarly situated individuals in formulating their consumption and savings plans.

Our main finding is that, instead of helping, social information on the consumption and savings plans of peers can have a detrimental effect on an individual's consumption and savings choices and thus his or her welfare, relative to the optimally chosen path. Specifically, when social information on average consumption choices is provided, subjects' consumption and savings plans depart *further* from the optimal path relative to an environment without social information on the consumption choices of others. Intuitively, observing that one's own consumption is below average may entice the observer to consume more than is individually optimal in a race to keep up with the Joneses. This finding is potentially important for understanding the dramatic decline in national savings rates that has taken place in many developed countries (France, Italy, Japan, Spain, the U.K. and the U.S.) since the 1970s as documented, e.g., by Dobrescu et al. (2012), as the availability of information on the consumption decisions of peers has likely increased over this same time period.

In addition to exploring the impact of information on peer behavior for lifecycle consumption and saving choices, we also explore how a leading theory of social preferences with regard to consumption choices– the theory of “external habit formation”– fares in the laboratory. According to this theory, an individuals's utility from consumption depends on their consumption choices relative to some external reference level of consumption, known as the “habit level” of consumption. Here we take this reference level to be the same, economy-wide prior period average level of consumption that we use in our social information treatment. Indeed, this choice for the reference point is a standard specification in the external habit formation literature. Specifically, we examine consumption decisions when the period utility function is modified so that individuals derive utility from consumption relative to the prior average level of consumption by all individuals in the economy. We are interested in whether modifying the period utility function so that agents' utility from consumption depends explicitly on the average consumption of other similarly situated individuals, yields any improvement in consumption planning relative to the case where this same reference level of consumption has no direct utility consequences.

2 Related Literature

There already exists an experimental literature examining whether and how individuals can optimally solve dynamic, intertemporal lifecycle consumption and savings problems. See, for example, Hey (1988), Hey and Dardanoni (1988), Johnson et al. (2001), Ballinger et al. (2003, 2011), Carbone and Hey (2004), Carbone (2006), Fehr and Zych (1998, 2008), Brown et al. (2009), Feltovich and Ejebu (2013) and Meissner (2014). A general finding of this literature is that, over the lifecycle, individuals initially consume too much (or save too little) relative to the optimal path so that towards the end of their lifecycle, savings are too low and consumption is below the optimal path. While our baseline treatment involving an individual, intertemporal lifecycle consumption problem has much in common with the design used in these prior studies, one important difference is that the dynamic optimization problem that we study is *non*-stochastic, making it perhaps the simplest environment yet studied in this literature. Specifically, the entire income sequence over the lifecycle is perfectly known at date 0 as is the constant interest rate on savings as well as the length of the planning horizon. We deliberately chose such a simple environment because we wanted to minimize the role of uncertainty (and uncontrollable attitudes towards risk) and focus attention instead on the question of whether and how optimal consumption plans can be achieved, and the role played by information on the consumption decisions of other similarly situated individuals.

The role of social learning in the formation of lifecycle consumption plans has been previously addressed in experimental studies by Ballinger et al. (2003) and Brown et al. (2009). Those authors report that observation by subjects of the *prior lifecycle consumption plans* of other subjects (who faced the exact same planning problem and horizon) enables the observer subjects to form lifecycle consumption plans that are closer to the optimal intertemporal path relative to the case of no observation. Brown et al. (2009) refer to this kind of social learning as "intergenerational imitation." However, this is just *one* kind of social learning that may be operative. Another form of social learning is that individuals look to the decisions of their contemporaries or peers in deciding how much to consume and save in every period, a kind of social learning we might term "contemporaneous peer imitation." This is the type of social learning that we pursue in this paper. Feltovich and Ejebu (2013) have also recently examined peer-to-peer social learning in a lifecycle consumption/savings task. However, they only show subjects information on the highest *payoffs earned* among a cohort of subjects and do not reveal information on actual consumption/savings decisions. By contrast, we study whether and how information on contemporaries' consumption decisions, specifically information on the economy-wide average level of consumption, affects individual consumption decisions. Specifically we ask whether average information on the consumption decisions of others is used and if so, whether it improves individual decision-making in the direction of the optimal consumption path. Intuitively, since dynamic intertemporal optimization can be computationally difficult, it may be that provision of information on average consumption behavior is a useful aid in solving the intertemporal planning problem.

Our focus on average consumption has another motivation as we also use this same statistic in a third, "external habit" formation treatment. The motivation for this external habit formation treatment comes from the observation that many researchers use external habit formation specifications for the period utility function to capture other regarding social concerns, i.e., keeping up with the Joneses as first formalized by Abel (1990); see Schmitt-Grohe and Uribe (2007) for a survey. The claim is that such specifications for utility aid in explaining a variety of macroeconomic phenomena such as the equity premium puzzle, (Campbell and Cochrane, 1999) or the hump-shaped response of consumption to various expansionary shocks (Christiano et al. 2005) that cannot be explained with standard, self-regarding utility function specifications. While there is some experimental evidence exploring *internal* habit formation specifications (e.g., Fehr and Zych (1998, 2008), Brown et al. (2009)) where the habit level of consumption is *internally unique* to each *individual*, there is little in the way of micro-level evidence for the external habit preference class, where the habit level of consumption is not unique to the individual but instead depends on the decisions of his or her peers. Here we do not address where such preferences come from but rather whether they come more naturally to laboratory subjects than preference functions that do not explicitly incorporate concerns for relative consumption.

3 Model and Experimental Design

The model we implement in the laboratory is a standard, workhorse finite-horizon, deterministic model of lifecycle consumption and savings decisions. Each agent's goal is to:

$$\max_{\{c_t\}} \sum_{t=1}^{T} u(c_t) \tag{1}$$

subject to

$$c_t + s_t \quad = \quad y_t + (1+r)s_{t-1}, \quad \text{and} \quad s_0 = s_T = 0. \tag{2}$$

Here, c_t, s_t and y_t denote period t consumption, savings and income, respectively, and $r > 0$ is the exogenous fixed and known real rate of interest; thus we are considering a partial equilibrium environment.

In one of our experimental treatments, subjects are also shown the ex-post average level of consumption, denoted by:

$$C_{t-1} = \frac{1}{N}\sum_{i=1}^{N} c_{t-1}.$$

In particular, they are shown this economy-wide average level of consumption for period $t-1$ after period $t-1$ has concluded but prior to making their consumption choice for period t. For period 1, no information on average past consumption was reported.

In this finite horizon lifecycle problem, there is no discounting, no uncertainty regarding the income process or the interest rate, and individuals can be presumed to have perfect foresight (at least as a benchmark). Borrowing is not allowed and there is no government/taxation. We deliberately chose to consider this simple, deterministic intertemporal optimal consumption framework not because it is realistic, but because it is both easy to explain to subjects and relatively easier to solve than more complicated, stochastic versions of the same model. If subjects have trouble with this simple, deterministic framework then one can expect that such difficulties will also carry over to more complicated (e.g., stochastic) intertemporal environments. Further, we wish to focus on the role played by observation of the decisions of others and induced external habits, and thus we wish to minimize the role played by other factors, e.g., uncertainty regarding the income process, infinite horizons, liquidity constraints, etc.

3.1 Parameterization

In all cases we chose to work with a population of $N = 10$ subjects who interact together for a finite lifetime of $T = 25$ periods. One can think of model periods as approximating one or two year periods in real time. We set the real interest rate on savings equal a constant, $r = .05$ in all of our treatments; the historical average annual real return on U.S. treasury bonds is 3.5 percent and on U.S. equities it is 6.5 percent so a 5 percent real rate of return on savings seemed to be a good compromise. The individual income process was also assumed to be constant, with $y_t = \bar{y} = 10$ for all $t = 1, 2, ...25$ periods. A constant and certain income level is unrealistic, of course, but we wanted to reduce any uncertainty arising from the determination of permanent income so as to better focus attention on the role played by social information in the formulation of consumption and savings plans.

The period utility function that we induced is specialized to the constant absolute risk aversion (CARA) exponential class:

$$u(x) = \kappa - \frac{1}{R}e^{-Rx}$$

where R denotes the coefficient of absolute risk aversion. As there is no uncertainty in treatments 1 and 2 of our experiment, the function $u(x)$ is essentially a means of converting from consumption units into monetary payoffs.[1] We wanted to a concave functional form for u to insure that the optimal consumption path was unique. We set $\kappa = 15$ and $R = .10$. These choices were made so as to ensure that payoffs were always strictly positive and that differences in monetary payoffs from different consumption amounts were sufficiently salient to subjects.

The parameterization of the environment was public knowledge to all N agents - that is all agents knew that every other participant had the same income process and faced the same decision problem involving the same induced utility function. Given this information it is (in principle) possible to calculate the optimal path. More importantly, as all individuals were similarly situated (in terms of income, induced preferences), it is reasonable to conjecture that individuals might find information on the *average* level of consumption useful in thinking about their own consumption and saving plans.[2]

3.2 Experimental Design and Hypotheses

Our experiment involves two main treatments:[3]

Treatment 1 Control: no information on C_{t-1} is provided.

Treatment 2 Social Information: information on C_{t-1} is provided prior to each individual's time t choice of c_t.

[1]We assume that subjects are risk neutral with regard to monetary payoffs; if they are not, this would add another layer of complexity to the function mapping from consumption to monetary payoffs.

[2]Another possible specification would be for each agent i to observe the average lagged consumption of the other $N-1$ agents excluding agent i. However, using this specification, each agent would potentially be observing different past average values for consumption, which makes the interpretation of such average information more difficult.

[3]Later, in section 5, we also introduce a third treatment where the external habit level of consumption, C_{t-1} directly enters into the period utility function.

Under both treatment conditions, the optimal lifecycle consumption path is determined as follows. First, repeated substitutions using the budget constraint (2) yields the lifetime budget constraint:

$$\sum_{t=1}^{T=25} \frac{c_t}{(1+r)^{t-1}} \leq \sum_{t=1}^{T=25} \frac{y}{(1+r)^{t-1}}. \tag{3}$$

Second, the first order necessary conditions for a maximum to the problem (1-2) are given by the Euler equation,

$$u'(c_t) = (1+r)u'(c_{t+1}), \tag{4}$$

which relates consumption at every date t to consumption at date $t+1$ and must be satisfied along the optimal equilibrium path. With $T = 25$, there are 24 such Euler equations. The optimal consumption path is found by simultaneously solving these 24 Euler equations together with the lifetime budget constraint (3) to obtain 25 different optimal consumption amounts for the 25 periods of an agent's life. Figure 1 depicts the optimal consumption path for the parameterization of the economy that we study along with the constant income level of 10 per period. The optimal consumption path is increasing since there is a positive real rate of return and no discounting. Notice that the optimal consumption path requires subjects to consume less than their period income of 10 in each of the first 10 periods and to consume more than their period income of 10 in each of the remaining 15 periods.

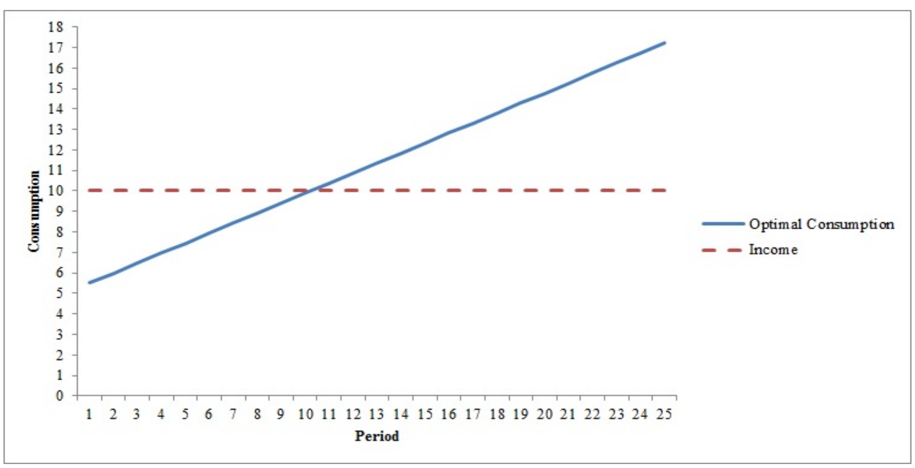

Figure 1: Optimal lifecycle consumption path for treatments 1 and 2

We hypothesize that since subjects face no uncertainty with respect to their income or the rate of return on savings that they will choose a path for consumption that approximates this optimal path as it maximizes their earnings in the experiment. An auxiliary hypotheses is that subjects get closer to the optimal consumption path with experience (we describe below how subjects acquire experience with lifecycle consumption planning in our experiment).

The only difference between treatment 1 and treatment 2 is that in the latter treatment subjects are informed of the average consumption amount by all N subjects in the prior period, $t-1$, i.e., C_{t-1}, before making consumption choices in period t. However, since C_{t-1} does not directly enter into subjects' utility (payoff) functions, the optimal consumption path remains the same as for treatment 1 as shown in Figure 1. Nevertheless, we hypothesize that providing social information on the group average consumption amount may enable subjects to get closer to the optimal consumption path. Intuitively, one may think of this environment as approximating a computational system involving distributed parallel processing (i.e., the processors are the 10 individual human subjects); since all 10 subjects are homogeneous in terms of their lifetime endowments and payoff objective (and this fact is public knowledge) it seems reasonable that they might assess their own period t consumption choice relative to the average consumption choice made for that same period and in doing so it is conceivable that they may collectively arrive at the optimal decision. Of course, the freely provided information on the past average consumption choice can also be ignored, in which case performance in treatment 2 should be no worse than in treatment 1.

Note that in our experimental design, information on the past average level of consumption is endogenous to each group of 10 subjects (each session). An alternative approach would be to provide subjects with information on the period-by-period past average level of consumption by *other* subjects in a *different* session of the same treatment. In our view, the latter approach is a less credible means of conveying social information on the consumption choices of *peers*. Also, the habit formation literature (referenced in section 2) models the habit level of consumption as an endogenous process and we wanted to be consistent with the approach used in that literature.

Each experimental session involved 10 subjects with no prior experience in any treatment of our experiment. That is, we adopt a "between–subjects" design. Subjects were recruited from the undergraduate population of the University of Pittsburgh. At the start of a session subjects were given written instructions which were also read aloud in an effort to make those instructions public knowledge.[4] Subjects had to correctly answer a number of comprehension questions prior to the start of the experiment to ensure that they had a good understanding of the written instructions. Neutral language was used throughout. Subjects were told that they would participate in two "sequences" each of length 25 periods. They were instructed

[4]Copies of these instructions including tables, figures and record sheets are given in Appendix B.

that for each sequence they would receive an endowment of 10 "tokens" ($y = 10$) at the start of each of the 25 periods of that sequence. They were further instructed that in each period of a sequence they could "convert" any number of their available tokens for that period into money earnings (this conversion act is meant to constitute "consumption," though we did not refer to it as such). Subjects were told that tokens not converted into money earnings, (i.e., tokens that were saved) would earn "interest" at the rate of 5 percent per period. They were also informed that any tokens held beyond the final, 25th period of a sequence would have no redemption value. In making token conversion decisions, subjects were instructed to consider how their token conversions converted into money earnings. The mapping from the number of tokens converted in period t, c_t, to a subject's "point" earnings for period t was given by our parameterization of the chosen utility function, $u(c_t) = 15 - 10e^{-.10c_t}$. Points were converted into money (US dollars) at the fixed and known rate of 1 point = \$0.06 and this final mapping from the number of tokens converted into money amounts was the one that was actually shown to subjects, i.e., subjects were told that their money earnings were given by $.06u(c) = .9 - .6e^{-.1c}$. While we reported to subjects this monetary payoff formula, we also provided them with a payoff table indicating how various amounts of token conversions they could make would translate into money earnings in each period. In addition to payoff tables, we also provided subjects with a figure illustrating the payoff function. In addition to payoff tables for token conversions (consumption), we also provided subjects with a table explaining how various amounts of tokens saved at time t, s_t, would result in additional token amounts $r \times s_t$ in the next period. Prior to making a token conversion decision, subjects were informed of the total tokens they had available which was always at least $y = 10$ tokens. For periods $1 < t \leq 25$, subjects could have additional tokens available to them in the amount $(1 + r)s_{t-1}$ depending on whether they had saved any of their token balance in the previous period, i.e., if $s_{t-1} > 0$. Thus in periods $1 < t \leq 25$, subjects had $y + (1 + r)s_{t-1}$ tokens available to convert into money earnings in that period t. In the initial period 1 of each sequence they only had their endowment of $y = 10$ tokens. Savings were restricted to be non-negative; there was no possibility of borrowing or lending tokens to other participants.

Subjects's monetary earnings accumulated over all 25 periods of each sequence (lifetime). Thus, subject i's cumulative monetary payoff for a given sequence was $\sum_{t=1}^{25} .06u(c_t^i)$. Two sequences of 25 periods were played so as to determine whether experience mattered or not. Subjects were told that at the end of the session, one of the two 25-period sequences would be randomly selected and they would be paid their total monetary earnings from the one chosen sequence together with a $5 show-up payment in cash and in private. Average total earnings (including a $5 show-up payment) were $21.87 for treatment 1 (standard deviation, 0.30) and $21.48 (standard deviation 1.41) for treatment 2. Each session was completed in approximately 1.25 hours.

4 Findings

We have data from three sessions of each of our two main treatments. As each session involved 10 subjects, we have data from $3 \times 2 \times 10 = 60$ subjects. We begin by noting that, as a basic test of rationality, most of our subjects understood that they should consume all of their wealth in the 25th and final period of each lifecycle (or sequence). Indeed, all but 2 of the 30 subjects did this in treatment 1 and all but 3 of 30 subjects did this in treatment 2. Our main results concern the consumption decisions of *all* subjects in each of our two main treatments.[5] We report these main results as a number of different findings. Our first (and main) finding concerns the effect that social information has on consumption choices relative to the optimal path:

Finding 1 *Social information on average past average consumption amounts causes individual consumption choices to deviate further away from the unconditional optimal path relative to the control treatment where such social information is absent.*

Support for Finding 1 comes from Figures 2a-2b and Table 1. Figure 2a shows the path of the average consumption choices in the second and final 25-period lifetime of each of the three sessions of Treatment 1, which is labeled 'Avg. Cons'.[6] Figure 2b shows the same for Treatment 2. Also shown in each figure is the time 0 *un*conditional optimal path for consumption (taken from Figure 1), labeled 'Optimal' and the average *conditionally* optimal path for the second and final 25-period lifetime in each session of each treatment (more on the conditionally optimal path below). Table 1 confirms the impression conveyed from a comparison of Figures 2a-2b that the MSD of consumption from the unconditional optimal path is lower in treatment 1 than in treatment 2.

[Insert Figures 2ab here.]

[5] We have verified that the results reported below are unaffected if we remove those few subjects who do not pass the rationality test of consuming all of their wealth in the final period.

[6] We show only the second lifetime to make the graphs clearer. The data analysis, however, makes use of both 25-period lifetimes.

Treatment -Session	All 25 Periods	Periods 1-5	Periods 6-10	Periods 11-15	Periods 16-20	Periods 21-25
1-1	26.74	13.01	18.58	17.57	23.81	60.75
1-2	16.07	11.17	13.19	8.32	19.06	28.60
1-3	20.24	13.42	13.89	28.48	16.88	28.52
1-All	21.02	12.53	15.22	18.12	19.92	39.29
2-1	45.33	29.78	42.94	30.37	42.30	81.25
2-2	27.60	10.67	7.334	6.18	10.66	103.16
2-3	57.40	16.27	23.77	39.66	72.64	134.68
2-All	43.44	18.90	24.68	25.40	41.87	106.37

Table 1: Averages of Mean Squared Deviations of Consumption from the Optimal Path, All 25 Periods and 5-period Non-Overlapping Subsamples for Both Sequences of Each Session of Treatments 1-2

Rounds	Treatment 1 vs. 2
1-5	z = -1.446, Pr $> \|z\| =$ 0.1483
6-10	z = -1.275, Pr $> \|z\| =$ 0.2025
11-15	z = -1.352, Pr $> \|z\| =$ 0.1765
16-20	z = -1.413, Pr $> \|z\| =$ 0.1576
21-25	z = -0.887, Pr $> \|z\| =$ 0.3750
All 1-25	z = -1.429, Pr $> \|z\| =$ 0.1531

Table 2: Wilcoxon-Mann Whitney tests of differences in MSD from the optimal consumption path across various rounds of the two treatments

Table 1 reports averages of the mean squared deviations between individual subjects' consumption paths (for both 25-period sequences) and the unconditional optimal consumption path as shown in Figure 1 for both treatments over all 25 periods and over 5 period non-overlapping intervals for the three sessions of each treatment

To determine whether these differences are statistically significant, we conducted pairwise Wilcoxon-Mann Whitney (WMW) tests of the null hypothesis of no significant differences in MSDs between our two treatments over all rounds as well as for 5-round non-overlapping intervals. These results are reported in Table 2. The results indicate that despite the larger MSD from the unconditional optimal path for treatment 2 relative to treatment 1, we cannot reject the null of no difference in MSD from the optimal consumption path between treatments 1 and 2. Of course, a difficulty with considering the MSD from the *un*conditional optimal consumption path is that mistakes made in early periods (e.g., under-saving) become compounded over time. A more reasonable measure of subjects' performance is to consider the MSD of consumption from the *conditionally* optimal path. The conditionally optimal consumption path for each subject i is constructed as follows: Subject i enters each period t with some cash on hand (COH) which consists of his or her endowment income, $y = 10$ (the same for all i), plus subject i's gross return on savings from the prior period, $(1.05)s_{t-1}^i$. We thus treat each individual's COH for period t as though it were the initial wealth level that the subject brought to solving a reduced, $T-t+1$ period consumption planning problem, and we calculate the optimal consumption and savings plan $\left\{c_{t+s}^{i*}\right\}_{s=0}^{T-t}$ for subject i conditional on subject i's COH_t^i, as of the start of period t. In the final period T, it is optimal for all subjects to consume *all* of their COH_T. In essence, we use only the current period optimal consumption amount, c_t^{i*}, given the current period COH_t^i as our measure of the *conditionally optimal consumption* amount for subject i and using this value we calculate the MSD as $(c_t^i - c_t^{i*})^2$ for each subject over all 25 rounds of each lifetime. Considering the MSD of consumption choices from the *conditionally* optimal path we have the following finding:

Finding 2 *Consumption is significantly further from the conditionally optimal path in treatment 2 than in treatment 1.*

Support for Finding 2 comes again from Figures 2a-2b and from Table 3 which, differently from Table 1 reports averages (for both 25-period sequences) of the MSD from the *conditionally* optimal consumption path, the derivation of which was described above. First we calculated each subjects' conditionally optimal consumption path at each time period and we then calculated that subjects' MSD from the conditionally optimal path. The MSDs reported in Table 3 are the mean values of those individual MSDs.

As Table 3 reveals, considering the mean squared deviation of consumption from the *conditionally* optimal path serves to reinforce and strengthen the earlier finding of Table 1 as summarized in Finding 1. In the case of conditionally optimal behavior we observe that treatment 2 has a much greater MSD from the conditionally optimal path as compared with treatment 1. Indeed, WMW tests as reported in Table 4 confirm the impression given by

Treatment -Session	All 25 Periods	Periods 1-5	Periods 6-10	Periods 11-15	Periods 16-20	Periods 21-25
1-1	18.85	15.51	27.90	19.19	10.91	20.71
1-2	11.47	13.58	19.84	9.71	8.37	5.86
1-3	15.45	15.09	19.09	29.31	8.99	4.77
1-All	15.26	14.73	22.28	19.40	9.43	10.45
2-1	34.07	31.32	48.53	28.14	28.92	33.44
2-2	27.79	12.71	12.46	12.92	15.88	85.00
2-3	367.59	18.92	37.96	81.49	167.45	1532.14
2-All	143.15	20.98	32.98	40.85	70.75	550.19

Table 3: Averages of Mean Squared Deviations of Consumption from the Conditionally Optimal Path, All 25 Periods and 5-period Non-Overlapping Subsamples for Both Sequences of Each Session of Treatments 1-2

Rounds	Treatment 1 vs. 2
1-5	z = -4.145 Pr $> \|z\| = 0.0000$
6-10	z = -3.749 Pr $> \|z\| = 0.0002$
11-15	z = -4.252 Pr $> \|z\| = 0.0000$
16-20	z = -3.103 Pr $> \|z\| = 0.0019$
21-25	z = -3.058 Pr $> \|z\| = 0.0022$
All 1-25	z = -4.152, Pr $> \|z\| = 0.0000$

Table 4: Wilcoxon-Mann Whitney tests of differences in MSD from the conditionally optimal consumption path across various rounds of the two treatments

Table 3 as well as Figures 2ab that the null hypothesis of no significant differences in MSDs between treatments can now be rejected in pairwise comparisons between treatments 1 and 2 (p¡.01) in favor of the alternative that the MSD from the conditionally optimal path is *greater* in treatment 2 than in treatment 1.

Our interpretation of the findings of Tables 1-4 is straightforward: social information on the consumption decisions of others as summarized by the past average consumption level, C, lead to greater departures of consumption from the unconditional or conditionally optimal path, due to a desire by subjects to keep up with the social norm (the Joneses). As this social norm information is *not* present in treatment 1, it does not impact on consumption decisions in that treatment.

4.1 Social Information, Learning and Wealth Effects on Consumption Decisions

In an effort to better understand the impact of social information and other potential factors on individual consumption decisions, we turn to a regression analysis of individual consumption decisions that is reported in Tables 5, 6 and 7. All results reported in these tables are from generalized least squares (GLS) random effects regressions with clustering of robust standard errors on group/session identity. In addition to a constant term, the explanatory variables in these regressions are as follows: “seq2” is a dummy variable indicator for whether the consumption decision was made in the second 25-period sequence of the session; “period” refers to the period number within each 25-period lifetime horizon; period × seq2 captures the interaction between the period number and the second sequence dummy variable, seq2; prioravgcons is the is the one-period-lagged average consumption level (C_{t-1}) that was visible at time t to subjects in treatment 2 only; finally, “wealth” refers to each subject’s available cash on hand at the start of period t which is given by: $10 + (1.05)s_{t-1}$. We also report on regressions combining data from both treatments 1 and 2. In these regressions, shown in the right-most column of these tables, “tr2” represents a dummy variable for treatment 2 (treatment 1 is the baseline), “period × tr2” and “prioravgcons × tr2” capture the interaction between the period number and prioravgcons, respectively, with the treatment dummy variable, tr2.

Table 5 reports on a regression analysis where the dependent variable is the individual consumption amount (tokens converted) in each period by all subjects. The regression results using the consumption data of treatment 1 only (first column) reveal that the coefficient on the constant term for this treatment is 5.6 which is a little higher than 5.5 for the unconditional optimal path as shown in Figure 1, and that there appears to be no effect from experience as the coefficient on the dummy variable, ‘seq2” is not significantly different from zero. We further observe that the coefficient on the period variable is positive and significantly different from zero indicating a slope coefficient of approximately 0.23, which is considerably lower (flatter) than the slope of the optimal consumption path shown in Figure 1, which has a slope of 0.49. Note also that the variable period × seq is insignificantly different from zero. Thus, relative to the unconditional optimal path, subjects begin both sequences of treatment 1 consuming more than is optimal in the early periods of their lives and consequently they have less wealth so that they are able to consume less over time, in the later periods of their lives as indicated by the flatter than optimal slope coefficient on actual consumption over time (see also Figure 2a). In addition, we observe that the coefficient on prioravgcons, the prior average level of consumption C_{t-1}, is *not* significantly different from zero, which is not surprising as subjects in treatment 1 did not have access to this social information when making their consumption decisions. On the other hand, the coefficient on wealth, while small, is positive and significant, indicating that subjects' available cash on hand was a determinant in their consumption choices.

Regression results using the data of treatment 2 indicate that subjects start out consuming much less than the optimal level - the intercept coefficient is 2.67 and significantly different from zero and the coefficient on the period variable is again statistically significant and lower than optimal at 0.21. The main difference however, between treatments 1 and 2 is that the consumption of subjects in treatment 2 is now largely determined by the prior average level of consumption as indicated by the positive and significant coefficient of 0.42 on this variable in the regression reported in Table 5. This high weight placed on the prior, economy-wide average level of consumption confirms the important role of social information in consumption decision-making and helps us to better understand the larger deviation of consumption from the unconditional or conditionally optimal paths in treatment 2 relative to treatment 1 as reported in Findings 1-2. As in treatment 1, in treatment 2 experience seems not to matter as the coefficients on both the dummy variable, 'seq2" and the period interaction variable, period $\times$ seq2, are not significantly different from zero. Wealth in treatment 2 continues to have a small, significant effect on consumption decisions, but it has less weight as compared with treatment 1.

The final regression combining consumption data from both treatments 1 and 2 serves mainly to confirm the individual treatment regression analyses. We note that all of our regression results remain robust if we eliminate from the specification those variables that are not statistically significant.[7]

In Table 6 we repeat the same regression exercise of Table 5 but here we use as the dependent variable the *deviation* of consumption from the unconditional (time 0) optimal path (as shown in Figure 1) for each period. Looking at the deviation, as opposed to the mean squared or absolute deviation as we did in Tables 1-3, tells us more about the impact of each explanatory variable on departures from the optimal path, e.g., the *sign*, positive or negative, of such departures. Note first that for treatment 1, the initial deviation from the unconditional optimal path is not significantly different from zero while for treatment 2 it is significantly negative as indicated by the coefficient estimate on the constant term. The

[7]Those regression results are available upon request.

Dependent Variable: Consumption

Variable	Treatment 1 Only Coefficient (St. Error)	Treatment 2 Only Coefficient (St. Error)	Treatments 1-2 Combined Coefficient (St. Error)
constant	5.60***	2.67**	6.79***
	(1.477)	(1.026)	(0.943)
seq2	-0.220	0.170	0.00
	(0.485)	(0.412)	(0.436)
tr2			-4.20*
			(1.756)
period	0.20***	0.21**	0.22***
	(0.028)	(0.073)	(0.051)
period × seq2	0.02	0.00	0.01
	(0.033)	(0.037)	(0.034)
period × tr2			-0.02
			(0.081)
prioravgcons	0.080	0.42*	
	(0.152)	(0.197)	
prioravgcons × tr2			0.42*
			(0.198)
wealth	0.07***	0.03*	0.04**
	(0.007)	(0.014)	(0.015)
No. Observations	1,440	1,440	2,880
No. Subjects	30	30	60
R^2	0.208	0.169	0.174

Notes: Robust standard errors clustered by session, appear in parentheses; *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table 5: Random effects Regression Estimates of Consumption Decisions

coefficient on the period variable is significantly negative for both treatments, indicating that the deviation from the unconditional optimal path was decreasing over the 25 period lifecycle which is evidence of some learning behavior. However, there is again no difference in the intercept or slope coefficients in the second 25 period sequence as compared with the first as indicated by the insignificant coefficients on the seq2 and period $\times$ seq2 variables.[8] Perhaps most importantly, social information on the prior average consumption of group members again results in a statistically significant and positive deviation of consumption away from the unconditional optimal path only in treatment 2; in treatment 1, where this information is not provided, it has no effect in explaining deviations of consumption from the optimal path. This is consistent with the finding reported in Table 5 that consumption in treatment 2 is positively and significantly affected by increases in lagged average consumption. Finally, we again observe that higher wealth (cash on hand) serves to increase the deviation of consumption from the unconditional optimal path. We summarize the main finding as follows:

Finding 3 *Subjects' consumption choices depend positively on their current wealth and steadily increase over the 25 periods of a lifecycle. Consumption is significantly affected by the prior average consumption amount in treatment 2 but not in treatment 1 (where that information was not provided). Specifically, in treatment 2, the higher is past average consumption, the greater is an individual's current own consumption and this dependency accounts for much of the deviation of consumption from the unconditional optimal path.*

Finally, in Table 7 we report on a regression analysis of the deviation of individual consumption choices from the *conditionally* optimal path (as described previously) using the same explanatory variables as in the regressions reported in Tables 5-6. In this regression analysis we observe that the initial deviation of consumption from the conditionally optimal path is again significantly positive only for treatment 2, as indicated by the coefficient on the constant term. We further observe that the deviation of consumption from the conditionally optimal path decreases as the period number increases suggesting again some evidence for learning.

The main differences in our regression analysis of deviations from the conditionally optimal path as reported in Table 7 are 1) the coefficient on prioravgcons is now insignificant for both treatments 1 and 2, and 2) the coefficient on wealth is now significantly negative for

[8]The insignificance of lifecycle experience in solving consumption/savings plans has also been observed in other experimental studies by Brown et al. (2009) and Meissner (2014).

Dependent Variable: Deviation of Consumption from the Unconditional Optimal Path

Variable	Treatment 1 Only Coefficient (St. Error)	Treatment 2 Only Coefficient (St. Error)	Treatments 1-2 Combined Coefficient (St. Error)
constant	0.74	-2.20*	1.86*
	(1.477)	(1.026)	(0.759)
seq2	-0.22	0.17	0.13
	(0.485)	(0.412)	(0.114)
tr2			-4.21*
			(1.793)
period	-0.29***	-0.28***	-0.26***
	(0.028)	(0.073)	(0.036)
period × seq2	0.02	0.00	
	(0.033)	(0.037)	
period × tr2			-0.02
			(0.081)
prioravgcons	0.08	0.42*	
	(0.152)	(0.197)	
prioravgcons × tr2			0.42*
			(0.204)
wealth	0.07***	0.03*	0.04**
	(0.007)	(0.014)	(0.015)
No. Observations	1,440	1,440	2,880
No. Subjects	30	30	60
R^2	0.2373	0.0627	0.1124

Notes: Robust standard errors clustered by session, appear in parentheses; *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table 6: Random effects Regression Estimates of the Difference between Actual and Optimal Consumption Decisions

both treatments. To understand these findings, recall that the *conditionally* optimal level of consumption each period depends only on the individual's own current period cash on hand, i.e., on the variable referred to as wealth in the regression analysis. As this wealth level changes from period to period, the conditionally optimal amount of consumption changes period by period as well and our regression analysis is studying the deviation of consumption choices from this conditionally optimal level. Hence, there is less of a role to be played by longer-term past average consumption considerations in understanding deviations from the conditionally optimal path and a greater role to be played by variations in the wealth variable in explaining such deviations. The finding that the coefficient on the wealth term is negative in Table 7 while it was positive in Table 6 can be explained as follows. High levels of wealth (cash on hand) may result from large departures from the *un*conditional optimal path (as we found in Table 6); for instance, subjects who saved without consuming much for many periods only to periodically consume all of their savings. On the other hand, high levels of wealth in any single period are evidence of some predilection to have saved in the immediate prior period. Conditioning on such wealth levels as is done in the regression analysis reported in Table 7, the savers (those with high wealth) are more likely to behave according to the conditionally optimal prediction than are those with less wealth, e.g., the non-savers, and this may account for the negative coefficient on the wealth variable in Table 7.

5 External Habit Formation

In this section we report on a third treatment where we replace the period utility function, $u(c_t)$, used in treatments 1 and 2 with an external habit formation specification, namely,

$$u(c_t, C_{t-1}) = u(c_t - \alpha C_{t-1})$$

where, as before, C_{t-1} denotes the economy-wide average level of consumption and $\alpha > 0$ is a parameter measuring the intensity of the external habit for current period consumption. As noted in section 2, this external "habit formation" specification is a standard means of injecting social concerns about relative consumption in the literature on consumption behavior (see, e.g., Schmitt-Grohé and Uribe 2008 for a survey) and so it seems reasonable to explore the extent to which laboratory subjects can solve the lifecycle, intertemporal consumption planning problem when they have such an *explicitly induced* concern for the

Dependent Variable: Deviation of Consumption from the Conditionally Optimal Path

Variable	Treatment 1 Only Coefficient (St. Error)	Treatment 2 Only Coefficient (St. Error)	Treatments 1-2 Combined Coefficient (St. Error)
constant	2.52	11.14**	6.89***
	(1.615)	(3.808)	(1.525)
seq2	-0.32	-1.27	0.63
	(0.234)	(0.853)	(0.398)
tr2			2.13
			(1.602)
period	-0.20***	-0.13	-0.13***
	(0.040)	(0.123)	(0.014)
period × seq2	0.03**	0.17	-0.02
	(0.012)	(0.125)	(0.081)
period × tr2			-0.02
			(0.081)
prioravgcons	0.24	-0.32	
	(0.211)	(0.376)	
prioravgcons × tr2			-0.28
			(0.294)
wealth	-0.05***	-0.22***	-0.18**
	(0.012)	(0.052)	(0.071)
No. Observations	1,440	1,440	2,880
No. Subjects	30	30	60
R^2	0.1254	0.4424	0.3757

Notes: Robust standard errors clustered by session, appear in parentheses; *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table 7: Random Effects Regression Estimates of the Difference between Actual and Conditionally Optimal Consumption Decisions

economy-wide average level of consumption, C_{t-1}.[9]

In this version of the model, the optimal consumption path is again found by maximizing (1) subject to (2) but where $u(c_t - \alpha C_{t-1})$ is used in place of $u(c_t)$ and C_0 is set equal to 0. For this version of the model we kept the parameterization of the environment exactly the same as in treatments 1-2. In particular, we continued to set $r = .05$ and $y = 10$ for all $T = 25$ periods. We again used the CARA specification, $u(x) = \kappa - \frac{1}{R}e^{-Rx}$, where $\kappa = 15$, $R = .10$ but where x is now equal to $c_t - \alpha C_{t-1}$. We chose to set $\alpha = .5$, the midpoint of the feasible range ($0 \leq \alpha \leq 1$). The solution is found in the same manner as before, by combining 24 Euler equations of the form:

$$u'(c_t - \alpha C_{t-1}) = E_t[(1 + r)u'(c_{t+1} - \alpha C_t)],$$

with the lifetime budget constraint to get a sequence of optimal consumption amounts in each of the 25 periods of an individual's lifetime. Notice that in this case, subjects must form expectations in period t of the value of C_t, which is not known until period $t + 1$. The optimal consumption path in this third treatment is constructed similarly to the case where $\alpha = 0$; in constructing this path we assume that agents take the sequence of external habit-level consumption amounts $\{C_t\}_{t=0}^{24}$ as if it were exogenously determined when solving for their optimal consumption decisions.[10] Figure 3 provides a comparison of the unconditional optimal consumption path in the case where $\alpha = .5$ with the original formulation used in treatments 1 and 2 where $\alpha = 0$.

Notice that when $\alpha = .5$, the optimal consumption path has a lower intercept and a steeper slope than the optimal consumption path when $\alpha = 0$. Intuitively, the explicit inclusion of the C_{t-1} term in the period utility function means that savings must now initially be greater (consumption must initially be lower) in the external habit formation treatment so that the individual may realize a positive utility from consumption later on in life when C_{t-1} is also larger. We hypothesized that the inclusion of the external habit formation term in the utility function would indeed lead subjects to save more in the earlier periods of their

[9] We chose to work with past average specification for the external habit level of consumption rather than (say) the contemporaneous average, C_t (which is also studied in the literature) to enable comparisons with our treatment 2 and so that subjects would be operationally able to condition their behavior on the habit level of consumption. Using instead the contemporaneous average, C_t, the external habit level for consumption is *endogenously* and simultaneously determined by subjects' time t consumption decisions, and thus subjects would not be able to condition on this statistic.

[10] With $N = 10$ subjects this seemed a reasonable assumption.

lives relative to the two treatments where $\alpha = 0$, and thus, that external habit formation might work to correct a tendency toward over-consumption as in our earlier treatments.

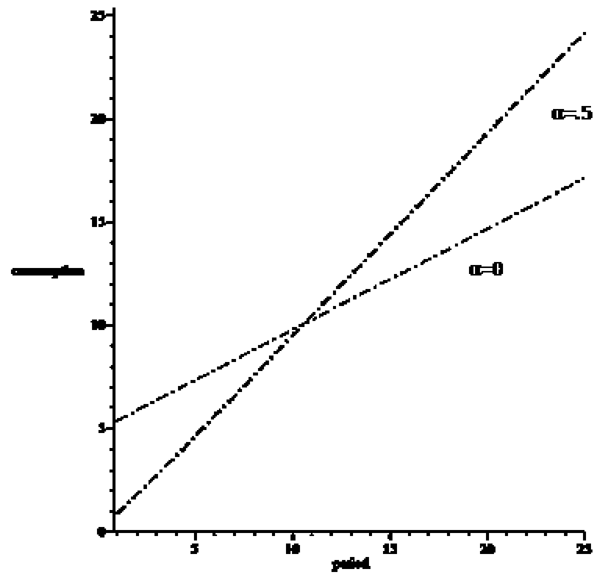

Figure 3: Optimal lifecycle consumption paths for the model parameterization when $\alpha = .5$ compared with the case where $\alpha = 0$.

Aside from the change in α from 0 to 0.5, the model economy of treatment 3 is identical to that of treatments 1 and 2. The experimental procedures were also similar to those used in treatments 1-2. As in treatment 2, subjects in treatment 3 were shown the past average level of consumption, C_{t-1}, on their computer screens prior to making their consumption decision in each period $t = 1, 2, ...25$, with $C_0 = 0$. The main difference between treatments 2 and 3 is that subjects in treatment 3 had an explicit incentive to condition their consumption/savings decision on the prior average level of consumption as this level now directly affected their payoff each period. While we reported to subjects the monetary payoff formula for treatment 3, as in treatments 1-2 we also provided subjects with a payoff table indicating how various amounts of token conversions they could make would translate into money earnings in each period. However, by contrast with treatments 1-2, the payoff table used in treatment 3 was *two*-dimensional showing monetary earnings for a large number of possible $\{c_t, C_{t-1}\}$ *pairs*. In addition to payoff tables, we also provided subjects with a 3-dimensional figure showing the payoff *surface* as a function of c_t and C_{t-1}.[11] In all other respects, the procedures were

[11]See the written instructions for the figures presented to subjects.

the same as for treatments 1-2. We conducted three sessions of treatment 3, each involving 10 subjects with no prior experience in our experiment who were drawn again from the undergraduate population of the University of Pittsburgh. Each session again consisted of decision-making in two 25-period lifetimes and each subject's earnings in one of these two lifetimes was randomly chosen for payment at the end of each session. Average total earnings for treatment 3 (including a \$5 show-up payment) were \$18.23 (standard deviation, 1.27) for an approximately 1.25 hour session.

5.1 Treatment 3 Findings

Table 8 reports averages of the mean squared deviations between individual consumption paths and the unconditional or conditionally optimal consumption path (for both 25 period sequences) over various periods of the lifecycle. Similar to Figures 2a-2b, Figure 4 shows the path of average consumption choices in the second and final 25-period lifetime of the three sessions of Treatment 3, labeled 'Avg. Cons.' along with the *un*conditional optimal path for consumption (taken from Figure 3) and the mean conditionally optimal consumption path for treatment 3. Note that for treatment 3, the conditionally optimal consumption path for each agent i as of period t depends on *both* the available cash on hand, COH_t^i, *and* the value of lagged average consumption C_{t-1}, which are known at the start of period t.[12] Thus unlike in treatment 2, the conditionally optimal path in treatment 3 explicitly conditions on the value of C_{t-1}.

[Figure 4 here].

By comparison with Tables 1-3 and Figures 2a-2b, we note several differences. First, the MSD from the *un*conditional optimal path is much greater in Treatment 3 as compared with Treatments 1-2. Further, these differences are statistically significant according to Wilcoxon-Mann Whitney tests as reported in Table 9. An explanation for the greater deviation of consumption from the unconditional optimal path in treatment 3 relative to the other two treatments is that the optimization problem in treatment 3 is considerably more difficult than in the other two treatments, as subjects have to consider their payoffs as a function of *two* variables, c_t and C_{t-1}, rather than just their own consumption choices.

[12]Of course in the next period, $t+1$, subject i may have an amount of cash on hand, COH_{t+1}^i, that is not optimal from the perspective of period t and thus we re-calculate subject i's optimal path *each* period over their ever-shortening planning horizon.

Deviation of Consumption from Unconditional Optimum						
Treatment -Session	All 25 Periods	Periods 1-5	Periods 6-10	Periods 11-15	Periods 16-20	Periods 21-25
3-1	48.33	42.10	12.68	8.56	53.32	124.99
3-2	45.78	33.05	18.16	19.09	53.21	105.40
3-3	53.18	31.05	13.78	9.40	41.70	169.95
3-All	49.10	35.40	14.87	12.35	49.41	133.45
Deviation of Consumption from Conditional Optimum						
Treatment -Session	All 25 Periods	Periods 1-5	Periods 6-10	Periods 11-15	Periods 16-20	Periods 21-25
3-1	11.41	24.94	13.59	8.90	2.94	6.67
3-2	18.03	19.40	18.45	14.53	11.66	26.12
3-3	21.16	20.19	16.31	21.05	42.02	6.25
3-All	16.87	21.51	16.12	14.83	18.87	13.01

Table 8: Averages of Mean Squared Deviations of Consumption from the Unconditional and Conditionally Optimal Path, All 25 Periods and 5-period Non-Overlapping Subsamples for Both Sequences of Each Session of Treatment 3

Comparison of Deviation of Consumption from Unconditional Optimum		
Rounds	Treatment 1 vs. 3	Treatment 2 vs. 3
1-5	z = -12.977, Pr > $\|z\|$ = 0.0000	z = -10.999, Pr > $\|z\|$ = 0.0000
6-10	z = -17.807, Pr > $\|z\|$ = 0.0000	z = -15.591, Pr > $\|z\|$ = 0.0000
11-15	z = -18.539, Pr > $\|z\|$ = 0.0000	z = -16.560, Pr > $\|z\|$ = 0.0000
16-20	z = -12.551, Pr > $\|z\|$ = 0.0000	z = -10.932, Pr > $\|z\|$ = 0.0000
21-25	z = -13.716, Pr > $\|z\|$ = 0.0000	z = -12.527, Pr > $\|z\|$ = 0.0000
All 1-25	z = -16.600, Pr > $\|z\|$ = 0.0000	z = -14.623, Pr > $\|z\|$ = 0.0000
Comparison of Deviation of Consumption from Conditional Optimum		
Rounds	Treatment 1 vs. 3	Treatment 2 vs. 3
1-5	z = 0.244 Pr > $\|z\|$ = 0.8069	z = 4.368 Pr > $\|z\|$ = 0.0000
6-10	z = -1.466 Pr > $\|z\|$ = 0.1427	z = 2.375 Pr > $\|z\|$ = 0.0176
11-15	z = -1.174 Pr > $\|z\|$ = 0.2405	z = 3.080 Pr > $\|z\|$ = 0.0021
16-20	z = -1.391 Pr > $\|z\|$ = 0.1643	z = 1.788 Pr > $\|z\|$ = 0.0738
21-25	z = 0.187 Pr > $\|z\|$ = 0.8520	z = 3.231 Pr > $\|z\|$ = 0.0012
All 1-25	z = -0.825, Pr > $\|z\|$ = 0.4091	z = 3.357, Pr > $\|z\|$ = 0.0008

Table 9: Wilcoxon-Mann Whitney tests of differences in MSD from the unconditional and conditionally optimal consumption path across various rounds of treatments 3 versus treatments 1-2.

Regarding deviations from the conditionally optimal path, we find that treatments 1 and 3 have roughly similar MSDs from the conditionally optimal path while treatment 2 has a much greater MSD from the conditionally optimal path. Indeed, WMW tests as reported in Table 9 confirm that the null hypothesis of no significant differences in MSDs between treatments cannot be rejected in pairwise comparisons between treatments 1 and 3 ($p = .41$) but can be rejected in pairwise comparisons between treatments 1 and 2 and between treatments 2 and 3 ($p < .01$) in favor of the alternative that the MSD from the conditionally optimal path is greater in treatment 2 than in the other two treatments. We summarize these findings as follows

Finding 4 *Consumption is furthest from the unconditional optimal consumption path in the external habit formation treatment 3. Regarding deviations from the conditionally optimal path, treatments 1 and 3 are not significantly different from one another while treatment 2 exhibits a significantly larger deviation from the conditionally optimal path than the other two treatments.*

Recall that the optimal consumption path in treatment 3 requires that subjects save much more in the first part of their 25-period lifetime than in treatments 1 or 2 -see again Figure 3. That is, the optimal consumption path in the external habit formation treatment has a lower intercept and a steeper slope than in treatments 1 and 2 where the external habit level of consumption does not directly enter into the period utility function. Consequently, if subjects initially approach the intertemporal, lifecycle planning problem similarly across all three treatments, then they are destined to do worse relative to the *un*conditional optimal path in treatment 3 as compared with the other two treatments. This is our explanation for the first part of Finding 4 that deviations from the *un*conditional optimal path are significantly larger in treatment 3 than in the other two treatments. On the other hand, as Finding 4 further indicates, the social information on average consumption provided in treatment 2 causes consumption to depart further from the *conditionally* optimal path due to a desire by subjects to keep up with the social norm (the Joneses), as reflected in the past average level of consumption. As the information on prior period average consumption is *not* present in treatment 1, it does not impact on consumption choices in that treatment. In treatment 3, the conditionally optimal consumption level depends on both the current period wealth (COH) *and* on the prior period past average consumption level, C_{t-1} (as this is now explicitly included in the period utility function) and consequently subjects are incentivized to take proper account of this social norm level of consumption in making their consumption decisions as that information directly affects their payoffs. As a consequence of this explicit need to condition consumption choices on the level of prior average consumption, deviations from the *conditionally* optimal path in treatment 3 are smaller than in treatment 2 and no worse than in treatment 1. A regression analysis of consumption behavior in treatment 3 similar to that reported in Tables 5-7 is available in Appendix A for the interested reader.

6 Conclusions

The role of social information and habits on intertemporal consumption and savings plans is thought to be important but is poorly understood. In this paper we have taken a first step toward understanding the role of *peer* influences on consumption behavior by designing and reporting on a laboratory experiment involving a simple lifecycle consumption planning problem. Our model has a fixed interest rate and no income uncertainty making it a relatively simple framework in which to evaluate intertemporal decision making. Furthermore, all agents are identical in terms of period income and preferences, thus enhancing the attractiveness as well as the relevance of peer influence. We find in our baseline treatment 1 that subjects have difficulty solving a 25-period lifecycle consumption optimization problem despite the absence of any uncertainty and given two opportunities to go about it. In particular, they tend to save too little relative to the optimal path (i.e. they over-consume), a phenomenon that has been found in other studies as well. Importantly, the provision of social information about the average consumption decisions of other, similarly situated agents in our treatment 2 leads to further deviations from the optimal path (Finding 1) and still further deviations from the conditionally optimal path – a more forgiving metric that conditions on subjects' current available cash on hand (Finding 2). Our interpretation of these findings is that subjects over-react to the social information on average consumption that is provided in treatment 2 resulting in larger deviations from the conditionally optimal path relative to treatment 1 where such social information is absent. In other words, social information can be detrimental to intertemporal decision-making when it serves to reinforce over-consumption and reduces savings relative to the optimal path. As suggested in the introduction, the latter finding might help to account for declining savings rates in developed countries since the 1970s as information on the consumption habits of others has become more readily available. Finally, in a third, "habit formation" treatment, we explicitly incorporate concerns for consumption relative to the prior past average level of consumption into subject's utility functions as in the external habit formation literature. We find that subjects have difficulty formulating optimal consumption plans in this environment as well, though their decisions are not any further from the conditionally optimal path than in the baseline treatment 1.

Our findings should be interpreted with some caution since the environment we study is one in which there is little or no uncertainty, as all individuals face the same lifetime income streams and rates of return on savings and individuals only differ from one another at any date in time according to their accumulated wealth (cash on hand). In more realistic settings, with greater uncertainty and/or heterogeneity in incomes and rates of return on savings, it could be that the role played by social influences is much reduced as individuals recognize that such comparisons may not have much relevance to their own intertemporal consumption and savings plans. Alternatively, individuals may also become more selective about the group of peers with whom they form social comparisons. We leave the evaluation of peer effects in such richer environments to future research.

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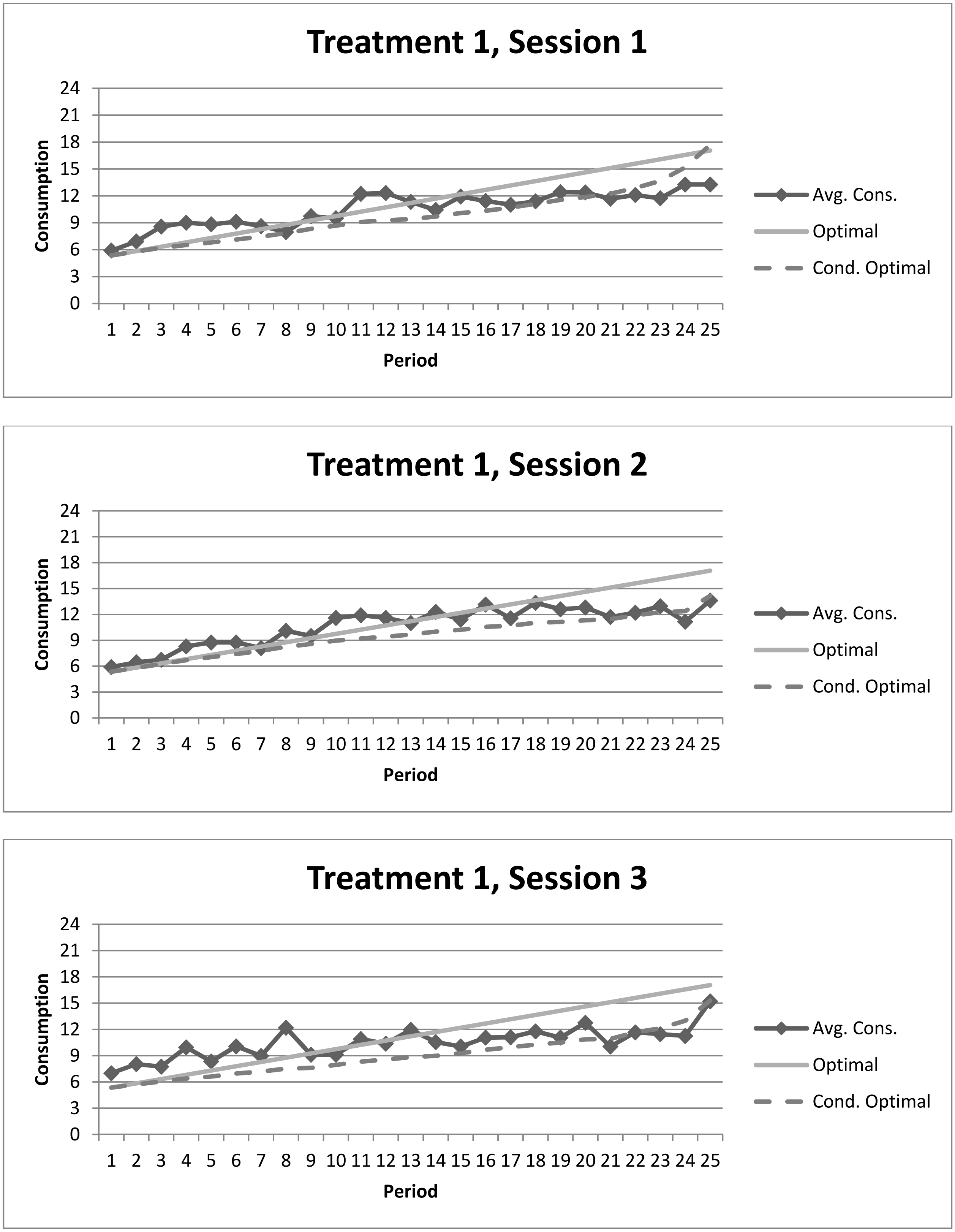


Figure 2a: Average Consumption (Second Sequence) in the three sessions of Treatment 1 relative to Optimal and Conditionally Optimal Consumption.

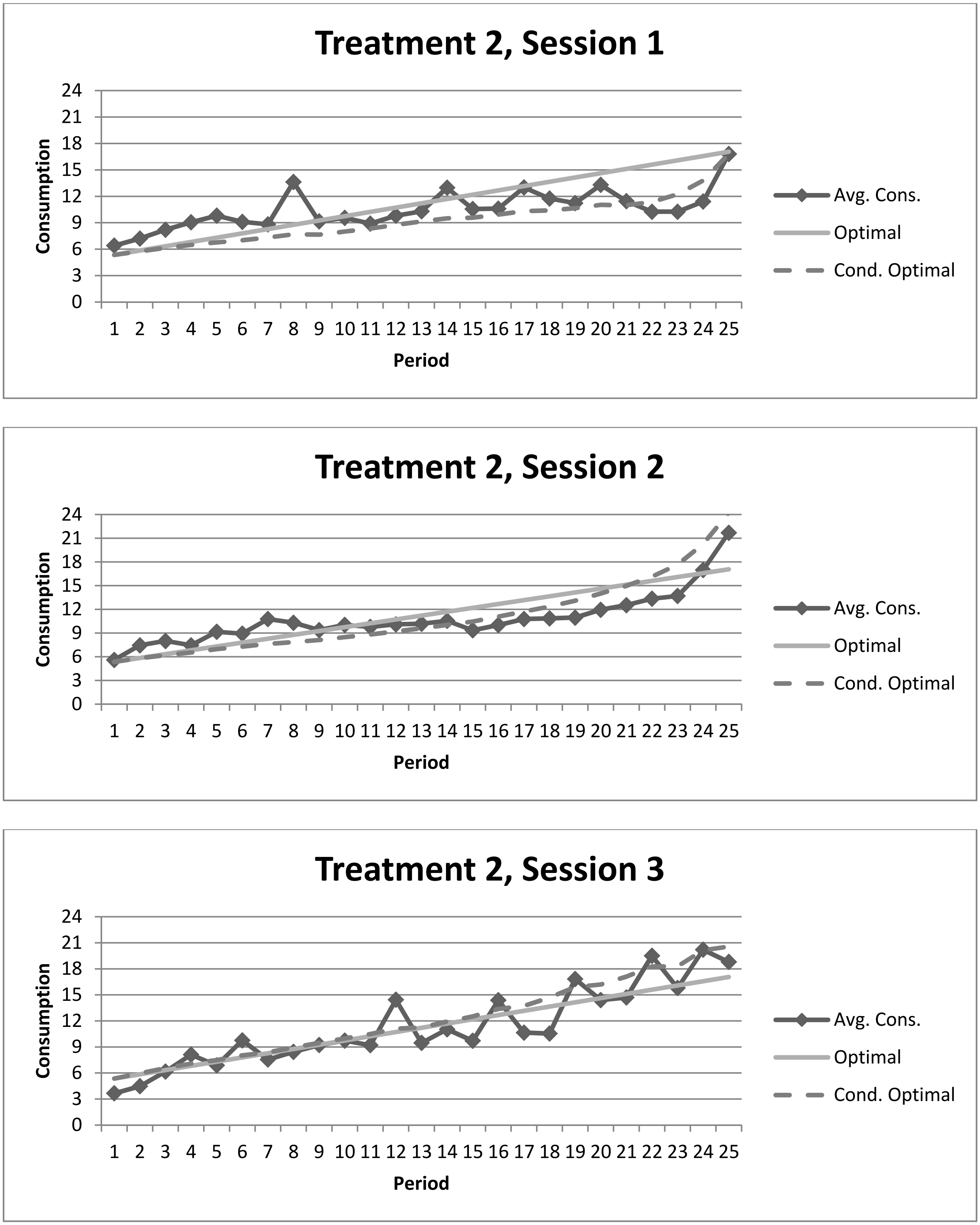
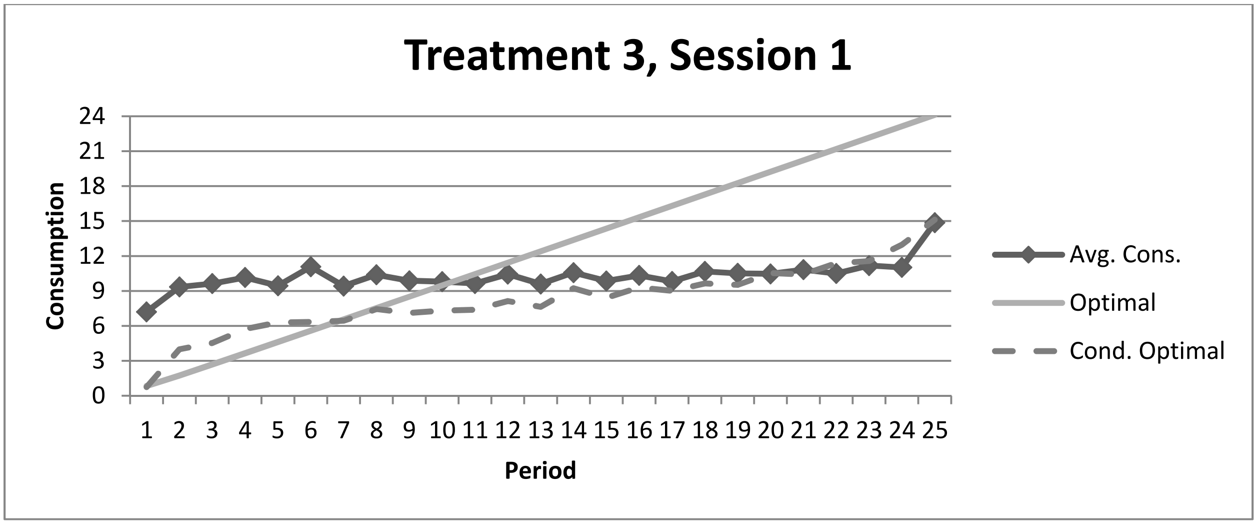
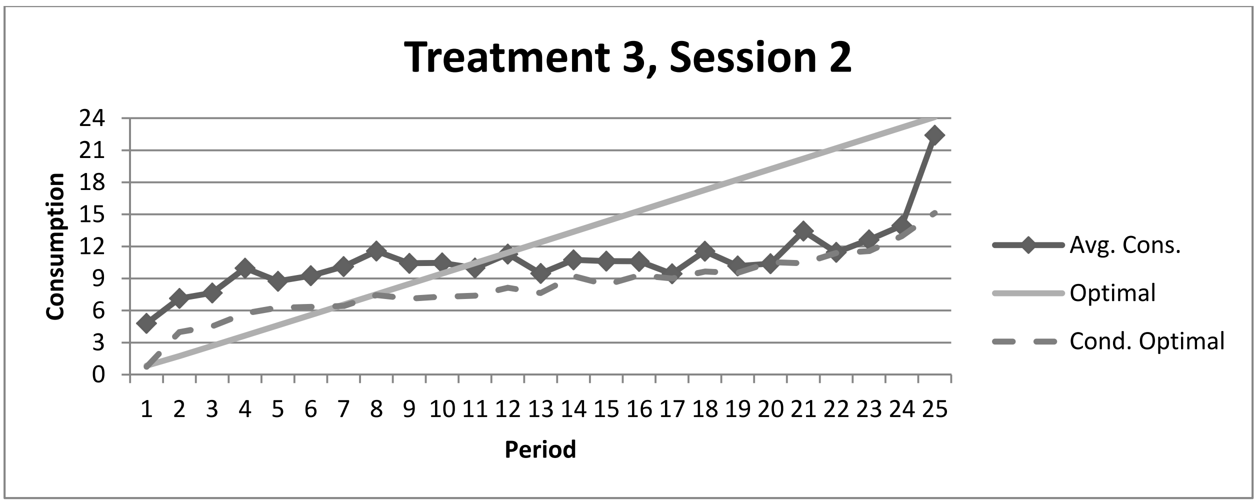


Figure 2b: Average Consumption (Second Sequence) in the three sessions of Treatment 2 relative to Optimal and Conditionally Optimal Consumption.





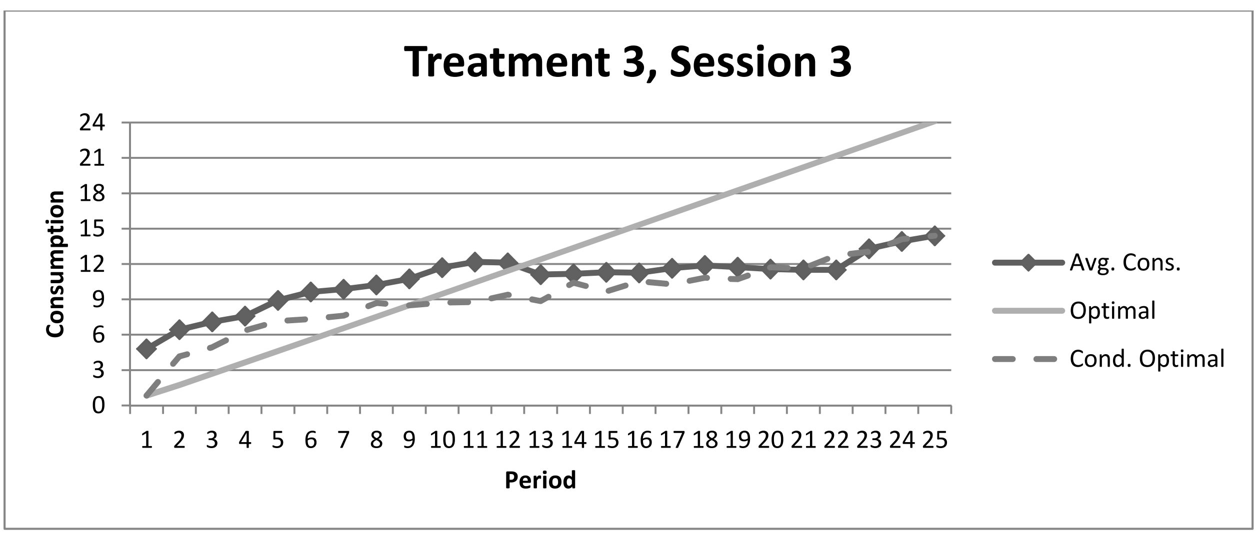


Figure 4: Average Consumption (Second Sequence) in the three sessions of Treatment 3 relative to Optimal and Conditionally Optimal Consumption.

Appendix A: Regression Analysis of Treatment 3

In this appendix we report on some regression results using the consumption data of treatment 3. In particular, as in Tables 5-7, we report on a regression analysis where the dependent variable is either (1) consumption, (2) the deviation of consumption from the unconditional optimal path or (3) the deviation of consumption from the conditionally optimal path. The explanatory variables are the same ones used in Tables 5-7 as explained in the text, albeit using data from treatment 3 only.

	Treatment 3 Data Only, Dependent Variable is:		
	Consumption	Dev. of Consumption from Uncond. Optimum	Dev. of Consumption from Cond. Optimum
Variable	Coefficient (St. Error)	Coefficient (St. Error)	Coefficient (St. Error)
constant	1.15	1.38	3.91***
	(0.972)	(0.966)	(0.965)
seq2	0.49	0.49	0.22
	(0.297)	(0.296)	(0.269)
period	0.10*	-0.87***	-0.26***
	(0.045)	(0.044)	(0.011)
period × seq2	-0.03	-0.03	0.00
	(0.018)	(0.018)	(0.018)
prioravgcons	0.65***	0.66***	0.30*
	(0.092)	(0.092)	(0.118)
wealth	0.06***	0.06***	-0.10***
	(0.004)	(0.004)	(0.013)
No. Observations	1,440	1,440	1,440
No. Subjects	30	30	30
R^2	0.239	0.625	0.482

Notes: Robust standard errors clustered by session, appear in parentheses; *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table 10: Random Effects Regression Estimates of Consumption or Deviations of Consumption from the Unconditional or the Conditionally Optimal Path, Treatment 3 Only

Regarding the first column, where the dependent variable is consumption, we observe that the intercept is lower than for treatments 1 and 2 (and not significantly different from zero), which is consistent with the optimal path for treatment 3, as shown in Figure 3. However, the slope of the consumption function, as measured by the period variable, is only 0.10 and is considerably flatter than in treatments 1-2 where it is approximately 0.20. In theory, this slope should be much steeper in treatment 3; the slope of the unconditional optimal consumption path for treatment 3 as shown in Figure 3 is approximately 0.975. There is again no impact of experience as indicated by the insignificance of the seq2 and period $\times$ seq2 variables (in all three regression specifications). However, prioravgcons, i.e., the variable C_{t-1}, has a strong positive impact on consumption choices in treatment 3 – an even stronger impact than in treatment 2. Finally, wealth again has a positive and significant effect on consumption behavior.

Regarding the second and third columns which explore deviations of consumption from the unconditional and conditionally optimal paths respectively, we observe that such deviations continue to be increased by information on prior average consumption, as indicated by the positive and significant coefficient on the prioravgcons variable in spite of the fact that the conditionally optimal path explicitly conditions on the prior average consumption level in addition to wealth. On the other hand, deviations are mitigated over the lifecycle, as indicated by the significantly negative coefficient on the period variable. As in treatments 1 and 2, subjects with a higher wealth are found to be further from the unconditionally optimal consumption path but closer to the conditionally optimal consumption path.

Appendix B: (Not Intended for Publication): Instructions Used in the Experiment

Instructions [Treatment 1]

Overview

Welcome to this experiment in the economics of decision-making. Please read these instructions carefully as they explain how you earn money from the decisions you make in today's session. There is no talking for the duration of this session. If you have a question, please raise your hand and your question will be answered in private.

Today's session consists of two "sequences". Both sequences consist of 25 "periods" of decision-making. At the start of each period you have a certain number of tokens available to you: this number will be shown to you on your computer screen. After viewing this number, you must decide how many of these tokens you wish to convert into money. You can convert any number of tokens from 0 on up to the maximum number of tokens you have available at the start of each period, and you can choose to convert fractions of tokens up to four decimal places. If the 25^{th} period has not yet been reached, the tokens that you do not convert into money each period will be saved for your use in the next period, and these savings will earn interest in the form of additional tokens available to you next period as explained in more detail below. In the 25^{th} period, any tokens you do not convert into money will become worthless.

Please look at the payoff table, labelled Table 1. This table shows you various amounts of money that you can earn from converting tokens each period. Notice several things. First, only some token amounts that you may wish to convert into money are shown in Table 1, that is, amounts are in increments 0, 1, 2, … , 25, 50, 100, 200, 300. As noted above, you may convert any number of tokens into money in amounts up to four decimal places from 0 on up to and including the maximum number of tokens you have available at the start of each period. The formula for converting tokens into money is given at the bottom of Table 1. Figure 1 illustrates this formula graphically, showing how tokens convert into money over a more continuous range of tokens converted each period. Second, notice that money payoffs are initially increasing in the number of tokens converted each period but this increase occurs at a diminishing rate: the difference in your earnings from converting 6 rather than 5 tokens is larger than the difference in your earnings from converting 16 rather than 15 tokens. Finally note that the more tokens you convert in any period, the less saved tokens you have available for conversion in future periods; saved tokens earn interest in terms of more tokens available to you next period as detailed below.

Specific Instructions

At the start of all 25 periods in a sequence you will be awarded 10 tokens. In addition, in periods 2,…25, you may have additional tokens depending on whether you have saved any tokens from prior periods; in that case, you will also receive interest on those savings, paid to you in additional tokens. Specifically, you will earn an interest rate of 5 percent paid to you in additional tokens at the start of the next period. Thus, if in this period you saved S>0 tokens then at the start of the next period you would have S +S ×.05, equivalently (1.05)×S tokens available to you next period in addition to the 10 tokens you receive at the start of each period. Table 2 shows how your token savings of S this period yield interest in tokens of (.05)×S so that you end up with (1.05)×S tokens available to you next period. As in Table 1, only some token savings amounts and interest earnings on those amounts are shown in Table 2, that is, S ranges from: 0, 1, 2, … , 25, 50, 100, 200, 300.

Thus, at the start of every period you will have some number X≥10 tokens available to you. Your decision screen will report this number to you, breaking it down according to:

1) Endowment of tokens this period: 10
2) Tokens saved from the last period: S
3) Interest earned on savings: S ×.05

The total tokens you have available to convert into money or save in the current period will be the sum of these three numbers.

Type the number of tokens you wish to convert into money (up to four decimal places) in the blue input box on your decision screen for each period. Then click the red Submit button to confirm your choice. You can change your mind anytime prior to clicking the Submit button.

Once the first 25-period sequence has been completed, you will begin playing a second, 25-period sequence. The rules for this second 25-period sequence are exactly the same as those for the first sequence. You will continue to receive an endowment of 10 tokens per period in this second sequence and will make token conversion decisions each period just as in the first sequence.

Information

Following the first period of a sequence and after every period thereafter, you will be reminded of your initial token balance and your token conversion decision for the period. You will also see the number of tokens you have saved, your money earnings for the period and your cumulative money earnings for the sequence. Please record these five pieces of information on your record sheets under the appropriate headings. When you have recorded this information press the Continue button. For your convenience, a history of your prior period decisions will be maintained for you at the bottom of the first decision screen.

Earnings

After the second 25-period sequence has been completed, the computer program will randomly select *one* of the two 25-period sequences that you played. Both sequences have an equal chance of being chosen. You will be paid your cumulative dollar earnings from the one chosen sequence. In addition you will also receive $5 for participating in today's session.

Note: Your earnings in today's session depend only on your own decisions and are not affected by the decisions of any other player.

Questions?

Now is the time for questions. If you have a question, please raise your hand and the experimenter will answer your question in private.

Quiz

Before continuing on to the experiment, we ask that you complete the following quiz. In answering these questions, feel free to consult the instructions and tables. Your performance on this quiz does not affect your payoff in any way. Write or circle your answers to the quiz questions where prompted. Do not put your name on this quiz. If any questions are answered incorrectly, we will go over the relevant part of the instructions again.

1. You will participate in ______ sequences. Each sequence consists of _____ periods.
2. You will be endowed with _____ tokens at the start of each period.
3. Suppose it is period 1. What is the maximum number of tokens you can convert into money this period? _______. What is the minimum number of tokens you can convert into money this period? ______.
4. Suppose you saved 2 tokens in some period t<25. How many tokens will you have available at the start of period t+1, including interest and the number of tokens you get at the start of every period? ______ Now suppose instead that you saved 8 tokens in period t. How many tokens will you have available at the start of period t+1 again including interest and the number of tokens you get at the start of every period? ______.
5. Suppose it is period 25. If you choose to save some of your available tokens in period 25, will they have any future value to you? Circle one Yes No.
6. True or false: Your earnings will depend on your cumulative earnings total from one of the two 25-period sequences you play, but you will not know which sequence will be chosen until the end of the session. Circle one: True False.

TABLE 1	
Tokens Converted, C	**Money Earned, $**
0	0.30
1	0.36
2	0.41
3	0.46
4	0.50
5	0.54
6	0.57
7	0.60
8	0.63
9	0.66
10	0.68
11	0.70
12	0.72
13	0.74
14	0.75
15	0.77
16	0.78
17	0.79
18	0.80
19	0.81
20	0.82
21	0.83
22	0.83
23	0.84
24	0.85
25	0.85
50	0.90
100	0.90
200	0.90
300	0.90

TABLE 2		
Tokens Saved,	**Interest Earned in Tokens**	**Savings+Interest**
0	0	0
1	0.05	1.05
2	0.1	2.1
3	0.15	3.15
4	0.2	4.2
5	0.25	5.25
6	0.3	6.3
7	0.35	7.35
8	0.4	8.4
9	0.45	9.45
10	0.5	10.5
11	0.55	11.55
12	0.6	12.6
13	0.65	13.65
14	0.7	14.7
15	0.75	15.75
16	0.8	16.8
17	0.85	17.85
18	0.9	18.9
19	0.95	19.95
20	1	21
21	1.05	22.05
22	1.1	23.1
23	1.15	24.15
24	1.2	25.2
25	1.25	26.25
50	2.5	52.5
100	5	105
200	10	210
300	15	315

$$Money = .9 - .6e^{-.1C}$$

$$C = Tokens\ Converted$$

$$Interest = .05S$$

$$S = Tokens\ Saved$$

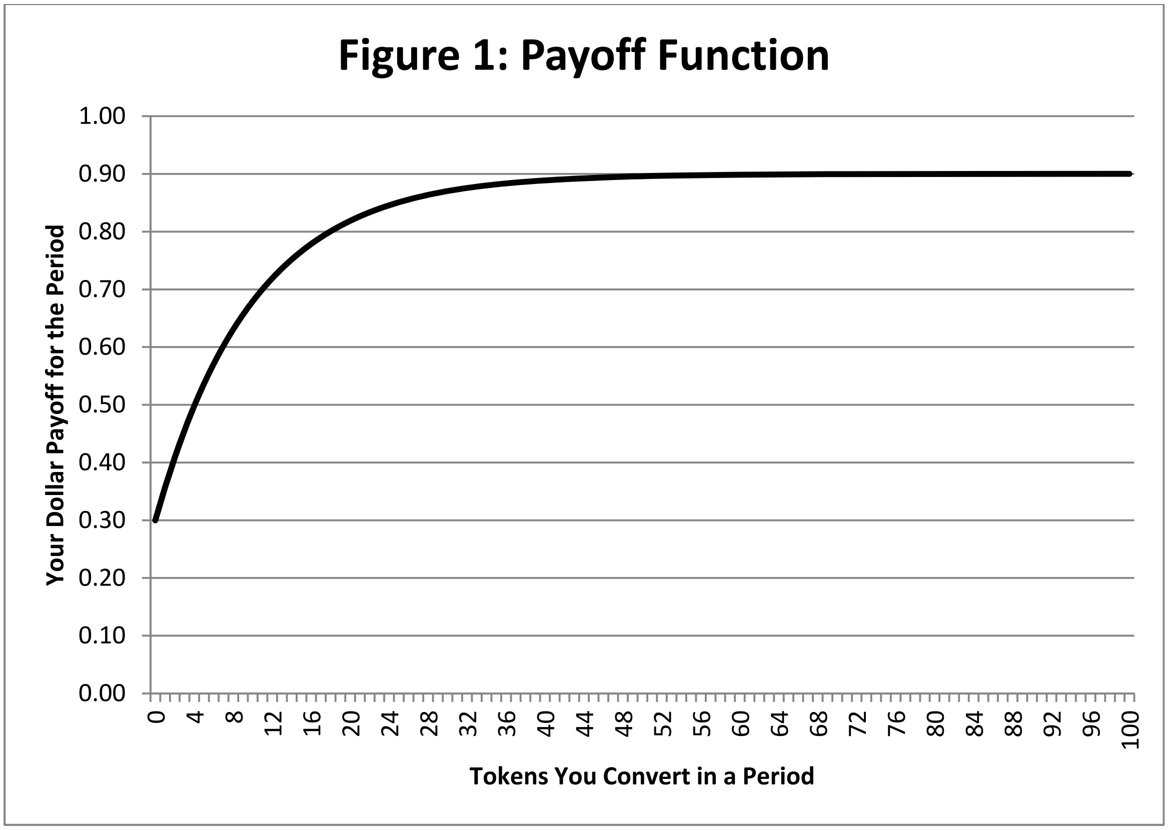


Figure 1: Payoff Function
Your Dollar Payoff for the Period
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
80
84
88
92
96
100
Tokens You Convert in a Period

Record Sheet Player ID ______ Age _____ Sex (Circle) F M

Sequence	Period	Initial Tokens you had at the Start of the Period	Number of Tokens You Converted this Period	Number of Tokens You Saved this Period	Dollar value of your Tokens Converted this Period	Cumulative Dollar Payoff from all Periods of this Sequence
1	1	10				
1	2					
1	3					
1	4					
1	5					
1	6					
1	7					
1	8					
1	9					
1	10					
1	11					
1	12					
1	13					
1	14					
1	15					
1	16					
1	17					
1	18					
1	19					
1	20					
1	21					
1	22					
1	23					
1	24					
1	25					

Record Sheet Player ID ______ Age _____ Sex (Circle) F M

Sequence	**Period**	**Initial Tokens you had at the Start of the Period**	**Number of Tokens You Converted this Period**	**Number of Tokens You Saved this Period**	**Dollar Payoff this period from Tokens Converted**	**Cumulative Dollar Payoff from all Periods of this Sequence**
2	1	10				
2	2					
2	3					
2	4					
2	5					
2	6					
2	7					
2	8					
2	9					
2	10					
2	11					
2	12					
2	13					
2	14					
2	15					
2	16					
2	17					
2	18					
2	19					
2	20					
2	21					
2	22					
2	23					
2	24					
2	25					

Instructions [Treatment 2]

Overview

Welcome to this experiment in the economics of decision-making. Please read these instructions carefully as they explain how you earn money from the decisions you make in today's session. There is no talking for the duration of this session. If you have a question, please raise your hand and your question will be answered in private.

Today's session consists of two "sequences". Both sequences consist of 25 "periods" of decision-making. At the start of each period you have a certain number of tokens available to you: this number will be shown to you on your computer screen. After viewing this number, you must decide how many of these tokens you wish to convert into money. You can convert any number of tokens from 0 on up to the maximum number of tokens you have available at the start of each period, and you can choose to convert fractions of tokens up to four decimal places. If the 25^{th} period has not yet been reached, the tokens that you do not convert into money each period will be saved for your use in the next period, and these savings will earn interest in the form of additional tokens available to you next period as explained in more detail below. In the 25^{th} period, any tokens you do not convert into money will become worthless.

Please look at the payoff table, labelled Table 1. This table shows you various amounts of money that you can earn from converting tokens each period. Notice several things. First, only some token amounts that you may wish to convert into money are shown in Table 1, that is, amounts are in increments 0, 1, 2, … , 25, 50, 100, 200, 300. As noted above, you may convert any number of tokens into money in amounts up to four decimal places from 0 on up to and including the maximum number of tokens you have available at the start of each period. The formula for converting tokens into money is given at the bottom of Table 1. Figure 1 illustrates this formula graphically, showing how tokens convert into money over a more continuous range of tokens converted each period. Second, notice that money payoffs are initially increasing in the number of tokens converted each period but this increase occurs at a diminishing rate: the difference in your earnings from converting 6 rather than 5 tokens is larger than the difference in your earnings from converting 16 rather than 15 tokens. Finally note that the more tokens you convert in any period, the less saved tokens you have available for conversion in future periods; saved tokens earn interest in terms of more tokens available to you next period as detailed below.

Specific Instructions

At the start of all 25 periods in a sequence you will be awarded 10 tokens. In addition, in periods 2,…25, you may have additional tokens depending on whether you have saved any tokens from prior periods; in that case, you will also receive interest on those savings, paid to you in additional tokens. Specifically, you will earn an interest rate of 5 percent paid to you in additional tokens at the start of the next period. Thus, if in this period you saved $S>0$ tokens then at the start of the next period you would have $S + S \times .05$, equivalently $(1.05)\times S$ tokens available to you next period in addition to the 10 tokens you receive at the start of each period. Table 2 shows how your token savings of S this period yield interest in tokens of (.05)×S so that you end up with (1.05)×S tokens available to you next period. As in Table 1, only some token savings amounts and interest earnings on those amounts are shown in Table 2, that is, S ranges from: 0, 1, 2, … , 25, 50, 100, 200, 300.

Thus, at the start of every period you will have some number $X \geq 10$ tokens available to you. Your decision screen will report this number to you, breaking it down according to:

1) Endowment of tokens this period: 10

2) Tokens saved from the last period: S

3) Interest earned on savings: S ×.05

The total tokens you have available to convert into money or save in the current period will be the sum of these three numbers.

Type the number of tokens you wish to convert into money (up to four decimal places) in the blue input box on your decision screen for each period. Then click the red Submit button to confirm your choice. You can change your mind anytime prior to clicking the Submit button.

Once the first 25-period sequence has been completed, you will begin playing a second, 25-period sequence. The rules for this second 25-period sequence are exactly the same as those for the first sequence. You will continue to receive an endowment of 10 tokens per period in this second sequence and will make token conversion decisions each period just as in the first sequence.

Information

Following the first period of a sequence and after every period thereafter, you will be reminded of your initial token balance and your token conversion decision for the period. You will also see the average number of tokens converted into money each period by all 10 players in today's session (including you). This group average number of tokens converted is for your information only and does not affect your payoff in any way. Finally, you will also see the number of tokens you have saved, your money earnings for the period and your cumulative money earnings for the sequence. Please record these six pieces of information on your record sheets under the appropriate headings. When you have recorded this information press the Continue button. For your convenience, a history of your prior period decisions will be maintained for you at the bottom of the first decision screen.

Earnings

After the second 25-period sequence has been completed, the computer program will randomly select *one* of the two 25-period sequences that you played. Both sequences have an equal chance of being chosen. You will be paid your cumulative dollar earnings from the one chosen sequence. In addition you will also receive $5 for participating in today's session.

Note: Your earnings in today's session depend only on your own decisions and are not affected by the decisions of any other player.

Questions?

Now is the time for questions. If you have a question, please raise your hand and the experimenter will answer your question in private

Quiz

Before continuing on to the experiment, we ask that you complete the following quiz. In answering these questions, feel free to consult the instructions and tables. Your performance on this quiz does not affect your payoff in any way. Write or circle your answers to the quiz questions where prompted. Do not put your name on this quiz. If any questions are answered incorrectly, we will go over the relevant part of the instructions again.

1. You will participate in ______ sequences. Each sequence consists of _____ periods.
2. You will be endowed with _____ tokens at the start of each period.
3. Suppose it is period 1. What is the maximum number of tokens you can convert into money this period? _______. What is the minimum number of tokens you can convert into money this period? ______.
4. Suppose you saved 2 tokens in some period t<25. How many tokens will you have available at the start of period t+1, including interest and the number of tokens you get at the start of every period? ______ Now suppose instead that you saved 8 tokens in period t. How many tokens will you have available at the start of period t+1 again including interest and the number of tokens you get at the start of every period? ______.
5. Suppose it is period 25. If you choose to save some of your available tokens in period 25, will they have any future value to you? Circle one Yes No.
6. True or false: Your earnings will depend on your cumulative earnings total from one of the two 25-period sequences you play, but you will not know which sequence will be chosen until the end of the session. Circle one: True False.

TABLE 1	
Tokens Converted, C	**Money Earned, $**
0	0.30
1	0.36
2	0.41
3	0.46
4	0.50
5	0.54
6	0.57
7	0.60
8	0.63
9	0.66
10	0.68
11	0.70
12	0.72
13	0.74
14	0.75
15	0.77
16	0.78
17	0.79
18	0.80
19	0.81
20	0.82
21	0.83
22	0.83
23	0.84
24	0.85
25	0.85
50	0.90
100	0.90
200	0.90
300	0.90

TABLE 2		
Tokens Saved,	**Interest Earned in Tokens**	**Savings+Interest**
0	0	0
1	0.05	1.05
2	0.1	2.1
3	0.15	3.15
4	0.2	4.2
5	0.25	5.25
6	0.3	6.3
7	0.35	7.35
8	0.4	8.4
9	0.45	9.45
10	0.5	10.5
11	0.55	11.55
12	0.6	12.6
13	0.65	13.65
14	0.7	14.7
15	0.75	15.75
16	0.8	16.8
17	0.85	17.85
18	0.9	18.9
19	0.95	19.95
20	1	21
21	1.05	22.05
22	1.1	23.1
23	1.15	24.15
24	1.2	25.2
25	1.25	26.25
50	2.5	52.5
100	5	105
200	10	210
300	15	315

$$Money = .9 - .6e^{-.1C}$$

$$C = Tokens\ Converted$$

$$Interest = .05S$$

$$S = Tokens\ Saved$$

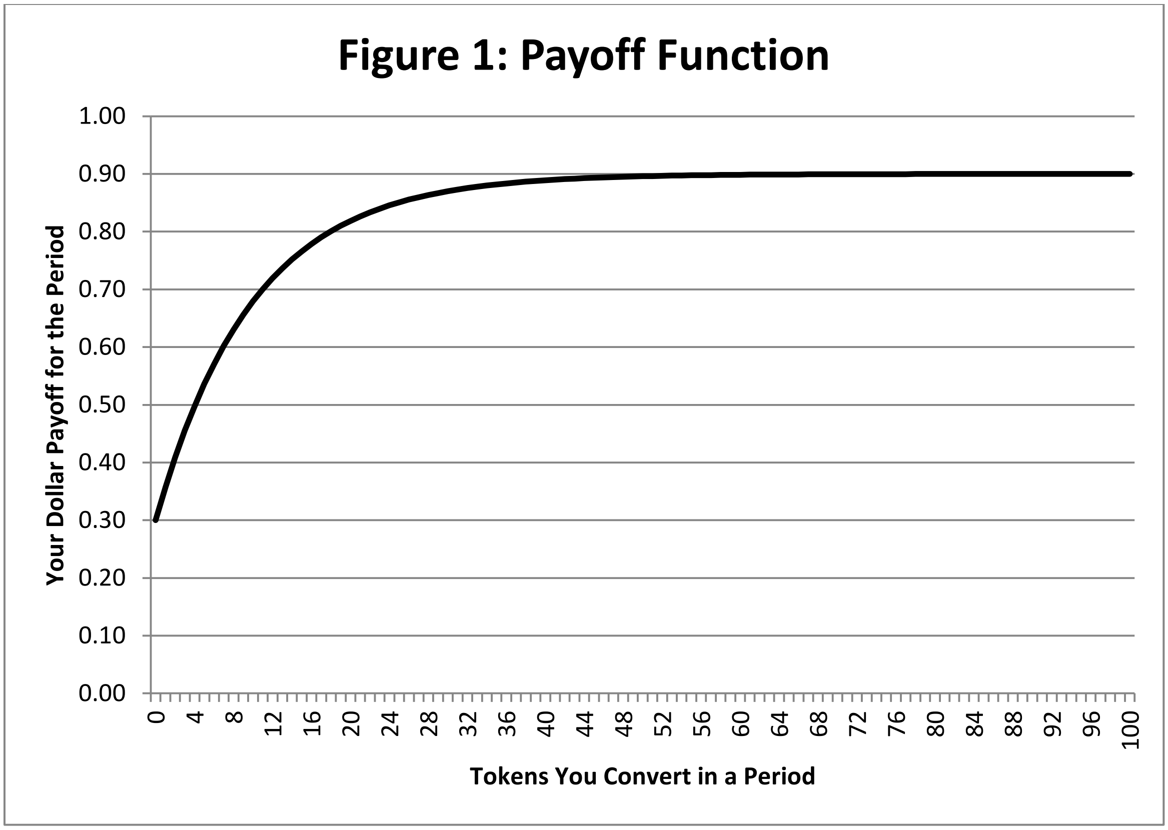


Figure 1: Payoff Function
Your Dollar Payoff for the Period
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72 76 80 84 88 92 96 100
Tokens You Convert in a Period

Record Sheet   Player ID _______   Age ______ Sex (Circle)   F   M

Sequence	Period	Initial Tokens you had at the Start of the Period	Number of Tokens You Converted this Period	Group Average Number of Tokens Converted	Number of Tokens You Saved this Period	Dollar value of your Tokens Converted this Period	Cumulative Dollar Payoff from all rounds of this Sequence
1	1	10					
1	2						
1	3						
1	4						
1	5						
1	6						
1	7						
1	8						
1	9						
1	10						
1	11						
1	12						
1	13						
1	14						
1	15						
1	16						
1	17						
1	18						
1	19						
1	20						
1	21						
1	22						
1	23						
1	24						
1	25						

Instructions [Treatment 3]

Overview

Welcome to this experiment in the economics of decision-making. Please read these instructions carefully as they explain how you earn money from the decisions you make in today's session. There is no talking for the duration of this session. If you have a question, please raise your hand and your question will be answered in private.

Today's session consists of two "sequences". Both sequences consist of 25 "periods" of decision-making. At the start of each period you have a certain number of tokens available to you: this number will be shown to you on your computer screen. After viewing this number, you must decide how many of these tokens you wish to convert into money. You can convert any number of tokens from 0 on up to the maximum number of tokens you have available at the start of each period, and you can choose to convert fractions of tokens up to four decimal places. If the 25^{th} period has not yet been reached, the tokens that you do not convert into money each period will be saved for your use in the next period, and these savings will earn interest in the form of additional tokens available to you next period as explained in more detail below. In the 25^{th} period, any tokens you do not convert into money will become worthless.

Please look at the payoff table, labelled Table 1. This table shows you various amounts of money that you can earn from converting tokens each period. Notice several things. First, only some token amounts that you may wish to convert into money are shown in Table 1, that is, amounts are in increments 0, 1, 2, … , 25, 50, 100, 200, 300. As noted above, you may convert any number of tokens into money in amounts up to four decimal places from 0 on up to and including the maximum number of tokens you have available at the start of each period. Second, the amount of money you earn depends on both the number of tokens *you* choose to convert in each period (vertical axis of Table 1) *and* on the *average* number of tokens converted by all 10 participants (including you) in the previous period (horizontal axis of Table 1). For example, if the average number of tokens converted last period was 8 and this period you choose to convert 5 tokens, then your money earnings are $0.36 for this period. For another example, if the average number of tokens converted last period was 5 and this period you choose to convert 8 tokens then your money earnings are $0.55 for this period. Third, the average number of tokens converted by all 10 participants last period will be reported to you prior to your making a token conversion decision this period. For the first period, the average number of tokens converted last period is set to 0. The formula for how converting tokens earns you money is given at the bottom of Table 1. Figure 1 illustrates this formula graphically, showing how tokens convert into money over a more continuous range of tokens converted by you this period and the prior period group average. Fourth, notice that the more tokens you convert in any period, the greater is the money you earn in that period, but the less saved tokens you have available for conversion in future periods; saved tokens earn interest in terms of more tokens next period as detailed below. Notice also that if the number of tokens you convert in a period is substantially below last period's group average you can earn negative payoffs for the period. You will see the group average number of tokens converted last period before making your token decision for this period. Keep in mind also that your token conversion decision this period affects the average number of tokens converted for the period which impacts on all participants' payoffs next period. Finally, notice that the amounts of money you earn from converting tokens is proportionally *diminishing*; for any given group average number of tokens converted last period, the difference in your earnings from converting 6 rather than 5 tokens is larger than the difference in your earnings from converting 16 rather than 15 tokens.

Specific Instructions

At the start of all 25 periods in a sequence you will be awarded 10 tokens. In addition, in periods 2,…25, you may have additional tokens, depending on whether you have saved any tokens from prior periods; in that case, you will also receive interest on those savings, paid to you in additional tokens. Specifically, you will earn an interest rate of 5 percent, paid to you in additional tokens at the start of the next period. Thus, if in this period you saved $S>0$ tokens then at the start of the next period you would have $S + S \times .05$, equivalently $(1.05)\times S$ tokens available to you in addition to the 10 tokens you receive at the start of every period. Table 2 shows how token savings amounts S in this period convert into token amounts of $(1.05)\times S$ in the next period. As in Table 1, only some token savings amounts and interest earnings on those amounts are shown in Table 2, that is, S ranges from: 0, 1, 2, … , 25, 50, 100, 200, 300.

Thus, at the start of every period you will have some number $X\geq 10$ tokens available to you. Your decision screen will report this number to you, breaking it down according to:

1) Endowment of tokens this period: 10

2) Tokens saved from the last period: S

3) Interest earned on savings: $S \times .05$

The total tokens you have available to convert into money or save in the current period will be the sum of these three numbers. You will also want to consider the average number of tokens converted in the previous period, which will be reported to you on your computer screens *before* you have to make a token conversion decision. For the first period, this average number is set equal to 0.

Type the number of tokens you wish to convert into money (up to four decimal places) in the blue input box on your decision screen for each period. Then click the Submit button to confirm your choice. You can change your mind anytime prior to clicking the Submit button.

Once the first 25-period sequence has been completed, you will begin playing a second, 25-period sequence. The rules for this second 25-period sequence are exactly the same as those for the first sequence. You will continue to receive an endowment of 10 tokens per period in this second sequence and will make token conversion decisions each period just as in the first sequence.

Information

Following the first period of a sequence and after every period thereafter, you will be reminded of your initial token balance and your token conversion decision for the period. You will also see the average number of tokens converted into money each period by all 10 players in today's session (including you). The group average number of tokens converted *this* period matters for your payoff *next* period, as explained above. Finally, you will also see the number of tokens you have saved, your money earnings for the period and your cumulative money earnings for the sequence. Please record these six pieces of information on your record sheets under the appropriate headings. You can also record the group average number of tokens converted this period in the second column of the next period of your record sheet under the heading "Average Number of Tokens Converted Last Period." When you have recorded all of this information press the Continue button. For your convenience, a history of your prior period decisions will be maintained for you at the bottom of the first decision screen.

Earnings

After the second 25-period sequence has been completed, the computer program will randomly select *one* of the two 25-period sequences that you played. Both sequences have an equal chance of being chosen. You will be paid your cumulative dollar earnings from the one chosen sequence. In addition you will also receive $5 for participating in today's session.

Questions?

Now is the time for questions. If you have a question, please raise your hand and the experimenter will answer your question in private.

Quiz

Before continuing on to the experiment, we ask that you complete the following quiz. In answering these questions, feel free to consult the instructions and tables. Your performance on this quiz does not affect your payoff in any way. Write or circle your answers to the quiz questions where prompted. Do not put your name on this quiz. If any questions are answered incorrectly, we will go over the relevant part of the instructions again.

1. You will participate in ______ sequences. Each sequence consists of _____ periods.
2. You will be endowed with _____ tokens at the start of each period.
3. Suppose it is period 1. What is the maximum number of tokens you can convert into money this period? _______ What is the minimum number of tokens you can convert into money this period? _______
4. Suppose you saved 2 tokens in some period t<25. How many tokens will you have available at the start of period t+1, including interest and the number of tokens you get at the start of every period? _______
5. Suppose instead that you saved 8 tokens in some period t<25. How many tokens will you have available at the start of period t+1 again including interest and the number of tokens you get at the start of every period? _______
6. Suppose it is period 25. If you choose to save some of your available tokens in period 25, will they have any future value to you? Circle one: Yes No.
7. Suppose the group average contribution last period was 7 tokens. If you convert 6 tokens this period, what is your payoff for the period? ________ If instead you convert 9 tokens what is your payoff for the period? ________ If you contribute 9 rather than 6 tokens this period how will your choice affect the average contribution that is used to determine payoffs in the next period (assuming the current period t<25)? The average contribution will be (circle one:) higher lower
8. True or false: Your earnings will depend on your cumulative earnings total from one of the two 25-period sequences you play, but you will not know which sequence will be chosen until the end of the session. Circle one: True False.

TABLE 1: Money Payoffs in Dollars ($)

	Average Number of Tokens Converted Last Period →																									
Tokens You Convert This Period ↓	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
0	0.30	0.27	0.24	0.20	0.17	0.13	0.09	0.05	0.00	-0.04	-0.09	-0.14	-0.19	-0.25	-0.31	-0.37	-0.44	-0.50	-0.58	-0.65	-0.73	-0.81	-0.90	-0.99	-1.09	-1.19
1	0.36	0.33	0.30	0.27	0.24	0.20	0.17	0.13	0.09	0.05	0.00	-0.04	-0.09	-0.14	-0.19	-0.25	-0.31	-0.37	-0.44	-0.50	-0.58	-0.65	-0.73	-0.81	-0.90	-0.99
2	0.41	0.38	0.36	0.33	0.30	0.27	0.24	0.20	0.17	0.13	0.09	0.05	0.00	-0.04	-0.09	-0.14	-0.19	-0.25	-0.31	-0.37	-0.44	-0.50	-0.58	-0.65	-0.73	-0.81
3	0.46	0.43	0.41	0.38	0.36	0.33	0.30	0.27	0.24	0.20	0.17	0.13	0.09	0.05	0.00	-0.04	-0.09	-0.14	-0.19	-0.25	-0.31	-0.37	-0.44	-0.50	-0.58	-0.65
4	0.50	0.48	0.46	0.43	0.41	0.38	0.36	0.33	0.30	0.27	0.24	0.20	0.17	0.13	0.09	0.05	0.00	-0.04	-0.09	-0.14	-0.19	-0.25	-0.31	-0.37	-0.44	-0.50
5	0.54	0.52	0.50	0.48	0.46	0.43	0.41	0.38	0.36	0.33	0.30	0.27	0.24	0.20	0.17	0.13	0.09	0.05	0.00	-0.04	-0.09	-0.14	-0.19	-0.25	-0.31	-0.37
6	0.57	0.55	0.54	0.52	0.50	0.48	0.46	0.43	0.41	0.38	0.36	0.33	0.30	0.27	0.24	0.20	0.17	0.13	0.09	0.05	0.00	-0.04	-0.09	-0.14	-0.19	-0.25
7	0.60	0.59	0.57	0.55	0.54	0.52	0.50	0.48	0.46	0.43	0.41	0.38	0.36	0.33	0.30	0.27	0.24	0.20	0.17	0.13	0.09	0.05	0.00	-0.04	-0.09	-0.14
8	0.63	0.62	0.60	0.59	0.57	0.55	0.54	0.52	0.50	0.48	0.46	0.43	0.41	0.38	0.36	0.33	0.30	0.27	0.24	0.20	0.17	0.13	0.09	0.05	0.00	-0.04
9	0.66	0.64	0.63	0.62	0.60	0.59	0.57	0.55	0.54	0.52	0.50	0.48	0.46	0.43	0.41	0.38	0.36	0.33	0.30	0.27	0.24	0.20	0.17	0.13	0.09	0.05
10	0.68	0.67	0.66	0.64	0.63	0.62	0.60	0.59	0.57	0.55	0.54	0.52	0.50	0.48	0.46	0.43	0.41	0.38	0.36	0.33	0.30	0.27	0.24	0.20	0.17	0.13
11	0.70	0.69	0.68	0.67	0.66	0.64	0.63	0.62	0.60	0.59	0.57	0.55	0.54	0.52	0.50	0.48	0.46	0.43	0.41	0.38	0.36	0.33	0.30	0.27	0.24	0.20
12	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.64	0.63	0.62	0.60	0.59	0.57	0.55	0.54	0.52	0.50	0.48	0.46	0.43	0.41	0.38	0.36	0.33	0.30	0.27
13	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.64	0.63	0.62	0.60	0.59	0.57	0.55	0.54	0.52	0.50	0.48	0.46	0.43	0.41	0.38	0.36	0.33
14	0.75	0.74	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.64	0.63	0.62	0.60	0.59	0.57	0.55	0.54	0.52	0.50	0.48	0.46	0.43	0.41	0.38
15	0.77	0.76	0.75	0.74	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.64	0.63	0.62	0.60	0.59	0.57	0.55	0.54	0.52	0.50	0.48	0.46	0.43
16	0.78	0.77	0.77	0.76	0.75	0.74	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.64	0.63	0.62	0.60	0.59	0.57	0.55	0.54	0.52	0.50	0.48
17	0.79	0.78	0.78	0.77	0.77	0.76	0.75	0.74	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.64	0.63	0.62	0.60	0.59	0.57	0.55	0.54	0.52
18	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.75	0.74	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.64	0.63	0.62	0.60	0.59	0.57	0.55
19	0.81	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.75	0.74	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.64	0.63	0.62	0.60	0.59
20	0.82	0.81	0.81	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.75	0.74	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.64	0.63	0.62
21	0.83	0.82	0.82	0.81	0.81	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.75	0.74	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.64
22	0.83	0.83	0.83	0.82	0.82	0.81	0.81	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.75	0.74	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67
23	0.84	0.84	0.83	0.83	0.83	0.82	0.82	0.81	0.81	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.75	0.74	0.74	0.73	0.72	0.71	0.70	0.69
24	0.85	0.84	0.84	0.84	0.83	0.83	0.83	0.82	0.82	0.81	0.81	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.75	0.74	0.74	0.73	0.72	0.71
25	0.85	0.85	0.85	0.84	0.84	0.84	0.83	0.83	0.83	0.82	0.82	0.81	0.81	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.75	0.74	0.74	0.73
50	0.90	0.90	0.90	0.90	0.90	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
100	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
200	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
300	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

$$\text{Money} = .9 - .6e^{-.1[C(t) - .5AC(t-1)]}$$

$C(t)$ = Your conversion of tokens in period t.

$AC(t-1)$ = Average conversion of tokens in period t-1.

Figure 1: Payoff Function

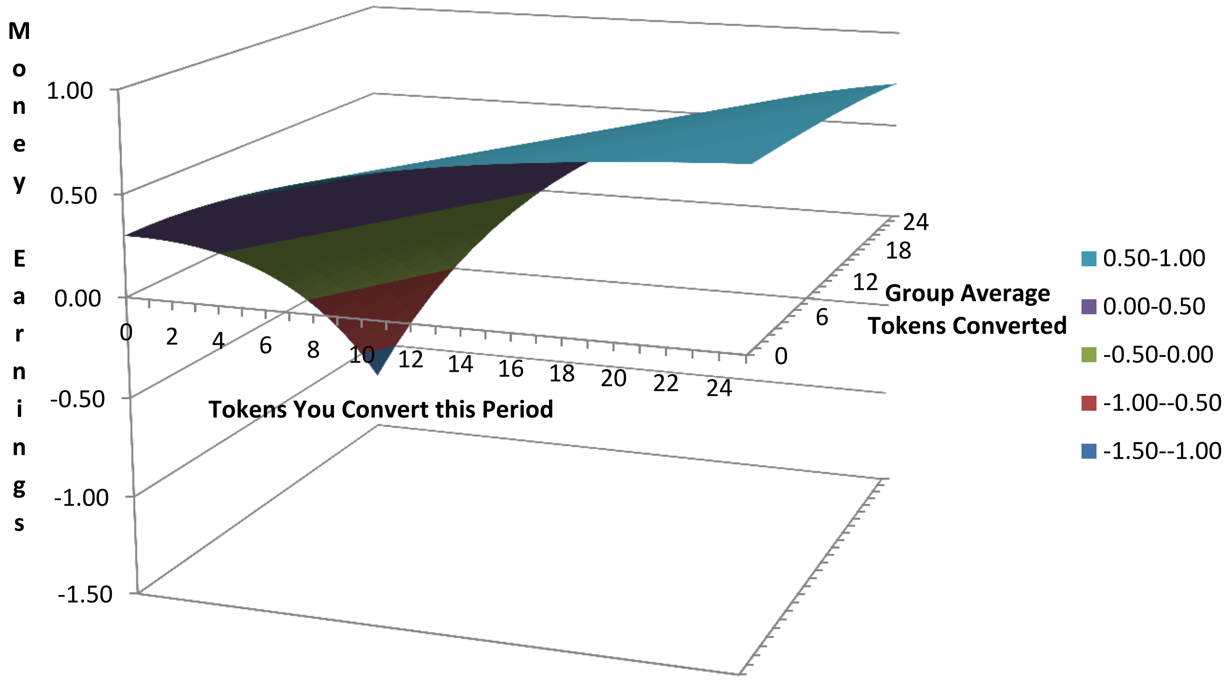


TABLE 2: Savings and Interest		
Tokens Saved,	**Interest Earned in Tokens**	**Savings+Interest**
0	0	0
1	0.05	1.05
2	0.1	2.1
3	0.15	3.15
4	0.2	4.2
5	0.25	5.25
6	0.3	6.3
7	0.35	7.35
8	0.4	8.4
9	0.45	9.45
10	0.5	10.5
11	0.55	11.55
12	0.6	12.6
13	0.65	13.65
14	0.7	14.7
15	0.75	15.75
16	0.8	16.8
17	0.85	17.85
18	0.9	18.9
19	0.95	19.95
20	1	21
21	1.05	22.05
22	1.1	23.1
23	1.15	24.15
24	1.2	25.2
25	1.25	26.25
50	2.5	52.5
100	5	105
200	10	210
300	15	315

$$Interest = .05S \qquad S = Tokens\ Saved$$

Record Sheet Player ID ______ Age _____ Sex (Circle) F M

Sequence	Period	Initial Tokens you had at the Start of the Period	Group Average Number of Tokens Converted Last Period	Number of Tokens You Converted this Period	Number of Tokens You Saved this Period	Group Average Number of Tokens Converted this Period (you can write this number again in column 4 for next period).	Dollar value of your Tokens Converted this Period	Cumulative Dollar Payoff from all Periods of this Sequence
1	1	10	0					
1	2							
1	3							
1	4							
1	5							
1	6							
1	7							
1	8							
1	9							
1	10							
1	11							
1	12							
1	13							
1	14							
1	15							
1	16							
1	17							
1	18							
1	19							
1	20							
1	21							
1	22							
1	23							
1	24							
1	25							

Record Sheet Player ID ______ Age _____ Sex (Circle) F M

Sequence	Period	Initial Tokens you had at the Start of the Period	Group Average Number of Tokens Converted Last Period	Number of Tokens You Converted this Period	Number of Tokens You Saved this Period	Group Average Number of Tokens Converted this Period – write this number again in column 4 for next period.	Dollar value of your Tokens Converted this Period	Cumulative Dollar Payoff from all Periods of this Sequence
2	1	10	0					
2	2							
2	3							
2	4							
2	5							
2	6							
2	7							
2	8							
2	9							
2	10							
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2	18							
2	19							
2	20							
2	21							
2	22							
2	23							
2	24							
2	25							

Record Sheet   Player ID _______   Age ______ Sex (Circle)   F   M

Sequence	Period	Initial Tokens you had at the Start of the Period	Number of Tokens You Converted this Period	Group Average Number of Tokens Converted	Number of Tokens You Saved this Period	Dollar value of your Tokens Converted this Period	Cumulative Dollar Payoff from all rounds of this Sequence
2	1	10					
2	2						
2	3						
2	4						
2	5						
2	6						
2	7						
2	8						
2	9						
2	10						
2	11						
2	12						
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2	22						
2	23						
2	24						
2	25						