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Effects of Retirement and Lifetime Earnings Profile on Health Investment

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Comments

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Abstract

We report the results of experiments where in each period of her lifetime the subject must choose how to allocate real earned income between health investment and life enjoyment in each period of a nine-period life in order to maximize aggregate life enjoyment. The key dynamic optimization challenge of the experiment to subjects derives from the fact that investments in health affect future income, but detract from current consumption. Our experimental results show that subjects were successful at reproducing the qualitative predictions of the theoretical model, investing more in health in the absence of retirement and with increasing income profiles. However, we did observe a systematic bias in health investments, being less than optimal in early periods and greater than optimal in late periods of life. We also found a significant effect due to social groupings. These results highlight the potential of lab experiments as a method to study health decisions and understand their determinants.

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1. Introduction

There are strong and cross-nationally robust associations among educational, income, health, and mortality (e. g. Kondo 2012, Rogers et al. 2010). Education is perhaps the strongest single demographic predictor of mortality differentials (e.g. Hummer and Hernandez 2013; Meara et al 2008), and socioeconomic status in childhood predicts both income and health in adulthood. The economic implications of these inequalities are very large. For example, LaVeist et al. (2009) studied differences in health care cost across different American minorities. African Americans, Hispanics, and Asian Americans had direct medical costs more than 30 percent greater than those faced by non-minorities, amounting to more than a $230 billion premium over a four-year period. Furthermore, after adding the indirect costs of these inequities over the same period, the tab came to $1.24 trillion.

In spite of the robustness of these empirical findings, there still exists a great deal of debate about the causal pathways underlying those relationships. Several different mechanism have been proposed to explain the causal link between education and health, including psychological factors (such as health-related knowledge, stress, and locus of control), behavioral factors (such as cigarette smoking, exercise, and diet), and access to health care services (Adler et al. 1994, McIntyre 1997, Cutler and Lleras-Muney 2006, 2010, Cutler, Angus and Lleras-Muney 2008). A principal problem of identification derives from the likely bi-directional causality that unfolds over the life course. For example, health early in life can impact educational attainment and future income. Selection biases, resulting from unobserved heterogeneities in health, could lead to overestimates of the causal links between education and health.

A similar set of problems plague our understanding of the impacts of retirement on health and mortality, a topic of increasing interest as the aging of the population is increasing the costs of public support systems. Health and many other potentially unobserved heterogeneities can influence the decision to retire, leading to biased estimates of the impacts of retirement on health and forcing researchers to rely on instrumental variables as analytical tools. For example, those who expect to earn more income and to maintain good health in the later periods of life should be less willing to retire than those whose do not.[1]. It is not surprising therefore that results of the estimating procedures have been mixed. Several studies have suggested that retirement has a positive effect on the retiree's health, justifying the perception that certain individuals should look forward to their retirement. This effect seems to be particularly prevalent when retirement is mandatory: such individuals self-report better health than those who stay working (Coe and Zamarro 2008, Insler 2014). Also, when an early retirement option is available, one study shows those who choose to retire early decrease their mortality rates (Bloemen et al. 2013). In contrast, several studies have observed negative relationships between retirement and health. Dave et al. 2008, studied the effect of retirement on indicators of physical and functional limitations, illness conditions, and depression. They found that complete retirement lead to increases in problems associated with mobility and daily activities, illnesses, and decline in mental health. Similar, outcomes have been found in Europe

[1] The relationship between retirement and health suffers from problems of endogeneity (Dwyer, D. S., & Mitchell, O. S. (1999). Most findings analyze naturally occurring data that include self-reported health status, and carry methodological problems similar to those found in the literature studying socio-economic conditions and health..

(Sahlgreen 2012). Furthermore, recent research shows that promoting late retirement can have a positive effect on maintaining an individual's cognitive capabilities (Bonsang et al. 2012).

The goal of this paper is to provide insights into the causal relationships underlying the relationship between education and health over the life course, and the impacts of retirement on health. To overcome the myriad of obfuscations presented in 'incomplete' and self-reported field data, we have implemented a novel health investment decision experiment. We ask individual subjects to make a sequence of temporally related investment choices in health and life enjoyment. We are able to study how these subjects adjust their investment patterns given perfect knowledge of the relationships between health, expected income, and the retirement institution that will prevail at life's end. Though their decisions and outcomes are independent of one and other, the experiment also enables cultural transmission and social interaction by allowing subjects to chat in groups briefly after each of a series of lifetimes has ended, recording every statement and query that is made. One of the advantages of lab experiments is the reliability of data collected: in this experiment a subject always knows with certainty her current health status and the direct consequence of an investment in health, allowing her to make informed health investments and life enjoyment choices. The measures of *health* and *health investment* in the experiment are independent of the cognitive ability to accurately report them, allowing us to identify the precise relationships between health and income and retirement opportunities.

To date, little has been accomplished concerning human ability to solve dynamic programming problems in the lab. Previous experiments on dynamic decision-making have studied how subjects adjust inventories and hire employees in a supply chain scenario (Sterman 1989, Seale and Rapoport 2000). To our knowledge, this is the first laboratory conducted dynamic programming environment that aims to embody a model of health investment. The first goal was to simply examine how well subjects comply with the predictions of a theoretical dynamic programing model of our health investment model. Our second goal was to improve our understanding of the effects that changes in lifetime income profiles have on health investment choices. A third goal was to assess whether there are any systematic behavioral biases in this type of decision making problem and whether there are any effects of cultural transmission, produced by individuals being able to observe the choices of others and being able to 'chat' with them in written communications. And a fourth goal was to establish a reliable platform which could later be used to examine even more complex health decision-making problems such as determining the value of insurance under threat of sudden health 'shocks', and assessing the consequence of social rewards in life enjoyment and health investment.

We employ Grossman's (1972a, 1972b) theoretical framework to study health investment choices. This model treats investment in health as a human-capital investment; health directly affects income through improved productivity but also combines with consumption to produce life enjoyment. The individual's problem consists of maximizing aggregate lifetime utility or enjoyment. To achieve this goal, in each period she must choose how to allocate earned income across health investment and life enjoyment. There are two experimental treatments: A) a life with and without retirement, and B) a flat vs. a tiered income stream. The tiered and flat income streams are designed to capture the effects of different levels of education on the distribution of earnings over the life course, while compensating for pure income effects. In the U.S., for example, those with high school degrees experience higher income than those with Bachelor's degrees until about age 30, at which point those with more education earn more (Baum et al. 2013). This is because income does remains essentially flat with age for those with less education, while it grows with age with increased education.

The model predictions we test are: (1) health investments early in life will have greater marginal impacts on lifetime utility than investments later in life, (2) extending the work life increases optimal investments in health; and (3) compensated shifts in income earning potential from earlier to later in life will increase optimal investments in health (see Kaplan and Robson 2002, and Robson and Kaplan 2003 for this prediction as an extension of the Grossman model). The next section of the paper outlines the theoretical model that structures the experimental design and payoffs to subjects, in detail.

2. The Health Investment Problem: Theory and Experimental Environment

The experiments to be reported were designed with several theoretical underpinnings in mind. Each individual participant worked to earn income and made a sequence of investment decisions in a series of unrelated lifetimes. Each lifetime was comprised of a sequence of 9 periods (t =1, 2,…9) of real earnings activity followed by decision making. Every lifetime ended (the participant died) after nine periods unless the participant's 'health' had degenerated to the point of death before the ninth period had arrived. After each lifetime ended, every participant was reincarnated into his next unrelated lifetime. Learning, which could display itself as strategy evolution across lifetimes, was expected and intended to simulate the accumulation and transmission of cultural wisdom that might accrue in the real world with overlapping generations of participants.

During the first part of each period in each life, participants were required to undertake a real-effort harvesting task in which the participant could earn revenue, R_t, that she could subsequently invest in either life enjoyment (a cash reward) or health preservation for subsequent periods of the current lifetime. The amount of time allowed for the harvesting task during each period (maximum 30 seconds) was directly proportional to the participant's current level of health, H_t, (between 0 and 100), so investment in upgrading health enabled a higher levels of harvesting in future periods. The initial health condition, 85, and the natural degeneration of health across all periods of life (-16, -17, … -23, -24) were preprogrammed and identical for all participants in all lifetimes in all experimental treatments. The health degeneration occurred after harvesting just before investment for the current period began. Never investing in health would result in the participant dying (not being able to continue to harvesting and investing) in period 5.

The harvesting task assigned to participants required vigilance and some manual dexterity but was designed so that most participants could perform at a high enough level that their harvest earnings and optimal investment strategies would be quite comparable. The task involved a sequence of 30 targets that would skirt across a circular harvesting field. Each target had a one of four different harvest values, and each target took two seconds to skirt across the field, after which it disappeared. To harvest the target the participant simply needed to click on the harvesting field while that target was viable. Once a click was made it would take 2 seconds to process the harvested target during which time the participant could harvest no other targets although she could see the unavailable targets as they skirted by. If the participant's current health were at level $H_t \in [0,100]$, then during the first $30x(100- H_t)/100$ seconds of the harvest period she would see targets go by that she was unable to harvest due to her deteriorated health. Similarly, if a target were only partially processed by the end of the previous period, processing would complete at the beginning of the next period adding a small increment to any downtime due to deteriorated health.

There were four different experimental environments dependent on the setting of two treatment variables. The first treatment variable dictated whether the harvest income potential was Flat or Tiered during the nine period lifetime of the participant. The second treatment variable dictated whether the participant was required to harvest during all nine periods of her lifetime (No Retirement) or was given a fixed income in periods 7 through 9 (Retirement) which was equal to 75% of her average harvest income during the first 6 periods of her life: $R_7 = R_8 = R_9 = (R_1+R_2+R_3+R_4+R_5+R_6)/6$.

The table below shows the target values available during the various periods of each income treatment, and the probabilities that each target would be the next to arrive. The optimal harvesting strategy was simply to harvest either the two or three most valuable targets (depending on conditions) whenever one became available and always ignore lower valued targets.[2] If the participant implemented the optimal harvesting policy during

[2] Appendix I illustrates the computation of the optimal harvesting strategy.

any particular harvesting period t, and had a current health level of H_t, then R_t* was her expected optimal harvesting revenue.

Treatment (Periods)	Period Target Vector	Target Probabilities	Expected Income
Flat (1,2…)	{13*, 10*, 8*, 6}	{.22, .29, .31, .18}	R_t* = 94 (H_t/100)
Tier 1 (1,2,3)	{10*, 7*, 4, 3}	{.28, .24, .24, .24}	R_t* = 67 (H_t/100)
Tier 2 (4,5…)	{21*, 17*, 14*, 10}	{.35, .15, .28, .22}	R_t* = 162 (H_t/100)

For any given 30 second period the actual harvest revenue can vary slightly about R_t* even if the optimal harvesting policy is applied, depending upon the random arrival sequence of the various targets. Furthermore, the skill level (hand eye coordination and required vigilance) of any participant in applying the optimal harvesting policy can reduce the expectation of revenue from harvesting. A perfectly skilled harvester who has a particular proportion, H_t/100, of harvesting time available in a given harvesting period because of his current health, collects expected revenues rev_c (H_t/100) where rev_{flat}=94, rev_{tier1}=67, and rev_{tier2}=162 are the revenue rates for the various conditions. Because the revenues collected from harvesting become income available to invest in health and life enjoyment, lesser harvesting skill can have a significant effect on the optimal investment plans for participants of varying skill.

Once the participant finished harvesting in period t, for which effort she had secured harvest revenue, R_t, proportional to current health, she was required to make investment decisions: how much to invest, I_t, in preserving health for future harvesting, how much to invest in life enjoyment, L_t, in order to be paid for her efforts, and how much (if any) to leave uninvested in a bank account, B_t, that would become available for future investments in life enjoyment or health. All participants were endowed with a beginning bank balance,

B_0, of 0, and should end up with a final bank balance, B_9, of 0, if they maximize their total gains from life enjoyment. The budget constraints governing investment in each period were given by:

$$I_t + L_t + B_t = B_{t-1} + R_t \quad \forall\ t=1, 2, \ldots 9$$

The non-linear return functions for investments in health and life enjoyment are given below. They were designed to have diminishing returns to scale, so that the optimal investment pattern across time would display properties similar to a Grossman model. The transition equation in our experimental system relating final health in period t (H_t) to final health in the previous period (H_{t-1}), given an investment (I_t) in preserving health, and a natural degeneration (d_t) of health that occurred during period t, was given by:

$$H_t = Min\ [100, H_{t-1} - \mathrm{d}_t + 30\frac{1 - e^{-.025\mathrm{I_t}}}{1 + e^{-.025\mathrm{I_t}}}]$$

A participant could theoretically regenerate health by up to 30 points in any given period if she had accumulated an infinite amount of harvest returns to invest, but an upper bound was imposed that prevented the state of health from ever exceeding 100. Furthermore, the parameters in the experimental environment were chosen such that the boundary condition, $H_{t+1} = 100$, was never approached under optimal or 'reasonable' decision making. Given the interior solution was always active, the marginal rate of return on health investment each period was given by:

$$\frac{dH_t}{dI_t} = \frac{1.5e^{-.025\mathrm{I_t}}}{1 + 2e^{-.025\mathrm{I_t}} + e^{-.05\mathrm{I_t}}}$$

Note that at $I_{t-1} = 0$, $dH_t/dI_t = 1.5$ and the rate of return on each subsequent resource unit invested in health is independent of initial state of health (H_t) until health reaches 100. Over many periods and lifetimes, this feature allowed participants to become very familiar with the curvature of the function governing diminishing returns on health investment.

The earnings equation relating investment in life enjoyment (L_t) to cash earned (E_t) by the participant in period t was given by:

$$E_t = 250(1 + H_t/100)(1 - e^{-.028L_t})$$

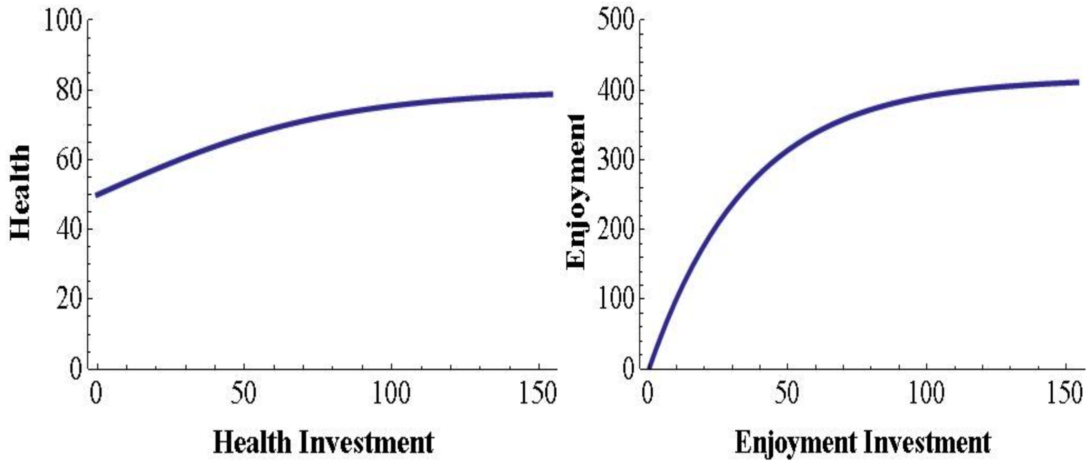
By convention, in any given period t, degradation of health occured after harvesting, then the health investment selected was implemented prior to the life enjoyment investment so that the upgraded state of health would be incorporated into the life enjoyment computation. The marginal rate of return on earnings from the life enjoyment investment made in period t was given by:

$$\frac{\mathrm{dE_t}}{\mathrm{dL_t}} = 7(1 + \mathrm{H_t}/100)(\mathrm{e}^{-.028\mathrm{L_t}})$$

The participants were given graphical representations of the health and life enjoyment investments that made it very clear that both had diminishing returns.[3] The participant's job was to correctly balance investment of harvesting revenue between health and life enjoyment, each period of her lifetime. For example, the graphs below indicate that starting from a current health of 50, the participant could increase next period's health up to 80 by making a large investment. Meanwhile, an investment of 50 could provide the participant with immediate life enjoyment of ~300 which would be translated to cash reward at

[3] The second derivatives are calculated in the Appendix I.

experiment's end. The participant used reciprocating scroll bars on the x-axis of each graph that would not allow her to spend more than the revenue she had accumulated.



In our environments, the shape of the Health investment graph would never alter: the starting point of the Y-axis, current health, would simply adjust from period to period. However the shape of the Enjoyment investment graph would flatten if health deteriorated or get steeper if health improved.

The participant's life enjoyment optimization across her entire life requires her to solve the following dynamic program:

Maximize: $\sum_{t=1,9} E_t = \sum_{t=1,9} \; 250(1 + H_t/100)(1 - \mathrm{e}^{-.028L_t})$

Subject to: $B_{t-1} + R_t = I_t + L_t \quad \forall\, t = 1, \dots 9$

$H_t = H_{t-1} - \mathrm{d}_t + 30\frac{1-e^{-.025\mathrm{I_t}}}{1+e^{-.025\mathrm{t}}} \quad \forall\, t = 1, \dots 9$

$R_t = rev_c(\mathrm{H_t}/100)$ during any active harvest (non-retirement) period

$$R_t = rev_c(H_1+H_2+H_3+H_4+H_5+H_6/100)/6 \text{ during any retirement period}$$

Rev_c is simply a constant that is conditional on the treatment and skill of the harvester. The parameters are set such that rev_{flat}=94, rev_{tier1}=67, and rev_{tier2}=162 are the revenue rates for a perfectly skilled harvester. In the experiments to be reported later, the participants displayed mean harvesting skills that were less than perfect (rev_{flat}=87, rev_{tier1}=61, and rev_{tier2}=151), but with fairly low variance. Because the revenues R_t collected from harvesting become the resources available to invest in health and life enjoyment, lesser harvesting skill can have a significant effect on the optimal investment schedule for participants of varying skill.

Note that H_t can be written as a function of initial health, H_0 and investments I_t in health.

$$H_t = H_0 + \sum_{k=1,t} -d_k + 30\frac{1-e^{-.025\mathrm{I_k}}}{1+e^{-.025\mathrm{I_k}}}$$

Solving the participant's constrained life enjoyment optimization is equivalent to maximizing the aggregate life enjoyment as a function of the sequence of health investments I_i and bank deposits B_t[4]:

$$\sum_{t=1,9} E_t = \sum_{t=1,9} 250(1+\left[H_0 + \sum_{k=1,t} -d_k + 30\frac{1-e^{-.025\mathrm{I_k}}}{1+e^{-.025\mathrm{I_k}}}\right]/100)(1-e^{-.028(B_{t-1}+R_t-I_t)})$$

[4] The parameters in the environments we designed were such that the optimal B_t^* was rarely anything other than 0. This considerably reduced the dimension of the decision making problem faced by participants. On rare occasions, during the move from harvesting to retirement (periods 6 to 7), there was a minor improvement in overall life enjoyment by banking some harvest income to smooth investment in life enjoyment.

This problem is easy to solve numerically for any given period t when H_{t-1}, B_{t-1}, R_t and B_t are known.[5] The initial conditions for health and bank balance were given by $H_0 = 85$ and $B_0 = 0$, the final bank balance B_9 must be zero, and R_t is always a linear function, $rev_i (H_{t-1}/100)$, of previous period's health or (in retirement) the initial 6 periods health. We can either apply non-linear optimization or dynamic programming techniques to find the optimal sequence of health investments, I_t, and the corresponding maximal aggregate life enjoyment $\sum_{i=1,9} E_t$. The optimal Health (H_t) profiles which participants should maintain by making health investments (I_t) that maximize total life enjoyment ($\sum E_t$) for the various treatments discussed earlier are given in the following table:

Treatment		Optimal Health (H_t)								
Income	rev_i	1	2	3	4	5	6	7	8	9
Flat Retire	.87	88	90	89	86	79	65	46	24	0
Flat NoRetire	.87	89	91	92	90	86	78	65	42	18
Tiered Retire	.61/1.51	85	83	78	80	81	76	61	38	14
Tiered NoRetire	.61/1.51	86	84	81	85	88	89	87	81	66

Given that all participants begin their lives in the same state of health (85), the optimal health trajectories in the table above display a few notable patterns. Investing in health early in life is more important in Flat rather than Tiered income treatments, and in Retirement rather than No Retirement treatments. However, investing in health late in life becomes less important in Flat rather than Tiered environments, and in Retirement rather than No Retirement treatments. The table below captures a more quantitative representation of these outcomes and hints at some behavioral difficulties participants

[5] Appendix I provides the example of period 9.

might encounter if their perception of optimal strategies is less than perfect. It shows the marginal rates of return for investments in life enjoyment in each period of life, and implicitly the rate of return on investment in health and banking for current and future enjoyment maximization.[6] It also shows the percentage of income earned (plus banked[7]) that must be devoted to optimal health maintenance in each period of life.

Treatment		Optimal Marginal Rate of Return, % of Income Invested in Health								
Income	rev_i	1	2	3	4	5	6	7	8	9
Flat Retire	.87	9.2, 82	7.8, 76	6.5, 68	5.4, 59	4.2, 48	3.1, 31	2.6, 13	1.9, 5	1.4, 0
Flat NoRetire	.87	10.0, 86	8.6, 80	7.4, 73	6.3, 67	5.3, 59	4.3, 50	3.3, 35	2.5, 0	2.5, 0
Tiered Retire	.61/1.51	11.3, 91	10.0, 83	8.7, 75	3.8, 63	2.9, 56	2.2, 40	2.2, 23	1.6, 0	1.3, 0
Tiered NoRetire	.61/1.51	12.4, 97	11.1, 89	9.9, 83	4.2, 67	3.4, 62	2.6, 56	2.0, 50	1.4, 40	.8, 21

Under all treatment regimes, savvy participants must recognize that between 82% and 97% of earned revenue from harvesting must be spent on health in period 1, and between 76% and 89% in period 2, while the marginal rates of return are 8 to 12 times larger than later in life: that is a skewed strategic requirement to be reckoned with in splitting earned harvest revenues between health and life enjoyment. Late in life (periods 8 and 9) under the first three treatments, participants must let go of their health and spend entirely on life enjoyment, while under the fourth treatment, Tiered No Retirement, subjects maximize earnings by spending significantly by continuing to maintain health.

[6] This is true for all periods except where a boundary condition is met (only in periods 8 and/or 9) and the marginal return on any investment in health is dominated by investment in life enjoyment (L_t) so the optimal investment in health is zero (I_t=0).

[7] There are only 2 periods in the 36 displayed where it behooves subjects to bank some earned revenue for the purpose income smoothing: in period 8 of the Flat No Retirement regime where health will fall precipitously in period 9, and in period 6 of the Tiered Retirement regime where income falls precipitously in period 7, the first period of retirement.

The complete solutions for all decision and state variables for each of the experimental treatments conducted are provided in the Computation Appendix.

3. Statistical Approach

In order to handle the repeated and clustered nature of the experimental design, we employed a mixed fixed and random effects linear model to analyze the data. Each subject made 63 repeated health decisions over seven lives of nine periods each, and subjects were clustered in chat-observation groups. Therefore, the model had to take into account the lack of independence among observations within and among individuals in groups. To do this, the model estimates the fixed effects of life, period, and experimental treatment, while assessing the random effects for chat group and individual.

4. Experimental Results

A total of 276 subjects allocated to 69 chat groups participated in the experiment. In this section, we analyze the choices made during the last seven of the ten lives each experimental subject lived. We found that by lifetime 4 the complexities of the computer interface had been mastered, the degree of harvesting proficiency stabilized, the relationship between health and payoff had been digested, and the probability that any subject would die prematurely due to totally inept harvesting or decision-making had decreased to zero.

We report 63 investment choices for each subject: 7 lifetimes with 9 periods in each life.

We distributed subjects into chat-groups each comprised of four members. Membership of each chat-group remained constant for the entire experiment. Members of each chat-group were free to observe and discuss (or not) each other's performances for 90 seconds at the end of each lifetime. We had 68 subjects (17 chat groups) participate in the Flat Retirement treatment, 64 subjects (16 chat groups) in the Tiered Retirement treatment, 72 (18 chat groups) in both the Flat No Retirement and Tiered No Retirement treatments. Table 1 below presents the results of mixed model regressions with fixed main effects of life, period, and experimental treatment, and fixed interaction effects of period by treatment, and random effects for individual subject and chat group[8]. Dependent variables in these regressions are amount invested in health, health, income, and the proportion of current plus banked income invested in health. The data show strong and significant effects of all fixed effects for all dependent variables (with the exception of life on health investment). Of particular note are the significant interactions of treatment by period. In addition, there were significant random effects at the level of both the chat group and the subject.

[8] Table 2 in Appendix II presents the complete results of mixed random and fixed effects models, run hierarchically. Each dependent variable, Health Investment, Health, Income and Health Investment/Income, was regressed as a function of various experimental design variables: lives, periods, dummy variables using the Flat Retirement treatment as the baseline, and adding interaction terms between the periods and the treatment dummy variables.

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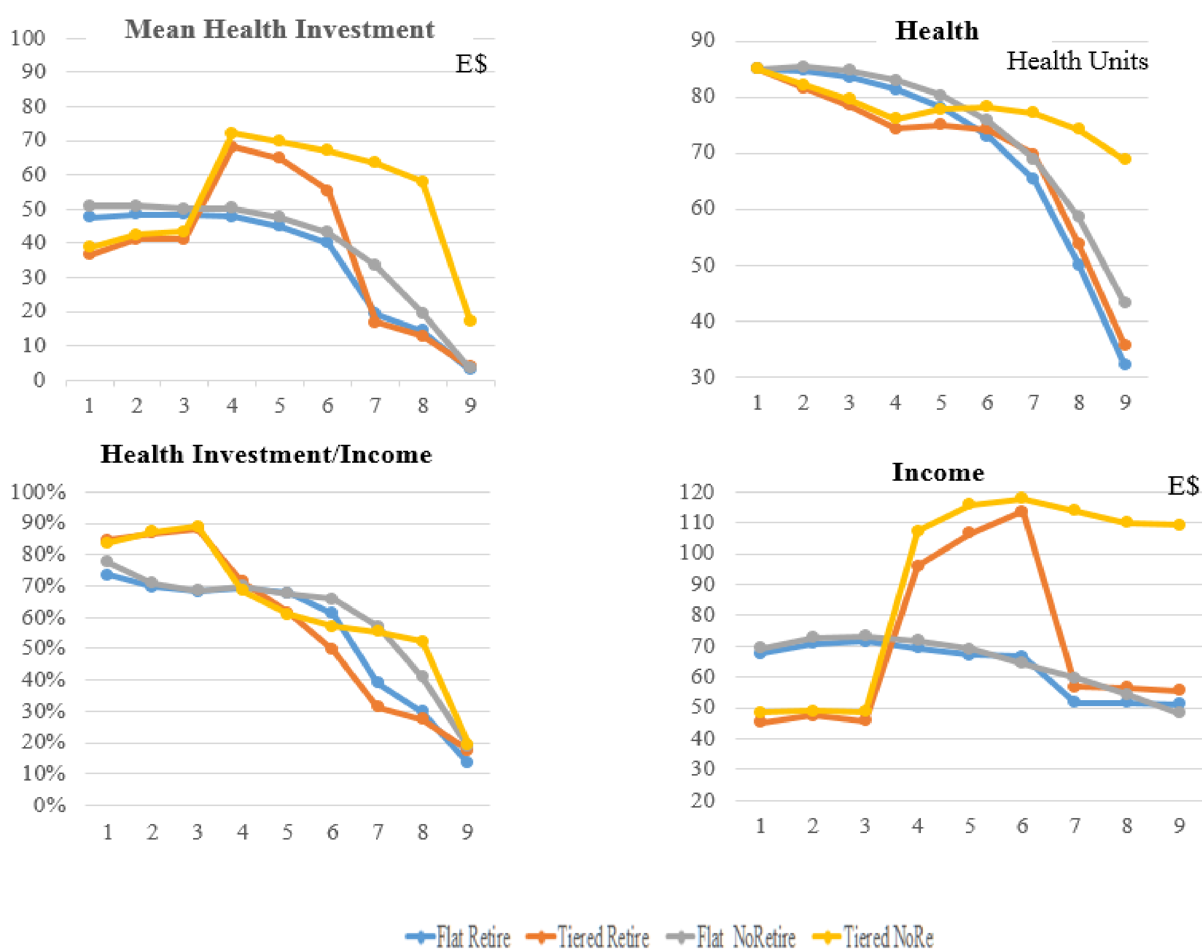
Table 1. Fixed and Random Effects Model Results: F- Table and Variance Decomposition

Independent Variables		Dependent Variables							
		Health Investment		Health		Income		Health Invest /Income	
Fixed effects	**Numerator df**	**F**	**Sig.**	**F**	**Sig.**	**F**	**Sig.**	**F**	**Sig.**
Intercept	1	3308	0.000	1115 4	0.000	7299	0.000	8147	0.000
Life	6	2	0.134	20	0.000	36	0.000	5	0.000
Period	8	2300	0.000	4142	0.000	1945	0.000	2369	0.000
Experimental Treatment	3	31	0.000	7	0.000	62	0.000	9	0.000
Period * Exp. Treat.	24	251	0.000	252	0.000	1171	0.000	67	0.000
Random Effects		**Var.**	**Sig.**	**Var.**	**Sig.**	**Var.**	**Sig.**	**Var.**	**Sig.**
Residual		229	0.000	80	0.000	173	0.000	0.045	0.000
Subject		32	0.000	39	0.000	57	0.000	0.003	0.000
Chat group		26	0.000	23	0.000	34	0.000	0.002	0.000

To aid in the interpretation of these regressions, Figure 1 plots the expected marginal means for each of the dependent variables by treatment and period: a) Health Investment, b) Health, c) Income and d) the ratio of Health Investment over Income Available. These figures show that subjects were quite successful in reproducing the qualitative predictions of the theoretical models for the various treatments.

Figure 1 Health Investment, Health, Income and Health Investment/Income per Treatment



Result 1. Health Investment Choices Support the Qualitative Predictions of the Model

Several findings are displayed in Figure 1. First, we can see that the pattern followed by the mean health investment shown in Figure 1a exhibits a surprising similarity with those depicted by the optimal health-investment strategies described in the theoretical section. The marginal means of health investment for each treatment support the three main implications of our theoretical model. First, health investment decreases across periods of constant income potential, while relative health investment (investment/income) decreases constantly from beginning to end of life. Second, health investment in Tiered treatments, as predicted, start below those observed in Flat treatments for periods 1-3, but then increase above those observed in Flat treatments for periods 4-6. Third, as predicted by the model, the absence of a retirement plan leads individuals to increase the amount they invest in health, not only for the last periods of their lives, but also for all previous periods.

On average, subjects seem to have understood the compounding effects that investing in health has in this dynamic setting under all treatments. They correctly perceive the appropriate tactic required to maximize their lifetime objective given the return on each unit invested in health not only induces a greater ability to enjoy life but produces higher income all subsequent periods. They also implicitly understand that in No Retirement treatments, even greater health is needed to generate income and life enjoyment in periods 7-9. Figures 1a and 1b show increased health investment in periods 4-6, resulting in health for the No Retirement treatments exceeding that for Retirement treatments.

Another indication that subjects seemed to understand the interaction among income, health, and health investment can be observed in the greater levels of health investment, health and income revealed for the Tiered No Retirement treatment in Figures 1a, 1b, and 1d. These subjects took advantage of the greater potential income during the periods 7-9 that this treatment offers. To do this, they needed to arrive at period 7 considerably healthier, and willing to invest a higher proportion of their income in health, than their peers in the other treatments. The yellow line in Figure 1b reveals that they did in fact accomplish this.

Figure 1c, displays that on average subjects recognized the different implications that the optimal health-investment strategies have for each treatment. Although the means of health investment for periods 1-3 of Tiered treatments were below those of Flat treatments, on average those in Tiered treatments were investing a larger proportion of their income than those in Flat treatments during those periods: more evidence to support the claim that subjects perceive the qualitative implications of the model governing the decision environment in which they are imbedded.

Figure 1 and the regression analysis above support the qualitative behavioral predictions of our model. We now proceed to evaluate how mean health investments compare to precise model predictions for all treatments.

Result 2. Early under-investment and late over-investment in health

Figure 2 Marginal Mean and Theoretical Health Investment. a) Flat Retirement b) Flat No Retirement

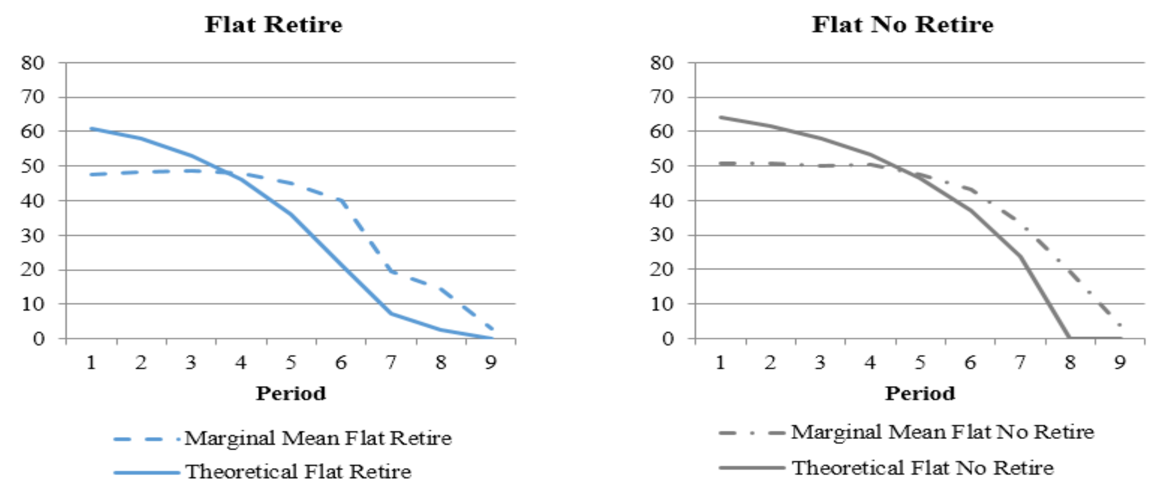
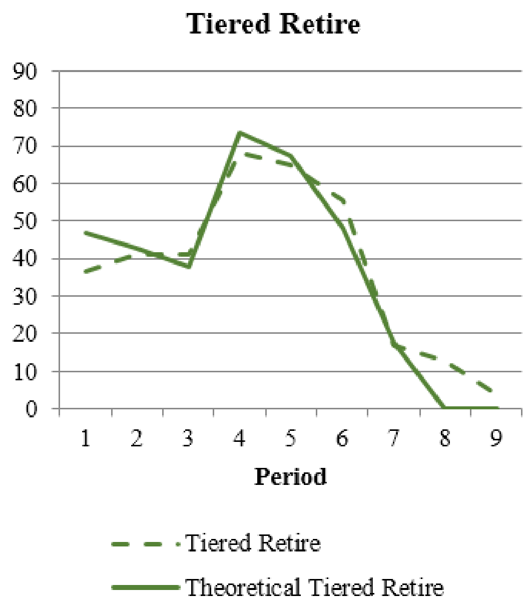


Figure 2 compares optimal behavior derived from the theoretical model with observed behavior for the two flat income profile conditions, with and without retirement respectively. Three facts are easily observed from Figures 2a and 2b. First, qualitatively, the observed and theoretical curves have similar shapes. Second, however, mean health investments for periods 1-3 are below the optimal health investments predicted by the model for both of the Flat treatments. Third, the mean health investments for periods 6-9 are above the optimal health investments predicted by the model for both flat treatments. This suggests that subjects understand that health investments early in life produce greater marginal effects of lifetime enjoyment, as they monotonically decrease investments with each period, but they underestimate, both early and late in life, how much they should bias investments.

Figure 3 Marginal Means and Theoretical Health Investment. a) Retirement b) No Retirement



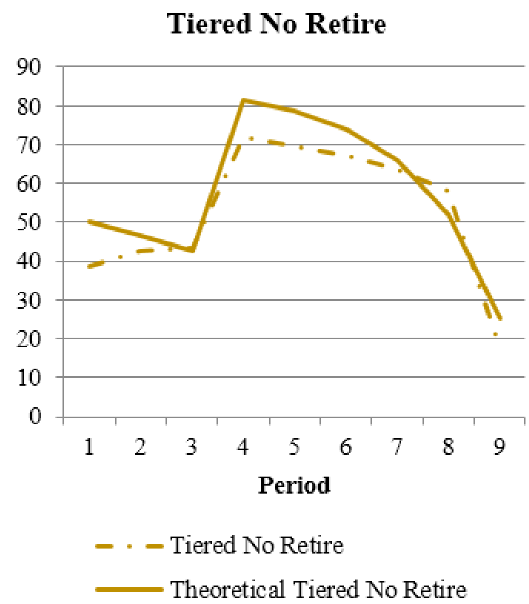


Figure 3 compares observed and optimal investments for the tiered conditions. The match in the shapes of the observed and theoretically predicted curves is striking. Again, however, in both Tiered treatments, with and without Retirement, initial health investments for periods 1 and 2 are below the optimal predicted by the model. Subjects display the same bias in all treatments. In the Tiered Retirement treatment, Figure 3a, significant deviations from the theoretical predictions are for fewer periods than in the Flat Retirement treatment.. Also, we see that although subjects raised their health investment in period 4, when their income opportunities increase, their health investments for periods 4 and 5 fall below the optimal predicted by the model. Finally, consistent with the finding for the Flat Retirement treatment, the mean health investments for periods 6-8-9 are above the optimal investments predicted by the model for Tiered Retirement. In the Tiered No Retirement treatment, Figure 3b, the optimal policy predicts an even greater increase in health investment following the income boost in period 4, but the mean health investment for periods 4, 5 and 6 falls short of predicted model optimal. This observed shortage in the adjustment of health investment appropriate to the corresponding increase in income, suggests that subjects' decisions might be influenced by other considerations. Finally, we note that in the Tiered No Retirement treatment, Figure 3b, mean health investments are very close to optimal for the final periods 7-9 of life.

5. Discussion and Conclusions

These findings support the three main predictions motivating our experimental design. First, consistent with human capital models of health investment (e.g. Grossman 1972a,b, Kaplan and Robson 2009) in which investments have decreasing marginal impacts with age, subjects in all conditions reduced the proportion of their earnings invested in health with each period as life progressed. In the flat income profile, absolute investments in health also decreased with each period. Second, the rising income profile with age was associated with higher average investments in health over the life course and higher health in the last three periods of life. This was true even in the retirement condition, under which health no longer had direct effects on income during those last three periods. Third, retirement had dramatic effects on health investments and as such, on health at each period. For both the tiered and the flat income profiles, retirement not only lowered health in the last three periods of life, but also lowered averaged investments in health in the first six periods of life, compared to the no retirement condition. This reflects subjects' recognition that health in later life depends on investments early in life.

Overall, after the first three lives during which subjects were still learning and performed much worse, subjects, on aggregate, tracked the optimal decision path quite well. This is promising, as determining the optimal path presents a formidable computational task. There is substantial conformity in the shapes of the observed investment profiles by period and the expected optima, based on maximizing earnings from the experiment. In the case of the flat earnings profile, both the optimal and observed investments decrease at an increasing rate with each progressive period. In the case of the tiered profile, both the observed and the optimal curves have lower absolute, but higher relative (to income) investments in periods one to three, followed by higher absolute and lower relative investments in periods 4-6, and then decreasing absolute and relative investments in health in the last three periods. Finally, retirement lowers investments in health at each period, holding tiered vs flat profile constant, for both the observed and optimal expectations. Stated differently, extending the work life increased investments in health in all periods of life.

There were some notable deviations in subjects' behavior from optimal expectations. In all treatments, flat and tiered with and without retirement, observed behavior reveals decreased investment in health during the first three periods of life relative to the optimum. In the flat income profile treatments, with and without retirement, towards the middle of life this trend reverses, and later in life investments in health exceed the optimum. Compared to observed behavior, optimal investment for the flat profiles would begin higher, but decrease more rapidly as life progressed. In the tiered retirement condition, subjects appear to more accurately invest in health in the later periods of life, while in the tiered no-retirement condition, they appear to under-invest in health in the later periods of life. This latter condition is one where subjects could earn substantially more income because of late life harvesting opportunities, but that required maintaining late life health without deterioration which became more and more costly.

There are several possible explanations for these deviations in observed behavior vis-à-vis optimal performance. One set of explanations derives from the difficulty of the task. Given the inherent complexity of solving a nine period dynamic optimization problem with nonlinear constraints and a nonlinear utility function, it is surprising how well subjects did on the aggregate. Significant health investments in periods one through three were critical to maximizing life enjoyment. In all conditions, it is possible that subjects did not correctly perceive the magnitudes of the decreasing marginal utility of health investments as periods progressed. It is also possible that they simply used some heuristic or rule of thumb (perhaps linear), by which they adjusted between period changes in investments.

Another set of explanations might involve time discounting or impatience in the subjects' performance (Lindahl et al. 2013). This would explain under investment in the flat earnings condition early in life, but would not explain over-investment late in life. Alternatively, it might reflect a desire for both consumption and health smoothing over the life course. Early in life, this would mean greater investment in life enjoyment and less in health, relative to the optimum. Late in life, it would mean greater investment in health and less in life enjoyment, relative to the optimum; just as we observe. This would imply that the subjects, at least in part, did internalize the experimental states and rewards, as life enjoyment and health, respectively.

Finally, it is interesting to note that there were significant random effects, both at the individual and chat-group levels. After taking into account the treatment effects, individual- and group-level random effects accounted for close to 10% of the residual variance, respectively. This means that some people consistently invested more in health than others. Interestingly, even though individuals were randomly assigned to four person chat-mutual observation groups, and even though their individual earnings were completely independent of each other, groups differed significantly in average behaviors. This suggests that individuals influenced each others' behaviors, either through chat or observation. A subsequent paper will examine these group and learning effects.

To conclude, it is important to assess the value and validity of this experimental approach to understanding health behavior and health outcomes. To our knowledge, this is the first set of experiments designed to investigate investments in health in a dynamic decision process embedded in work environment with direct impacts of health and retirement on earnings. The multi-life design with observation-chat allows subjects to learn, and to influence one another, simulating cultural evolution.

One way to assess the validity of the approach is to compare our findings to observed behavior in the real world. One study (Duggan et al. 2008), using data from the Social Security Administration Continuous Work History Sample, examined the relationship between earnings profiles and health found very similar results. Not only did lifetime income positively associate with health status, a *rising* trend in income over life was associated was later ages at death than a flat income profile, even after holding permanent income constant.

The results on the impacts of retirement on health, derived from empirical studies at the national level, have been quite mixed. There are serious identification problems, due to the fact that health has well known effects on the likelihood of retiring. Some recent econometric analyses have found strong negative impacts of retirement on health, disability and mortality (e.g. Dave et al. 2006; Sahlgren 2012, 2013; Kelly, Dave, and Spasojevic 2008; Behncke 2009), while others have found positive impacts (Bound and Waidman 2007, Bloemen et al. 2013, Insler 2014). Part of the differences may be due to whether retirement is voluntary or imposed by policy, with the negative effects being greater when retirement is involuntarily imposed (Kelly, Dave, and Spasojevic 2008). It also appears that there may be short term positive effects of retirement on health for a few years, but long term negative effects (Sahlgren 2013). It also appears that there are significant individual differences in whether retirement improves or hinders health. It is likely that there are opposing effects of retirement, due to increased leisure time, reduced stress, but also reduced social interaction and economic motivation to stay healthy. The value of the experimental approach is that each of these factors can be manipulated independently.

At the current time, there are many important policy decisions that are undergoing debate. Changes in retirement age and incentives to remain in the work force are being debated throughout the developed and developing worlds. Links between health care coverage and employment are undergoing change with new policies in the U.S., affecting incentives to retire. These institutional and policy debates will result in very expensive social engineering experiments. Laboratory-based experiments, in advance of policy decisions, have two main advantages in the health arena. First, they are much less expensive and time consuming to get results. Second, policy decisions are likely to have multiple effects, which may be opposing; laboratory experiments allow for manipulation of each of those effects, one at a time. Since health changes dynamically throughout life, and decisions which affect it have consequences for the future, multi-period experiments with opportunities to learn seem well suited to explore this complex domain.

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Appendix 1: Computation

The transition equation relating health at the end of period t to health at the end of period t-1 is given by:

$$H_t = Min\,[100, H_{t-1} - \mathrm{d}_t + 30\frac{1 - e^{-.025\mathrm{I_t}}}{1 + e^{-.025\mathrm{I_t}}}]$$

The first derivative of health w.r.t. investment in health is given by:

$$\frac{dH_t}{dI_t} = 30 \cdot .025e^{-.025\mathrm{I_t}}\left[\frac{1}{1 + e^{-.025\mathrm{I_t}}} + \frac{(1 - e^{-.025\mathrm{I_t}})}{(1 + e^{-.025\mathrm{I_t}})^2}\right]$$

or,

$$\frac{dH_t}{dI_t} = \frac{1.5e^{-.025\mathrm{I_t}}}{1 + 2e^{-.025\mathrm{I_t}} + e^{-.05\mathrm{I_t}}}$$

The second derivative of health w.r.t. investment in health is given by:

$$\frac{d^2H_t}{dI_t^{\,2}} = 1.5\left[\frac{-.025e^{-.025\mathrm{I_t}}}{1 + 2e^{-.025\mathrm{I_t}} + e^{-.05\mathrm{I_t}}} + \frac{.05(e^{-.025\mathrm{I_t}})(e^{-.025\mathrm{I_t}} + e^{-.05\mathrm{I_t}})}{(1 + 2e^{-.025\mathrm{I_t}} + e^{-.05\mathrm{I_t}})^2}\right]$$

or,

$$\frac{d^2H_t}{dI_t^{\,2}} = 1.5\left[\frac{-.025e^{-.025\mathrm{I_t}} - .05e^{-.05\mathrm{I_t}} - .025e^{-.075\mathrm{I_t}}}{(1 + 2e^{-.025\mathrm{I_t}} + e^{-.05\mathrm{I_t}})^2} + \frac{.05(e^{-.05\mathrm{I_t}} + e^{-.075\mathrm{I_t}})}{(1 + 2e^{-.025\mathrm{I_t}} + e^{-.05\mathrm{I_t}})^2}\right]$$

$$\frac{d^2H_t}{dI_t^{\,2}} = -.025\left[\frac{e^{-.025\mathrm{I_t}} - e^{-.075\mathrm{I_t}}}{(1 + 2e^{-.025\mathrm{I_t}} + e^{-.05\mathrm{I_t}})^2}\right]$$

The consumption function which gives subject earnings, E_t, from life enjoyment in period t as a function of the portion of harvest and retirement returns that are invested in life enjoyment, L_t, is given by:

$$E_t = 250(1 + H_t/100)(1 - e^{-.028L_t})$$

The first derivative of life enjoyment w.r.t. investment in life enjoyment is given by:

$$\frac{dE_t}{dL_t} = 7(1 + H_t/100)(e^{-.028L_t})$$

The second derivative of life enjoyment w.r.t. investment in life enjoyment is given by:

$$\frac{d^2E_t}{dL_t^{\,2}} = -.196(1 + H_t/100)(e^{-.028L_t})$$

The final period (9) life enjoyment optimization problem is given by: (note that E_9 is a function of the final period investment decisions, I_9 and L_9, and several pre-determined parameters, B_8 (what's remaining in the bank after the previous period 8) and R_9 (returns from harvesting or retirement in current period 9) and d_9 (degeneration of health (=24) that occurs in current period 9 before investing)

Maximize: $E_9 = 250(1 + H_9/100)(1 - e^{-.028L_9})$

Subject to: $B_8 + R_9 = I_9 + L_9$

$$H_9 = H_8 - \mathrm{d}_9 + 30\,\frac{1-e^{-.025\mathrm{I}_9}}{1+e^{-.025\mathrm{I}_9}}$$

Which is equivalent to maximizing the unconstrained function of I_9:

$$E_9 = 250(1 + (H_8 - d_9 + 30\frac{1-e^{-.025I_9}}{1+e^{-.025I_9}})/100)(1 - e^{-.028(B_8+R_9-I_9)})$$

Taking the first order condition with respect to final health investment, I_9, and setting equal to 0 we get:

$$\frac{dE_9}{dI_9} = 0 = 250(100 + H_8 - d_9 + 30\frac{1-e^{-.025I_9}}{1+e^{-.025I_9}})/100)(-.028e^{-.028(B_8+R_9-I_9)}$$
$$+ 75(\frac{.025e^{-.025I_9}}{1+e^{-.025I_9}} + \frac{.025e^{-.025I_9}(1-e^{-.025I_9})}{(1+e^{-.025I_9})^2})(1 - e^{-.028(B_8+R_9-I_9)})$$

$$\frac{dE_9}{dI_9} = 0 = 2.5(100 + H_8 - d_9 + 30\frac{1-e^{-.025I_9}}{1+e^{-.025I_9}})(-.028e^{-.028(B_8+R_9-I_9)})$$
$$+ 75(\frac{.025e^{-.025I_9} + .025e^{-.05I_9}}{(1+e^{-.025I_9})^2} + \frac{.025e^{-.025I_9} - .025e^{-.05I_9}}{(1+e^{-.025I_9})^2})(1$$
$$- e^{-.028(B_8+R_9-I_9)})$$

$$\frac{dE_9}{dI_9} = 0 = 2.5(100 + H_8 - d_9 + 30\frac{1-e^{-.025I_9}}{1+e^{-.025I_9}})(-.028e^{-.028(B_8+R_9-I_9)})$$
$$+ 150\frac{.025e^{-.025I_9}}{(1+e^{-.025I_9})^2}(1 - e^{-.028(B_8+R_9-I_9)})$$

Letting $d_9 = 24$, we get:

$$0 = (190 + 2.5H_8 + 75\frac{1 - e^{-.025\mathrm{I}_9}}{1 + e^{-.025\mathrm{I}_9}})(-.028e^{-.028(B_8+R_9-I_9)}) + \frac{3.75e^{-.025\mathrm{I}_9}}{(1 + e^{-.025\mathrm{I}_9})^2}(1 - e^{-.028(B_8+R_9-I_9)})$$

$$0 = (190 + 2.5H_8)(1 + e^{-.025\mathrm{I}_9})^2 - 2.1\left(e^{-.028(B_8+R_9-I_9)}\right)(1 - e^{-.05\mathrm{I}_9}) + 3.75e^{-.025\mathrm{I}_9}(1 - e^{-.028(B_8+R_9-I_9)})$$

The first four of the following tables provide the complete optimal decision trajectories in the Flat Retirement, Flat No Retirement, Tiered Retirement, and Tiered No Retirement treatments for decision makers who are perfect harvesters, and the second set of four tables provide the optimal decision trajectories in all treatments for decision makers who possess the average harvesting skill demonstrated by our experimental subjects.

Flat Retirement								Harvest Rate Per Health = 0.94		
Period	0	1	2	3	4	5	6	7	8	9
Investment Health	85	69	72	73.3	72.6	69.3	62.3	49.5	29.1	5.1
End Health	85	89	91.3	91.6	89.3	83.3	71.5	52.1	29.1	5.1
Harvest	0	79.9	83.6	85.8	86.1	83.9	78.3	62.2	62.2	62.2
Health Investment	0	64.2	61.2	56.8	50.2	40.4	25.3	7	0	0
Life Investment	0	15.7	22.4	29	35.9	43.5	53	55.2	62.2	62.2

Cash On Hand	0	0	0	0	0	0	0	0	0	0
Life Enjoyment	0	252	334.2	399.7	450.4	483.9	497.1	448.8	399.3	325.1
Marginal ROR		8.52	7.15	5.95	4.85	3.79	2.72	2.27	1.58	1.29
% Invest in Health		80	73	66	58	48	32	11	0	0

Flat No Retirement							Harvest Rate Per Health = 0.94			
Period	0	1	2	3	4	5	6	7	8	9
Investment Health	85	69	72.7	75.1	75.9	74.7	71.1	64.3	52.8	33.6
End Health	85	89.7	93.1	94.9	94.7	92.1	86.3	75.8	57.6	33.6
Harvest	0	79.9	84.3	87.5	89.2	89	86.6	81.2	71.3	54.2
Health Investment	0	68	66.1	63.3	59.1	53.2	44.6	32.3	12.9	0
Life Investment	0	11.9	18.2	24.2	30.1	35.9	42	48.9	58.4	54.2
Cash On Hand	0	0	0	0	0	0	0	0	0	0
Life Enjoyment	0	202.3	289.3	359.7	415.5	456.5	483.1	491.5	475.8	391.1
Marginal ROR		9.51	8.12	6.93	5.86	4.92	4.02	3.13	2.15	2.05
% Invest in Health		85	78	72	66	60	52	40	18	0

Tiered Retirement							Harvest Rate Per Health = .66/1.62			
Period	0	1	2	3	4	5	6	7	8	9
Investment Health	85	69	68.7	66.3	61.4	64.5	65.8	61.5	49.3	27
End Health	85	85.7	84.3	80.4	84.5	86.8	83.5	72.3	51	27
Harvest	0	55.9	56.4	55.4	130	136.6	140.4	71.8	71.8	71.8
Health Investment	0	50.1	46.1	40.9	81.4	77	54	30.2	4.5	0

Life Investment	0	5.8	10.2	14.5	48.5	59.6	65.1	62.9	67.4	71.8
Cash On Hand	0	0	0	0	0	0	21.3	0	0	0
Life Enjoyment	0	105.2	172.4	225.9	514.1	568.4	577	535.1	480.3	412.4
Marginal ROR		11.05	9.69	8.41	3.32	2.46	2.07	2.07	1.60	1.19
% Invest in Health		90	82	74	63	56	38	32	6	0

Tiered No Retirement								Harvest Rate Per Health = .66/1.62		
Period	0	1	2	3	4	5	6	7	8	9
Investment Health	85	69	69.2	67.6	63.7	67.7	70.4	71.7	71	67.1
End Health	85	86.2	85.6	82.7	87.7	91.4	93.7	94	91.1	81.7
Harvest	0	55.9	56.7	56.3	133.8	141.8	147.8	151.5	151.9	147.3
Health Investment	0	52.2	48.9	44.6	87.6	86.1	82.7	76.4	65.2	42.6
Life Investment	0	3.7	7.8	11.7	46.2	55.7	65.2	75.1	86.7	104.8
Cash On Hand	0	0	0	0	0	0	0	0	0	0
Life Enjoyment	0	68.9	136.9	191.6	510.9	567	609.2	638.5	653.5	645.3
Marginal ROR		11.75	10.44	9.21	3.60	2.81	2.18	1.66	1.18	0.67
% Invest in Health		93	86	79	65	61	56	50	43	29

Flat Retirement								Harvest Rate Per Health = 0.87		
Period	0	1	2	3	4	5	6	7	8	9
Investment Health	85	69	71.3	71.9	70.2	65.8	57.5	43.3	23	0
End Health	85	88.3	89.9	89.2	85.8	78.5	65.3	46	24	0
Harvest	0	74	76.8	78.2	77.6	74.7	68.3	56.2	56.2	56.2

Health Investment	0	61	58	52.9	46	36.2	21.1	7.4	2.6	0
Life Investment	0	12.9	18.8	25.3	31.6	38.5	47.2	48.8	53.6	56.2
Cash On Hand	0	0	0	0	0	0	0	0	0	0
Life Enjoyment	0	214.6	291.9	360.2	409.5	441.4	454.5	408	361.2	297.3
Marginal ROR		9.18	7.85	6.52	5.37	4.25	3.08	2.60	1.93	1.45
% Invest in Health		82	76	68	59	48	31	13	5	0

Flat No Retirement								Harvest Rate Per Health = 0.87		
Period	0	1	2	3	4	5	6	7	8	9
Investment Health	85	69	71.9	73.3	72.9	70.4	65.1	56.1	41.7	17.7
End Health	85	88.9	91.3	91.9	90.4	86.1	78.1	64.7	41.7	17.7
Harvest	0	74	77.3	79.4	80	78.6	74.9	67.9	56.3	36.3
Health Investment	0	63.9	61.5	58.1	53.2	46.5	37.2	23.6	0	0
Life Investment	0	10	15.8	21.4	26.7	32.1	37.7	44.3	49.6	43
Cash On Hand	0	0	0	0	0	0	0	0	6.7	0
Life Enjoyment	0	173.7	256.5	323.9	376.2	414	435.5	439	398.9	309
Marginal ROR		9.99	8.60	7.38	6.31	5.30	4.34	3.33	2.47	2.47
% Invest in Health		86	80	73	67	59	50	35	0	0

Tiered Retirement								Harvest Rate Per Health = .61/1.51		
Period	0	1	2	3	4	5	6	7	8	9
Investment Health	85	69	67.8	64.5	58.7	60.4	60	54.1	37.6	13.6
End Health	85	84.8	82.5	77.7	80.4	81	76.1	60.6	37.6	13.6
Harvest	0	51.8	51.7	50.3	116.3	120.4	121.2	63.9	63.9	63.9
Health Investment	0	47	42.9	37.6	73.4	67.2	47.9	17.6	0	0
Life Investment	0	4.8	8.8	12.7	42.8	53.1	61.5	58.2	63.9	63.9

Cash On Hand	0	0	0	0	0	0	11.9	0	0	0
Life Enjoyment	0	86.6	149.2	198.9	472.6	525.5	542.3	484.2	429.9	354.9
Marginal ROR		11.31	9.98	8.71	3.81	2.86	2.20	2.20	1.61	1.33
% Invest in Health		91	83	75	63	56	40	23	0	0

Tiered No Retirement								Harvest Rate Per Health = .61/1.51		
Period	0	1	2	3	4	5	6	7	8	9
Investment Health	85	69	68.6	66.4	62	65.1	66.7	66.5	63.8	57.1
End Health	85	85.6	84.4	81	85.1	87.7	88.5	86.8	81.1	66.3
Harvest	0	51.8	52.2	51.4	121.2	127.3	131.2	132.5	129.9	121.3
Health Investment	0	50	46.7	42.5	81.3	78.7	73.9	65.9	52.3	25.3
Life Investment	0	1.7	5.4	8.9	39.9	48.6	57.3	66.5	77.7	96
Cash On Hand	0	0	0	0	0	0	0	0	0	0
Life Enjoyment	0	32.8	97.7	149.9	467	523.3	564.9	591.9	601.8	581
Marginal ROR		12.39	11.10	9.87	4.24	3.37	2.65	2.03	1.44	0.79
% Invest in Health		97	89	83	67	62	56	50	40	21

Appendix 2: Table 2: Multilevel Hierarchical Regressions Full Description

Table 2 below presents the complete results of mixed random and fixed effects models, run hierarchically. Each dependent variable below, Health Investment, Health, Income and Health Investment/Income, was regressed as a function of various experimental design variables: lives, periods, dummy variables using the Flat Retirement treatment as the baseline, and adding interaction terms between the periods and the treatment dummy variables.

Observations were organized according to a hierarchical structure. Two hierarchies, one at the individual chat-group level, and a second at the individual level, allow us to consider the chat-group and individual effects on the observed variance. Table 2 displays the outcomes of four regressions, one for each dependent variable. For each regression, we display the full list of the interaction terms' coefficients and each of their significance levels. These coefficients capture the differences between the overall mean of the dependent variable and the marginal means at lives, periods, and treatment level. Two main outcomes can be observed in Table 2. First, when we pool the data of all the treatments, they all present negative and significant coefficients for health and health investment starting in period 4. These coefficients are consistent with what we observe in Figures 1a and 1b: on average, as the value of future health decreases, for all the treatments the marginal means of health and health investment decrease.

The described effects of the treatments are not captured by their intercepts, but by the interaction terms representing the difference between the baseline treatment's (Flat Retirement) observed marginal means and those given for each period and treatment different than the baseline. Most of the period/treatment interaction terms are significant. Furthermore, the sign of the interaction terms in the Health Investment regressions support those predicted by the theoretical model: all the interaction terms of the tiered treatment are significant and positive..

VARIABLES	**H**ealth **I**nvestment	Health	Income	**HI**/Income
Life 5	0.514	1.177***	1.421***	-0.00632
	(0.429)	(0.254)	(0.373)	(0.00656)
Life 6	0.648	1.302***	2.282***	-0.0133**
	(0.429)	(0.254)	(0.373)	(0.00656)
Life 7	0.945**	2.256***	3.823***	-0.0208***
	(0.430)	(0.254)	(0.374)	(0.00657)
Life 8	1.047**	2.198***	3.793***	-0.0209***
	(0.430)	(0.254)	(0.374)	(0.00657)
Life 9	0.598	2.173***	4.386***	-0.0290***
	(0.430)	(0.254)	(0.374)	(0.00657)
Life 10	0.116	1.530***	3.570***	-0.0286***
	(0.430)	(0.254)	(0.374)	(0.00657)
Period 2	0.863	-0.349	3.055***	-0.0371**
	(0.979)	(0.579)	(0.851)	(0.0150)
Period 3	0.878	-1.443**	3.868***	-0.0509***
	(0.979)	(0.579)	(0.851)	(0.0150)
Period 4	0.313	-3.555***	1.616*	-0.0381**
	(0.979)	(0.579)	(0.851)	(0.0150)
Period 5	-2.658***	-6.830***	-0.590	-0.0555***
	(0.979)	(0.579)	(0.851)	(0.0150)
Period 6	-7.674***	-11.97***	-1.166	-0.123***
	(0.979)	(0.579)	(0.851)	(0.0150)
Period 7	-28.36***	-19.66***	-15.99***	-0.343***
	(0.979)	(0.579)	(0.851)	(0.0150)
Period 8	-33.24***	-34.92***	-15.99***	-0.433***
	(0.979)	(0.579)	(0.851)	(0.0150)
Period 9	-44.76***	-52.85***	-16.50***	-0.599***
	(0.979)	(0.579)	(0.851)	(0.0150)

D_ Tiered with Retirement	-11.18***	0.0739	-22.39***	0.115***
	(2.212)	(2.015)	(2.504)	(0.0208)
D_ Flat No Retirement	3.196	0	1.574	0.0450**
	(2.142)	(1.953)	(2.425)	(0.0201)
D_ Tiered No Retirement	-8.894***	0	-19.30***	0.105***
	(2.142)	(1.953)	(2.425)	(0.0201)
Tiered Ret#Period 2	3.750***	-3.169***	-0.765	0.0585***
	(1.417)	(0.837)	(1.232)	(0.0216)
Tiered Ret#Period 3	3.609**	-5.219***	-3.493***	0.0869***
	(1.417)	(0.837)	(1.232)	(0.0216)
Tiered Ret#Period 4	31.09***	-7.319***	48.94***	-0.0941***
	(1.417)	(0.837)	(1.232)	(0.0216)
Tiered Ret#Period 5	30.94***	-3.299***	61.67***	-0.175***
	(1.417)	(0.837)	(1.232)	(0.0216)
Tiered Ret#Period 6	26.46***	0.922	69.41***	-0.226***
	(1.417)	(0.837)	(1.232)	(0.0216)
Tiered Ret#Period 7	8.711***	4.159***	27.48***	-0.188***
	(1.417)	(0.837)	(1.232)	(0.0216)
Tiered Ret#Period 8	9.683***	3.373***	27.24***	-0.136***
	(1.417)	(0.837)	(1.232)	(0.0216)
Tiered Ret#Period 9	12.01***	3.233***	26.65***	-0.0683***
	(1.417)	(0.837)	(1.232)	(0.0216)
Flat No Ret#Period 2	-0.875	0.644	0.374	-0.0308
	(1.366)	(0.807)	(1.187)	(0.0209)
Flat No Ret#Period 3	-1.787	1.144	0.0431	-0.0400*
	(1.366)	(0.807)	(1.187)	(0.0209)
Flat No Ret#Period 4	-0.873	1.457*	0.962	-0.0385*
	(1.366)	(0.807)	(1.187)	(0.0209)
Flat No Ret#Period 5	-0.624	2.058**	0.356	-0.0464**
	(1.366)	(0.807)	(1.187)	(0.0209)
Flat No Ret#Period 6	-0.0161	2.669***	-3.638***	0.00575
	(1.366)	(0.807)	(1.187)	(0.0209)
Flat No Ret#Period 7	10.83***	3.584***	6.394***	0.138***
	(1.366)	(0.807)	(1.187)	(0.0209)
Flat No Ret#Period 8	1.849	8.430***	1.055	0.0671***
	(1.366)	(0.807)	(1.187)	(0.0209)
Flat No Ret#Period 9	-2.676*	10.96***	-4.508***	0.0128
	(1.366)	(0.807)	(1.187)	(0.0209)
Tiered No Ret#Period 2	2.879**	-2.427***	-2.543**	0.0733***
	(1.366)	(0.807)	(1.187)	(0.0209)
Tiered No Ret#Period 3	3.624***	-4.013***	-3.580***	0.103***
	(1.366)	(0.807)	(1.187)	(0.0209)
Tiered No Ret#Period 4	32.93***	-5.408***	57.20***	-0.114***
	(1.366)	(0.807)	(1.187)	(0.0209)
Tiered No Ret#Period 5	33.42***	-0.371	68.19***	-0.170***
	(1.366)	(0.807)	(1.187)	(0.0209)

Tiered No Ret#Period 6	35.85***	5.094***	70.68***	-0.142***
	(1.366)	(0.807)	(1.187)	(0.0209)
Tiered No Ret#Period 7	53.02***	11.67***	81.62***	0.0617***
	(1.366)	(0.807)	(1.187)	(0.0209)
Tiered No Ret#Period 8	52.12***	23.95***	77.54***	0.120***
	(1.366)	(0.807)	(1.187)	(0.0209)
Tiered No Ret#Period 9	23.04***	36.33***	77.41***	-0.0401*
	(1.366)	(0.807)	(1.187)	(0.0209)
Constant	47.14***	83.48***	64.88***	0.748***
	(1.562)	(1.410)	(1.756)	(0.0151)
Observations	17,271	17,271	17,271	17,271
Number of groups	69	69	69	69

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.