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To examine how the length of retirement life affects people’s mistakes in choosing a saving plan, a laboratory experiment was conducted in which subjects face a simple life-cycle consumption/saving problem without interest rate, price and income volatilities, and any uncertainty. Lifetime is divided into working periods with a certain and constant amount of income and retirement periods with no income. We compared three treatment groups: the retirement periods are the last 5 periods out of 25 life periods (SR), these are the last 16 periods out of 36 life periods (LL), and these are the last 16 periods out of 25 life periods (SW). In all treatments, the subject’s lifetime income was the same. Our main findings are twofold. First, the magnitude of misconsumption (i.e., the deviation from conditional optimal consumption) is significantly positive for each treatment. Thus, people cannot find an optimal saving plan even in our simple life-cycle problem. Second, the subjects overreacted to both the long life and large income, which caused over-saving behavior in LL and under-saving behavior in SW, whereas there is no particular trend for mistakes in SR.

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Effect of Longevity on Saving Behavior: An Experimental Study on the Simple Intertemporal Life-Cycle Problem[§1]

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Abstract

To examine how the length of retirement life affects people's mistakes in choosing a saving plan, a laboratory experiment was conducted in which subjects face a simple life-cycle consumption/saving problem without interest rate, price and income volatilities, and any uncertainty. Lifetime is divided into working periods with a certain and constant amount of income and retirement periods with no income. We compared three treatment groups: the retirement periods are the last 5 periods out of 25 life periods (SR), these are the last 16 periods out of 36 life periods (LL), and these are the last 16 periods out of 25 life periods (SW). In all treatments, the subject's lifetime income was the same. Our main findings are twofold. First, the magnitude of misconsumption (i.e., the deviation from conditional optimal consumption) is significantly positive for each treatment. Thus, people cannot find an optimal saving plan even in our simple life-cycle problem. Second, the subjects overreacted to both the long life and large income, which caused over-saving behavior in LL and under-saving behavior in SW, whereas there is no particular trend for mistakes in SR.

Keywords: consumption/saving; life-cycle problem; life length after retirement; economic experiment.

JEL Classification: C91, D91, E31

1. Introduction

In recent years, life after retirement has been prolonged due to a remarkable increase in life expectancy worldwide. In Japan, one of the representative countries with high average life expectancy, the Financial Services Agency released a report in 2019 that life plans relying on the public pension system alone could lead to a shortage of funds.[1] The report estimates that a couple would need to withdraw about 20 million yen (more than four times the average annual income in Japan) of financial assets to live until the age of 95 without a drastic drop in the living standard and encourages the public to prepare long-term wealth accumulation for retirement in anticipation of "100 years of life."

Can people save the right amount for such a long life? Following models of household saving behavior in modern micro-founded macroeconomics, beginning with the life-cycle theory of consumption (Modigliani and Brumberg 1954) and the permanent income hypothesis (Friedman 1957), agents will optimally reduce their consumption so as to smooth consumption over their future as their life after retirement is prolonged if the expected future income remains unchanged. While these models usually assume that agents are unboundedly rational and can always solve dynamic programming problems, the results shown in previous studies of experiments on intertemporal life-cycle consumption/saving problems suggest that individuals are unable to correctly identify the optimal consumption plan. Furthermore, they seem to adopt some heuristics or rules-of-thumb for dynamic problems, and their mistakes are not random but have systematic tendency toward under-saving (e.g., Ballinger et al. 2003; Brown et al. 2009; Carbone

[1] WHO notes in its annual report World Health Statistics 2019 that in the 16 years since 2000, the average life expectancy of the world has increased by 5.5 years. As of 2018, Japan's life expectancy is 83.7 years, corresponding to first in the country rankings.

and Duffy 2014) or over-saving (e.g., Johnson et al., 1987; Anderhub et al., 2000; Bernasconi and Kirchkamp 2000; Yamamori et al. 2018) relative to the optimal path.

The aim of this study is to explore experimentally how individuals who are unable to find the optimal consumption/saving plan react to the length of the retirement period. How does the length of retirement life affect people's mistakes in choosing a saving plan? It should be intuitively clear for individuals that the longer the retirement period, the more they need to save before retirement. Then, does long retirement life enhance people's tendency to over-save? Does this affect individuals' welfare by inducing their large mistakes? This study investigates these questions using a laboratory experiment on a simple intertemporal life-cycle consumption/saving problem.

Overviewing previous experimental studies on the intertemporal life-cycle problem, people seem to overreact to the length of retirement periods. For example, in the experiment of Carbone and Duffy (2014), in which subjects exhibit under-saving behavior in early periods, there is a fixed income in each of 25 life periods, that is, there is no retirement. On the other hand, in the experimental studies of Yamamori et al. (2018), in which subjects exhibit over-saving behavior, they can only withdraw initial savings over 20 life periods, that is, all periods are after retirement. Johnson et al. (1987) also found that most subjects display over-saving behavior in their experimental study based on a questionnaire in which the subjects chose annual consumption under a hypothetical life scenario from the age of 35 until death at 75, with a fixed amount of income each year until the age of 65, that is, the age of death is ten years after retirement. The difference in the direction of mistakes, over- or under-saving, among these experimental studies may be relevant to the relative length of the retirement periods. However, experimental designs in these studies differ in many ways, including the presence and size of interest rates, length of life time, and borrowing availability, so it is hard for us to extract pure effects of the length of the retirement periods on saving behavior from these experimental results.[2]

Our study is based on an experiment in which subjects face a life-cycle consumption/saving problem with a lifetime of T periods. Lifetime is divided into young (working) periods with a certain and constant amount of income and the old (retirement) periods with no income. In each period, a subject can spend his/her wealth (i.e., past savings and current income) to buy only one commodity, of which price is $5{,}000$ points (experimental currency units) across all periods. His/her overall payoff is the sum of an instantaneous payoff, which is given by the square root of the consumption amount. The rate of return on savings is always 1, and there is no borrowing or investment. The length of lifetime, commodity price, and income of every period are known by the subject. That is, there is no uncertainty in the payoffs.

In order to extract the pure effect of the length of retirement life on the subjects' consumption/saving behavior, we employ the simplest design possible: there are no interest rate, price and income volatilities, interaction with others, or uncertainty. It would be quite easy for people to solve these life-cycle problems. Indeed, the subjects only need to allocate their (real) lifetime income evenly among each period regardless of the length of retirement periods in order to maximize their overall payoffs. However, Yamamori et al. (2018) conducted an experiment on a simple intertemporal life-cycle

[2] Johnson et al. (1987) concluded that the subjects' over-saving behavior is due to underestimating the power of compound interest, that is, subjects suffered from exponential growth bias. We are not sure if this is the cause of over-saving because the real interest rate in their experiment is lower than that in Carbone and Duffy (2014), in which subjects exhibit under-saving behavior.

consumption/saving problem similar to the retirement periods in our experiments (i.e., there was an income only at the beginning of the first period) and found that their subjects exhibited under-consumption (over-saving) behavior during early periods. Thus, people made mistakes even in such a very simple problem.

Our question is, then, how a subject who is unable to find the optimal consumption plan reacts to the length of the retirement periods. We conducted three treatments. In the short retirement treatment (denoted by SR), of the lifetime of 25 periods, the working periods are the first 20 with income of $225{,}000$ points per period, and the retirement periods are the last 5. In the long life treatment (denoted by LL), the working periods and income per period are the same as in SR, while the retirement periods are the last 16; thus, the lifetime is 36 periods. Finally, in the short work treatment (denoted by SW), the lifetime is 25 periods, similar to SR, and the retirement periods are the last 16, similar to LL; however, the working periods are the first 9 with income of $500{,}000$ points per period. In all treatments, the subject's lifetime income was $4{,}500{,}000$ points.

The length of the periods after retirement in LL is 3.2 times that in SR. Therefore, if subjects who cannot find the optimal consumption plan overreact to the long retirement periods, over-saving behavior would be more observed in the LL than in SR. However, even if this arises, the subjects might not overreact to the long retirement periods themselves but to the long life periods. Indeed, the optimal consumption in each period in LL is lower than that in SR because of the same lifetime income and longer life period, but it is irrelevant to the length of the retirement period. In SW, while the length of the retirement periods is three times longer than SR (like the LL), SW has the same life periods and the same optimal consumption path as those of the SR. Therefore, if over-saving behavior was more observed in the SW than in SR, the subjects would have overreacted to a relatively longer retirement period. However, income in each working period in SW is more than twice that in SR and in LL. Empirically, it is well known that households' consumption has *excess sensitivity* (Flavin 1981) to current income. Therefore, a large income would cause the subjects to make a mistake in the opposite direction, that is, under-saving behavior. Thus, compared to SR, SW has two factors that may cause the subjects to over-react in different directions: one is the large income that may cause under-saving, and the other is the long retirement periods, which may cause over-saving.

Our data provided strong evidence that people cannot find an optimal consumption plan even in a simple life-cycle problem. For each treatment, the magnitude of misconsumption (i.e., the deviation from *conditional* optimal consumption) was significantly positive not only in the working period but also in retirement periods where the subjects only need to allocate their current wealth evenly among the remaining periods. Comparing the rates of deviation of misconsumption in the three treatments, those were largest in SW, followed by LL and SR. On the other hand, those in retirement periods are smaller in SW and LL than in SR. As a result, we could not observe a significant difference in overall payoffs among the three treatments.

As noted above, previous experimental studies on life-cycle problems showed that the mistakes of subjects are not random but have systematic tendency toward under-saving or over-saving relative to the optimal path. Our subjects in LL and SW also made mistakes in a particular direction, while there was no particular trend in SR. The direction was different for LL and SW. In the LL, the subjects seemed to be too cautious for long retirement periods, and their savings were too much relative to the optimal. This trend of over-saving became stronger after retirement. Thus, the longer the life periods, the more subjects tend to make over-savings. On the other hand, the subjects in SW overreacted to the large income in each working period, and their savings were too low relative to the optimal. However, this trend of over-consumption vanished after retirement. This result implies that if the periods of life and lifetime income are the same, relatively long retirement (short working) periods cause people to over-consume in working periods because of the large income.

The remainder of this paper is organized as follows. In Section 2, we describe our experimental design. In Section 3, the experimental results are presented. In Section 4, we summarize our results and discuss their implications.

2. Experiment

2.1. Design

To extract the pure effect of the length of retirement life on the subjects' consumption/saving behavior, we consider the following simple intertemporal life-cycle consumption/saving problem where a subject hypothetically lives a discrete and finite number of periods $t = 1,2,\dots,T$. In each period, a subject can spend his/her wealth (cash-in-hand) to buy only one commodity, of which price p is constant across all periods. Let x_t be the amount of the commodity purchased in period t. Then, his/her payoff function is given by

$$\sum_{t=1}^{T}\sqrt{x_t}.$$

The instantaneous payoff $\sqrt{x_t}$ is a constant-relative, risk-averse utility function with a coefficient of $1/2$. The discount rate is always 1, and the wealth that remains after period T is irrelevant to his/her payoff. Let W_t and Y_t be the subject's wealth and income in period t, respectively. Then, the intertemporal budget constraint is given by

$$W_1 = Y_1,$$

$$W_{t+1} = S_t + Y_{t+1},$$

where S_t is the savings at the beginning of period $t + 1$, that is, $S_t = (W_t - px_t)$. The rate of return on savings is always 1 (the interest rate is 0), and there is no borrowing and banking. We also assume that the lifetime T, commodity price p, and income of every period are known by the subjects. That is, there is no uncertainty in the payoffs.

This setup is the simplest of the previous experimental studies on intertemporal life-cycle consumption problems. Other studies are based on experimental designs with uncertain income (e.g., Ballinger et al. 2003; Carbone and Hey 2004; Brown et al. 2009), with uncertain time horizons (e.g., Anderhub et al. 2000), with positive interest rates (e.g., Johnson et al. 1987; Carbone and Duffy 2014), or with endogenous or exogenous price fluctuations (Bernasconi and Kirchkamp 2000; Yamamori et al. 2018). To extract the pure effect of the length of retirement life, we eliminate these factors that complicate the calculation of the optimal path and make the calculation for optimization sufficiently simple for all subjects.

Indeed, it would be quite easy for people to solve the life-cycle problem without interest rate, price and income volatilities, and any uncertainty: the subjects only need to allocate their (real) lifetime income evenly among each period. That is, the sequence $(x_t)_{t=1}^{T}$ of consumption, in which

$$x_t = x^* = \frac{\sum_{t=1}^{T} Y_t}{pT}$$

for any t, maximizes a subject's overall payoff.[3] Needless to say, once a subject's consumption deviates from such optimality, this consumption sequence is no longer

[3] In Friedman's (1957) term, the amount x^* of consumption is called permanent income.

optimal for the remaining periods. However, even in this case, it would not be difficult for him/her to find the *conditional* optimal consumption in any remaining period since the commodity price and future incomes are fixed. He/she only needs to allocate the sum of the wealth at that time and the future incomes evenly among the remaining periods. That is, in any period $h\ (\geq 2)$, the payoff in the remaining periods, $\sum_{t=h}^{T}\sqrt{x_t}$, is maximized by the sequence $(x_t)_{t=h}^{T}$ of consumption, in which

$$x_t = x(W_h) = \frac{W_h + \sum_{t=h+1}^{T} Y_t}{p(T-h+1)}$$

for any t.

The experimental design consisted of three treatments. Regardless of the treatment, the commodity price is $5{,}000$ points (experimental currency units) and lifetime income, $\sum_{t=1}^{T} Y_t$, is $4{,}500{,}000$ points. Furthermore, in all treatments, the subject's lifetime is divided into two stages: the working periods ($t = 1, 2, \dots, R-1$) with a positive income ($Y_t > 0$) and retirement periods ($t = R, R+1, \dots, T$) with no income ($Y_t = 0$).

Table 1. Summary of our three treatments

Treatment	SR	LL	SW
Lifetime	25 periods	36 periods	25 periods
Working periods	First 20 periods	First 20 periods	First 9 periods
Retirement periods	Last 5 periods	Last 16 periods	Last 16 periods
Incomes in each working period Y_t	$225{,}000$	$225{,}000$	$500{,}000$
Lifetime income $\sum_{t=1}^{T} Y_t$	$4{,}500{,}000$	$4{,}500{,}000$	$4{,}500{,}000$
Optimal consumption x^*	36	25	36

Optimal savings at retirement	900,000	2,000,000	2,880,000
Maximum overall payoffs	150	180	150

In the short retirement treatment (denoted by SR), of the lifetime of 25 periods, the working periods are the first 20 with income of $225{,}000$ points per period, and the retirement periods are the last 5. In the long life treatment (denoted by LL), while the working periods are the first 20 periods with income of $225{,}000$ points, same as the SR, the retirement periods are the last 16; thus, the lifetime is 36 periods. That is, the length of the retirement periods of LL is 3.2 times that of SR. Finally, in the short work treatment (denoted by SW), the lifetime is 25 periods, similar to the SR, and the retirement periods are the last 16, similar to LL; however, the working periods are the first 9 with income of $500{,}000$ points per period.

There are no experimental studies that systematically analyze the effects of retirement length on consumption/saving behavior. However, as noted before, subjects seemed to overreact to the length of the retirement periods in several experimental studies on the intertemporal life-cycle problem. Furthermore, Anderhub et al. (2000) reported that the subjects are too cautious for an uncertain time horizon and tend to over-save in early periods in their experiment based on a dynamic decision problem with an uncertain number of periods. If subjects who cannot find the optimal consumption plan are too cautious for long retirement periods and overreact to it, then over-saving behavior will be more commonly observed in the LL than in SR.

Since the lifetime periods and lifetime income in the SR are the same as those in SW, the *unconditional* optimal amounts of consumption x^* are the same in these treatments.

However, income in each working period in SW is more than twice that in SR (and in LL). Empirically, it is well known that households' consumption has *excess sensitivity* (Flavin 1981) to current income, contradicting Friedman's (1957) permanent income hypothesis.[4] The fact that people overreact to current income has also been confirmed in laboratory experiments. For example, Carbone and Hey (2004) conducted an intertemporal life-cycle experiment in which the current income of a subject (either high or low) is determined by a stochastic process. Their experimental results showed that the subjects overreact to their current size of income: subjects tend to consume too much in periods of high income and too little in periods of low income. Based on this empirical evidence, the actual consumption during working periods in SW may be larger than the *conditional* optimal consumption. On the other hand, as in LL, long-term retirement periods may make the subject's consumption behavior cautious. Thus, compared to SR, SW has two factors that may cause the subjects to over-react in different directions: one is the large income, which may cause under-saving, and the other is the long retirement periods, which may cause over-saving. We compare these two factors to verify whether the latter is stronger than the former.

2.2. Procedure

Our experiment was conducted at Dokkyo University and Takasaki City University of Economics. We recruited subjects by displaying posters and distributing fliers. They were undergraduate students from several faculties at two universities that had not participated in any prior life-cycle experiments; furthermore, each subject could only participate in

[4] For a survey of econometric studies of the permanent income hypothesis based on field data, see, e.g., Chapter 7 in Romer (2012).

one treatment. All treatments were conducted in the same laboratory in each university, and each computer terminal in the laboratory was assigned a computer program associated with one of the treatments. Subjects were seated in front of a computer terminal at random. Each desk had a calculator and an envelope containing all the experimental materials, including the instructions and a recording sheet. During the experiment, subjects could use the calculator on the desk at any time. The total number of subjects who participated in (i.e., was assigned a computer terminal with) treatments SR, LL, and SW was 30, 32, and 29, respectively.

Each subject was asked to carefully read the instructions, which provided all the information about the structure of the treatment to which they had been allocated. Before the actual experiment began, subjects were told to solve the practice problems to confirm that they understood the instructions for the experiment. All practice problems were the same in the three treatments. To suggest that consumption smoothing is always optimal for any remaining periods, the problem set contains a simple life-cycle consumption problem with two periods in which the first period is the working period and the second is the retirement period.[5] No subject could begin the actual experiment unless all problems had been answered correctly. Furthermore, just before the actual experiment, subjects were told to practice on the same computer screen as in the actual experiment in order to get used to the computer operation. In this phase, subjects were required to solve a life-cycle consumption problem with six periods in which the first three periods are the working periods and the last three are the retirement periods. There were no rewards for this practice.

In each period of the actual experiment, each subject was asked to input his expenditure

[5] The instructions and the practice problems are presented in the Appendix.

on the commodity for the current period. In other words, subjects did not choose the amount of commodity x_t directly but rather chose expenditure on the commodity, px_t. On the computer screen, each subject could always observe the amount of income (Y_t) and the amount of wealth he/she currently holds (W_t). Past consumption (x_t), expenditure (px_t), and instantaneous payoff ($\sqrt{x_t}$) were also displayed on the screen.[6] Once the expenditure for the current period had been entered, the next period automatically began.

Decision-making time was not restricted. Therefore, the session duration differed by participant but was approximately one hour for most subjects. After the experiment, each subject was asked to answer a questionnaire. The reward given to the subjects was a kind of two-part tariff: the fixed participation fee was ¥500, and proportional payment was ¥12 × realized payoff shown at the beginning of this section. The reward was paid in cash to each subject privately after the session. Subjects earned an average of ¥2,170 in treatment SR, ¥2,114 in treatment SW, and ¥2,479 in treatment LL. The earnings in the treatment LL are larger than those in the other two because the maximum overall payoff in LL is larger than that in the other two (see Table 1).

3. Results

3.1. Overview

This section discusses the experimental results. We graphically checked the transitions of subjects' average consumptions for each treatment in our experiment. The actual, optimal, and conditional optimal consumptions over the period are shown in Figure 1. If the actual

[6] The total payoff up to that period was not displayed on the screen. However, if subjects wanted to know the amount, they could get it using the displayed information and the calculator.

consumption is observed to be higher (lower) than conditional optimal consumption, the subjects are likely to over- (under-) consume the commodity. The figure provides two graphical features. First, at the beginning of every treatment, subjects are likely to over-save their points, suggesting that subjects tend to make prudent decisions initially in the experiment. Second, subjects seem to greatly display over-saving behaviors in LL than in the other two treatments during retirement. The graphical results imply that the presence or absence of income and lengths of working and retirement periods may influence the subjects' consumption behaviors.

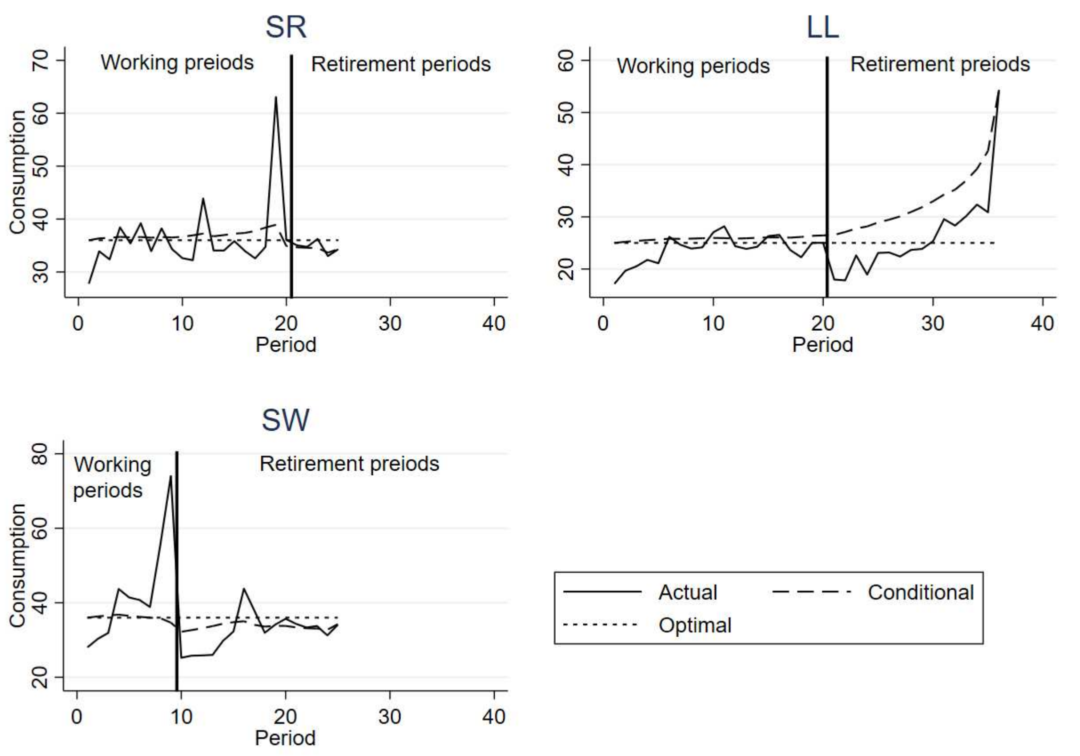

Figure 1. Transitions for actual, conditional optimal, and optimal consumptions

3.2. Tests for subjects' performance among treatments

As noted in the previous subsection, our design is the simplest experimental study on intertemporal life-cycle consumption problems. Therefore, we first test whether the subjects can optimally solve even our simple problem. To measure a subject's performance in the problem, we consider the gap between *actual and conditional* optimal consumptions. We do not rely on the deviation from the *unconditional* optimal consumption x^* to assess subjects' performance since once a subject's consumption deviates from x^*, this is no longer optimal for the subsequent periods. Mistakes in early periods in this sense become compounded over time.

For any period t, let D_t be the difference between the *conditional* optimal and actual consumption (hereafter misconsumption). That is, $D_t = x(W_t) - x_t$, where x_t is the actual consumption in period t. When considering the average of D_t, the negative value (overconsumption) and positive value (over-saving) cancel each other out, meaning that subjects exhibit optimal consumption, on average. To avoid this misunderstanding, we use the absolute value $|D_t|$ instead of D_t. The literature relied on D_t^2, the mean squared deviation of actual consumption from the *conditional* optimal consumption (e.g., Carbone and Duffy 2014), or $|D_t|$ (e.g., Yamamori et al. 2018) to assess subjects' performance.

There are some subjects whose conditional optimal consumption $x(W_t)$ is zero because they have exhausted their total income before the last period. We have decided to partly drop the observations for such subjects in the analysis to avoid that their behaviors are regarded as optimal. Suppose that some subjects in SR wiped out their total income at the period of 22. In this case, three observations' (i.e., periods of 22, 23, and 24) $|D_t|$ are zero. Therefore, we do not use such observations in the analysis. The numbers of omitted observations in SR, LL, and SW are 10, 0, and 14, respectively. In addition, we do not use observations in the last periods of each treatment.

Table 2 shows the descriptive statistics for the subjects' performance, $|D_t|$. We test the subjects' performance in the working periods and the retirement periods separately since it is slightly easier to calculate the *conditional* optimal consumption in a period during retirement than during a working period. Two types of mean comparison t-tests are also presented in the table. The first t-test is for the hypothesis that each mean is equal to zero. The test results are shown on the right side of each mean. The second t-test, assuming unequal variances, is for testing the null hypothesis that each performance in the working periods is equal to that in the retirement periods. The results are presented in the last column.

Subjects in all treatments cannot optimally consume because the t-values are sufficiently large. Comparing the behavioral change between the working and retirement periods, the trends are not the same among treatments. We find that the subjects' consumption behaviors change before and after retirement in all treatments, suggesting that the magnitude of misconsumption shrinks after retirement.

Result 1: For each treatment, actual consumption is neither optimal in the working periods nor in the retirement periods.

Table 2. Comparison of performance between working and retirement periods

treatment	working periods					retirement periods					t-value	
	obs.	mean	s.d.	t-value		obs.	mean	s.d.	t-value			
SR	600	13.879	1.238	11.21	***	110	4.180	0.870	4.81	***	6.41	***
LL	640	13.356	0.537	24.89	***	480	10.940	0.941	11.62	***	2.23	**
SW	261	23.160	3.678	6.30	***	421	6.961	0.990	7.03	***	4.25	***

Note: ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.

3.3. Econometric analysis for subjects' performance

The previous simple mean-comparison test does not control for other factors influencing the subjects' consumption behaviors. For example, characteristics such as gender and major in a university may be related to consumption behavior. Therefore, controlling for such variables, we regress the performance on dummies of retirement and dummies of each treatment. The additional variables were obtained from the questionnaire collected immediately after our experiment.

We use two types of performance measures to calculate the magnitude of subjects' misconsumption. One is the absolute value of misconsumption ($|D_t|$) used in the literature. However, we cannot perform econometric analysis using all observations because the c*onditional* optimal consumption in LL is smaller than that in SR and SW, even if W_t is the same, meaning that the same misconsumption has different impacts on the overall payoff among these treatments. Therefore, when using $|D_t|$ as an independent variable, we need to separately conduct econometric analysis for each treatment. A second is the rate of deviation of misconsumption ($|D_t/x(W_t)|$) to overcome this issue. That is, we use the performance of the percentage deviation from the optimal path. This measure enabled us to compare the subjects' performance among the treatments, even when using all observations.

Table 3 presents the estimation results from econometric analysis, where the independent variables are $|D_t|$ and $|D_t/x(W_t)|$ in models (1) to (3) and (4) to (7), respectively. Models (1) and (4) represent the estimation results when using the observations in SR only. Likewise, models (2) and (5), and (3) and (6) are the results restricting samples to LL and SW only, respectively. The last column (7) denotes the estimation results from using all observations. All models include unobserved individual fixed effects.

In models (1) to (6), the coefficients of *Dummy for retirement* are found to be significant and negative, suggesting that subjects are likely to make less misconsumption in the retirement period regardless of whether the retirement period is long or short. These results are consistent with the results of the t-test (see Table 2). We do not confirm that the estimation results change significantly depending on the independent variables.

We observe the comparison results among treatments from model (7). Although *a* negative sign is obtained in the coefficient for *Dummy for retirement*, the coefficients of the interaction terms with *Dummy for retirement* and *LL/SW* are negative at the 1% significance level. This means that subjects in LL and SW are likely to make misconsumption less than in SR during retirement periods. It is confirmed that the longer retirement period, the fewer subjects may mis-consume in retirement periods.

As for the working period, it is confirmed that subjects in SW make misconsumption the most, then LL and SR because the coefficients of *Dummy for SW* and *LL* are 0.649 and 0.587 in model (7). These values denote that rates of deviation of misconsumption in SW and LL are, on average, larger than in SR by 0.649 and 0.587, respectively. Because the rates of deviation are used in models (4) to (7), we must be careful in interpreting the results.

Result 2: Misconsumption shrinks after retirement. The rates of deviation of misconsumption in working periods are largest in SW, followed by LL and SR. Those in retirement periods are smaller in SW and LL than in SR.

Table 3. Estimation results for subjects' performance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		|D_t|			|D_t/x(W_t)|		
	SR	LL	SW	SR	LL	SW	ALL
Dummy for retirement	-15.88***	-4.073***	-19.36**	-0.279***	-0.385***	-0.679**	-0.189***
	(3.170)	(1.318)	(7.514)	(0.0802)	(0.0779)	(0.264)	(0.0637)
Dummy for retirement×LL							-0.336***
							(0.0592)
Dummy for retirement×SW							-0.376***
							(0.127)
Dummy for LL							0.587***
							(0.102)
Dummy for SW							0.649***
							(0.110)
Male	-19.14***	-21.84***	18.15***	-0.526***	-0.615***	0.331***	-0.292***
	(6.422)	(2.096)	(2.490)	(0.124)	(0.0657)	(0.0539)	(0.0678)
Age	-8.461***	-0.501	1.596**	-0.354***	0.0116	0.0524***	-0.0203
	(2.163)	(0.511)	(0.736)	(0.0699)	(0.0144)	(0.0179)	(0.0343)
Living alone	-27.67***	-4.656***	27.97***	-0.499***	-0.225***	0.662***	-0.194**
	(8.812)	(1.197)	(4.266)	(0.138)	(0.0422)	(0.0993)	(0.0962)
Favarite for math	-6.347**	8.249***	8.368***	-0.111**	0.150***	0.189***	-0.0546
	(3.198)	(1.108)	(1.093)	(0.0479)	(0.0317)	(0.0256)	(0.0417)
Economics	4.874	16.16***	-15.14***	-0.166	0.250***	-0.325***	-0.232***
	(3.758)	(1.765)	(1.968)	(0.151)	(0.0552)	(0.0481)	(0.0724)
Period	0.720***	0.0947	0.397	0.0213***	0.00588*	0.0234*	0.0139***
	(0.234)	(0.0733)	(0.365)	(0.00484)	(0.00353)	(0.0134)	(0.00323)
Constant	239.4***	24.97**	-69.30***	8.810***	0.519*	-1.857***	1.893**
	(43.53)	(10.89)	(17.10)	(1.490)	(0.300)	(0.412)	(0.758)
Observations	710	1,120	682	710	1,120	682	2,512
F-value	25.76***	50.57***	16.67***	19.87***	62.43***	12.40***	35.10***
Adj. R-squared	0.315	0.476	0.201	0.342	0.377	0.334	0.345

Note: ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively. Robust standard errors were used. All models include subjects' fixed effects and income dummies. To save space, we decided to omit the results for these variables. We can provide them upon request.

3.4. Tests for tendency of misconsumption

As mentioned in the introduction, previous studies of intertemporal life-cycle experiments have shown that deviations from the optimal solution of subjects' behavior are not random but rather systematic. Therefore, for each treatment, we also tested this observation in our experiment. The subjects in the life-cycle consumption/saving problem can make mistakes in two ways, namely under-consumption (over-saving), that is, $D_t > 0$, or over-consumption (under-saving), that is, $D_t < 0$. In each treatment, if their misconsumption does not tend toward either mistake, the average value of D_t should be close to zero.

To statistically check the direction of misconsumption, we employ the simple mean comparison t-test. The test results are shown in Table 4. Similar to Table 2, two types of t-tests were conducted. In addition to the working and retirement periods, descriptive statistics with all observations (i.e., all periods) are presented in the table. We find different consumption tendencies among treatments. There is no particular trend for consumption behaviors in SR. In contrast, subjects in LL are likely to under-consume throughout, with particularly strong under-consumption trends after retirement. For SW, subjects exhibit over-consumption tendencies during the working period, whereas the tendency vanishes in retirement periods. The results imply that length of periods may enhance subjects' under-consumption.

Result 3: The longer the period, the more subjects tend to make under-consumption. The trend becomes stronger after retirement.

Table 4 Comparison of misconsumption between working and retirement periods

treatment	working periods					retirement periods					t-value	
	obs.	mean	s.d.	t-value		obs.	mean	s.d.	t-value			
SR	600	0.533	1.362	0.39		110	-0.404	0.877	-0.46		0.58	
LL	640	2.058	0.749	2.75	***	480	7.464	1.010	7.39	***	-4.30	***
SW	261	-6.637	3.927	-1.69	*	421	1.501	1.011	1.49		-2.01	**

treatment	all periods				
	obs.	mean	s.d.	t-value	
SR	720	0.377	1.144	0.33	
LL	1120	4.375	0.614	7.13	***
SW	696	-1.550	1.608	-0.96	

Note: ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.

3.5. Tests for payoffs among treatments

We can also consider another measure to examine a subject's performance, namely his/her actual payoffs. Note that even if a subject's consumption is suboptimal, the difference between his/her payoff and the maximum payoff could be small. Thus, we also test whether the actual overall payoff is maximum in each treatment. To compare the payoff among the three treatments, we again rely on the rate of deviation from the maximum overall payoff rather than just deviation because the maximum payoff of LL is larger than that of SR and SW. Therefore, we calculate the deviations of the payoffs for SW and SR as $(150 - actual\ payoff)/150$. The value of 150 is replaced with 180 when calculating those in LL. These values are the maximum payoffs in the treatments (see Table 2).

The means of the payoff and their deviation in each treatment are presented in the first and second rows of Table 5. The average payoffs are 139.2, 164.9, and 134.5 in SR, LL, and SW, respectively. These values are statistically smaller than the maximum values of the payoffs at the 1% level, suggesting that subjects in every treatment could not optimally spend their income throughout. If they could make optimal decisions at all periods, the deviations would be zero. We also report the t-test results for testing whether each deviation is equal to zero. We can find the same results even in deviations of payoffs. The results for comparing the deviations among treatments are shown at the bottom of the table. We cannot observe a significant difference, implying that overall length of working and retirement periods do not affect overall payoffs.

Table 5. Payoffs and their deviations by treatment

	SR			LL			SW		
payoff	139.2	(18.09)	***	164.9	(19.61)	***	134.5	(24.52)	***
deviations of payoff	0.072	(0.121)	***	0.084	(0.109)	***	0.103	(0.163)	***
LL		-0.41			-			-	
SW		-0.83			0.54			-	

Note: ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.

Result 4: Subjects in all treatments could not make optimal consumption. The ratios of misconsumption did not differ across the treatments.

4. Concluding remarks

Nowadays, people are required to formulate consumption/saving plans for a longer retirement time period. However, there are no systematic studies that analyze the effects of retirement length on peoples' consumption/saving behavior, while they seem to overreact to it in previous experimental studies on life-cycle consumption/saving problems. To study how the length of retirement life affects people's mistakes in choosing a saving plan, a laboratory experiment was conducted in which subjects face a life-cycle consumption/saving problem without interest rate, price and income volatilities, interaction with other subjects, and any uncertainty. Lifetime is divided into working periods with a certain and constant amount of income and retirement periods with no income. We compared three treatment groups: the retirement periods are the last 5 periods out of 25 life periods (SR), these are the last 16 periods out of 36 life periods (LL), and these are the last 16 periods out of 25 life periods (SW). In all treatments, the subject's lifetime income was the same. Therefore, SR and SW have the same optimal consumption and that of LL is smaller.

Our main findings are twofold. First, the magnitude of misconsumption is significantly positive for each treatment. It is slightly easier to calculate the *conditional* optimal consumption in a period during retirement than during a working period since there is no income in the retirement periods. Indeed, mistakes are reduced after retirement in each treatment. However, subjects cannot find optimal consumption even in retirement periods.

Second, the subjects overreacted to both the long life and large income, which caused over-saving behavior in LL and under-saving behavior in SW, whereas there is no particular trend for mistakes in SR. In the LL, the subjects seemed to be too cautious for long retirement periods, and their savings were too much relative to the optimal. This trend of over-saving became stronger after retirement. On the other hand, the subjects in SW overreacted to the large income in each working period and their savings were too low relative to the optimal. However, this trend of over-consumption vanished after retirement. This result implies that if the periods of life and lifetime income are the same, relatively long retirement (short working) periods cause people to over-consume in working periods because of the large income.

Our experiment provides evidence that how people make mistakes in life-cycle consumption/saving problems depends on the income in each working period and the length of life, even if they have the same lifetime income. However, individuals' saving behavior in life-cycle problems may also be distorted by a sequence of incomes (usually it increases with age) in working periods and the size of retirement allowance depending on the length of lifetime. Exploring how these variables affect an individual's saving plan remains a task for future research.

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Appendix

The Appendix contains the English translation of the general instructions, instructions for the short retirement treatment (SR), and practice problems in Japanese.

General instructions: Working process until the start of the experiment and cautions (the original text was in Japanese)

Thank you very much for participating in our economic experiment. Please read the following instructions before beginning the experiment.

1. You will find the following materials on your desk: Please check whether you have all of them on your desk. If you are missing any items, please let us know by raising your hand quietly.
    - ID card
    - Envelope
    - Receipt
    - Calculator
    - Ballpoint pen

Please read the following precautions.

> Do not talk to anyone, and do not make any eye contact. Turn off your cellphone. Do not touch the computer until you are instructed to do so. If you do any of these, you will be asked to leave the experiment.
> If you feel ill during the experiment, please do not overdo it and let us know.
> If you have any questions during the experiment, please raise your hand quietly.

2. Please fill in your name, address, telephone number, and student ID number on the receipt.
3. Please fill in your ID number on the note paper in your envelope.
4. Please read the instructions in your envelope carefully.

When you have finished reading and completing the preparation, please let us know by raising your hand quietly.

Instructions for the short retirement treatment

(the original text was in Japanese)

You are now taking part in an economic experiment. Please read the following instructions carefully:

<u>Summary of experiment</u>

Suppose that you are the consumer of a hypothetical commodity. The experiment consists of 25 trading periods. From the 1st to the 20th period, you will be given 225,000 points (experimental currency units) for purchasing the commodity at the start of each period. From the 21st to the last period, you will not be given any additional points. In each period, you decide the number of points from your remaining points to use to purchase the commodity. The remaining points in each period are carried over to the next period. You cannot purchase the commodity beyond the points you hold. In each period, the price of the commodity is fixed at 5,000 points. Please refer to the table below.

Trading period	Additional points	Price of the commodity
1	225,000	5,000
2	225,000	5,000
3	225,000	5,000
4	225,000	5,000
5	225,000	5,000
6	225,000	5,000
7	225,000	5,000
8	225,000	5,000
9	225,000	5,000
10	225,000	5,000
11	225,000	5,000
12	225,000	5,000
13	225,000	5,000
14	225,000	5,000
15	225,000	5,000

Trading period	Additional points	Price of the commodity
16	225,000	5,000
17	225,000	5,000
18	225,000	5,000
19	225,000	5,000
20	225,000	5,000
21	0	5,000
22	0	5,000
23	0	5,000
24	0	5,000
25	0	5,000

Calculation of your reward

The payoff you earn in each trading period is determined according to the following formula:

Your payoff in a trading period

$$= \sqrt{Quantity\ of\ the\ purchased\ commodity\ in\ this\ period}$$

For example, if you buy 4 (=20,000/5,000) units of the commodity for 20,000 points, then your payoff in this period is 2. The monetary amount you earn in this experiment is determined according to the following formula:

Your earnings in the experiment

$$= ¥500 + ¥12 \times \{(Payoff\ in\ period\ 1) + (Payoff\ in\ period\ 2) + \cdots + (Payoff\ in\ period\ 25)\},$$

where the mark "¥" stands for "Japanese Yen." That is, the sum of all payoffs you earned in each period multiplied by 12 in addition to the showing-up fee of 500 yen will be your reward in the experiment. Your reward will be paid in cash at the end of the experiment.

Note: The quantity of the purchased commodity is not necessarily an integer but is sold by measure. For reward amounts smaller than ¥1, we round down. Points not used up at the end of the last period will be irrelevant to your earnings.

<u>Experimental procedure</u>

Note: Please do not start using the PC until directed to do so.

Step 1: Please answer the practice exercises.

The following figure shows the sample computer screen.[7] Please input your answer within the box marked in yellow. Please answer all the questions. After checking all

[7] See Practice Problems in this Appendix for the actual exercises.

questions, please click the “Next” button.

Problem ##

(1) **

answer [ ]

(2) **

answer [ ]

Please click the “Next” button after answering all questions. [Next]

If the question is answered incorrectly, a warning is displayed. If a warning message appears, please note the mistake, and answer the question again. You can progress to the next step after correctly answering all questions.

Step 2: Please practice purchasing the commodity.

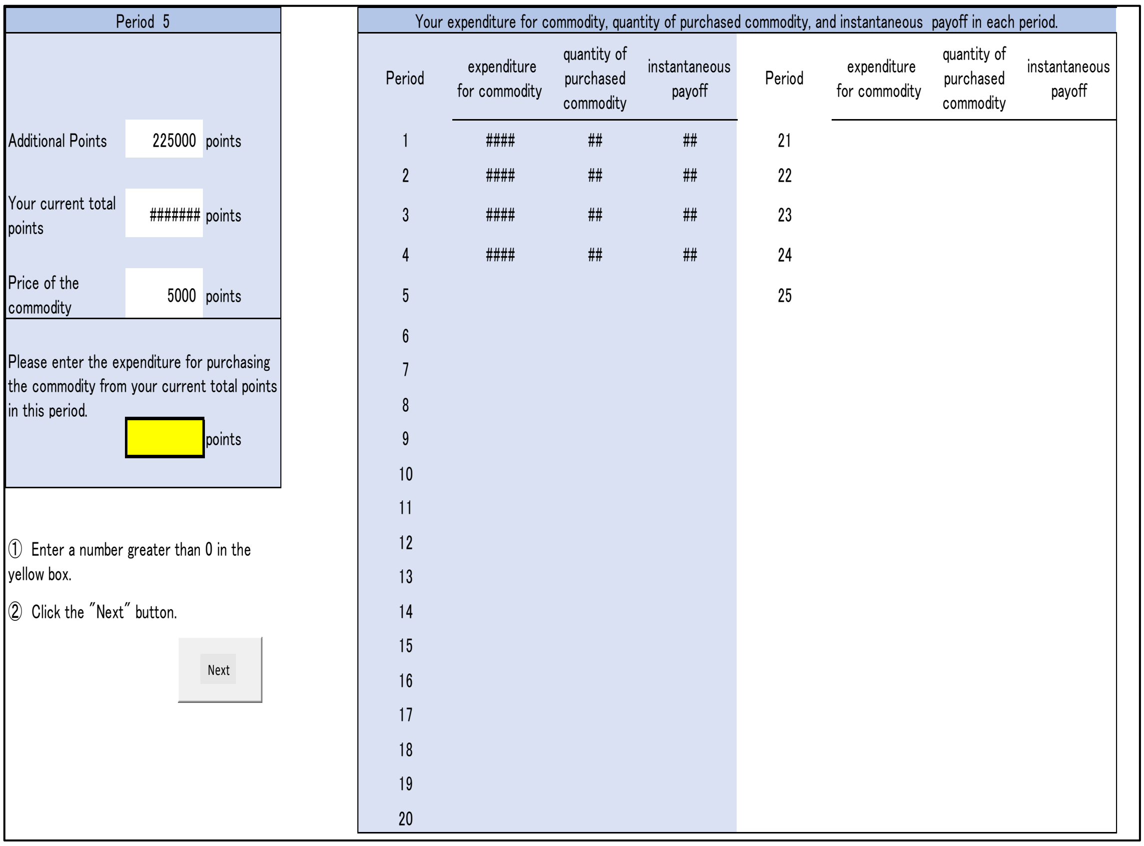
This exercise consists of 6 trading periods. From the 1^{st} to the 3^{th} period, you will be given 1,000 points for purchasing the commodity at the start of each period. From the 4^{th} to the last period, you will not be given any additional points. The price of the commodity is fixed at 100 points. As in the experiment, please choose the number of points in each period. The calculation of the payoff for each period is the same as in the actual experiment, but the payoff earned in this exercise is not reflected in your reward.

Step 3: Please confirm your ID number.

After you finish Step 2, you will see your ID number on the display. Please confirm your ID number. If the displayed ID number is incorrect, please let us know by raising your hand.

Step 4: Please start the experiment.

Please decide the number of points used to purchase the commodity in sequential order from the first to the 25th period. The following figure shows a sample computer screen during the fifth period.



On the computer screen, you can confirm the following information:

- **Current trading period:** The top of the left area shows the current trading period.
- **Additional points:** The number of points you will be given at the start of this period is displayed as "Additional points." In periods where you will not be given any points, your additional points are displayed as "0 points."
- **Your current total points:** This is the amount of money you currently hold, which is the maximum amount you can spend in this period. Points are displayed with up to two decimal places.
- **Price of the commodity:** This is the price of the commodity.
- **Quantity of purchased commodity, Expenditure for commodity, and payoffs:** In the right area of the screen, quantities of the commodity you purchased, expenditure for commodity, and payoffs in past periods are displayed. Quantities of the commodity are not always an integer because they are calculated as the points you enter for purchasing the commodity divided by 5,000 points, the price of the commodity. Quantities of the commodity and payoffs are displayed with up to two decimal places.

After you confirm your current total points, within the yellow box, please input <u>the number of points</u> used for purchasing the commodity. You can input a decimal number in this box. However, you cannot input a negative number or a number that exceeds your current total points. If you have 0 points, you can only input "0." When you click the "Next" button, the screen automatically switches to the next period screen. <u>Once you click the "Next" button, you will not be able to return to the previous screen</u>. If you need a calculator, please use the one on your desk. You are prohibited from using any calculator applications installed on your PC.

Step 5: Please confirm your earnings, and call a staff member.

After the 25th period is completed, your earnings in this experiment are displayed on the computer screen.

Your earnings in this experiment are ¥ ####

Please confirm your earnings, and then call a staff member, who will save your experiment result.

Step 6: Please answer the questionnaire.

A staff member will give you a questionnaire. Please answer all the questions.

Step 7: Please move to the payment office.

After answering all the questions in the questionnaire, please go to the payment office with your ID card and the questionnaire. Your cash reward will be paid there. When you leave your seat, please just take your ID card and the questionnaire; do not take the handouts.

Warning

If you do something that is not part of the instructions, a system error may occur. If we cannot obtain the experiment results because of your mistake, you will not be rewarded.

If you fully understand these instructions, please raise your hand quietly. A staff member will activate the computer.

Practice Problems and Training of PC operation

(the original text was in Japanese)

Problem 1: Enter the most suitable numerical value for the following parentheses.

(1) The experiment consists of ( ) trading periods.

answer [ ]

(2) Additional points are awarded in each period from period 1 to period ( ).

answer [ ]

Please click the "Next" button after answering all questions.

[Next]

Problem 2: For each of the following sentences, select the number of the most appropriate phrase for the parentheses.

(1) At each trading period, you decide ( ).

1. expenditure on the commodity 2. quantity of the commodity

answer [ ]

(2) If the price of the commodity is 100 and your expenditure on the commodity is 250 points in the current period, the quantity of the purchased commodity in the current period is ( ).

1. 1 unit 2. 2 units 3. 2.5 units

answer [ ]

Please click the "Next" button after answering all questions.

[Next]

Problem 3: Suppose that there are only two periods, and you will be given 1,800 points in period 1 and 0 points in period 2. If the price of the commodity is 100 points in both periods, which of the following plans will maximize your earnings?

1. purchasing 18 units of the commodity in the first period
2. purchasing 18 units of the commodity in the second period
3. purchasing 9 units of the commodity in the first period and 9 units of the commodity in the second period

answer [ ]

Please click the "Next" button after answering the question.

[Next]

Training of PC operation: To get used to the computer operation, please solve a life-cycle consumption problem with six periods. In this exercise, there are only six periods, and you will be given 1,000 points in each period from 1 to 3 and 0 points in the rest of the periods. The price of the commodity is always 100 points. There are no rewards for this practice.

Please click the "Next" button after reading the above explanation.

[Next]

Period 1

Additional Points	1000	points
Your current total points	1000	points
Price of the commodity	100	points

Please enter the expenditure for purchasing the commodity from your current total points in this period.

① Enter a number greater than 0 in the yellow box.
② Click the "Next" button.

Next

Your expenditure for commodity, quantity of purchased commodity, and instantaneous payoff in each period.

Period	expenditure for commodity	quantity of purchased commodity	instantaneous payoff	Period	expenditure for commodity	quantity of purchased commodity	instantaneous payoff
1				4			
2				5			
3				6			