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THE EFFECTS OF INFLATION AND INTEREST RATES ON DELAY DISCOUNTING IN HUMAN BEHAVIOR

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Interest and inflation rates may be major determinants of delay discounting, but these variables have not been controlled in past experiments because they depend on macroeconomic conditions. This study uses a computer game-like task to investigate the effects of inflation rates on people's subjective valuation of delayed rewards. During the task, participants saved virtual money, received interest, and bought items under inflation and interest rate conditions controlled by the experimenter. The subjective values participants placed on delayed rewards were measured during choice periods, after participants learned of item price changes and expected interest earnings. In 2 of 3 experiments, the effects of inflation rates were investigated when the nominal interest rate (Experiment 1) or the real interest rate (Experiment 3) was constant across the 3 experimental conditions (inflationary, zero-inflationary, and deflationary). The effect of nominal interest rates under the deflationary condition was also investigated (Experiment 2). The results suggest that inflation and interest rates affect participants' subjective discounting of delayed rewards.

Humans regard a delayed future reward as less valuable than an immediate reward if the amount of the reward is the same. The present value of a future reward is discounted in proportion to the length of time before the reward is received. Previous studies of delay discounting (Loewenstein & Prelec, 1992; Mazur, 1987; Rachlin, Raineri, & Cross, 1991) have shown that the preference between delayed and immediate rewards is well described either by the following hyperbolic function:

$$V = \frac{A}{1 + kD} \tag{1}$$

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in which V is the present discounted value of the delayed reward, A is the amount of the delayed reward, D is the length of the delay, and k is the discount rate.

However, normative economic models assume that future value is discounted exponentially as length of delay increases, as follows:

$$V = Ae^{-kD} \quad (2)$$

The exponential model applies to the discounting of delayed rewards such as those provided by bank accounts. The amount of savings in a bank account increases through the compounding of a fixed interest rate over time. For example, if you save $100 in a bank account at a 10% rate of interest for 10 years, you will receive $259 in 10 years; that is to say, the present value of $259 that is to be received in 10 years is $100.

Two seemingly more influential economic factors affecting delay discounting are the inflation rate and the nominal interest rate. The inflation rate is an index of the rate of change of the prices of goods and services in an economy. In an economy with 10% annual inflation, a price of $100 today will be $110 next year. That is, the purchasing power of $100 is reduced to approximately 90% of its current value in 1 year. With regard to delay discounting experiments, an understanding of the impact of inflation on purchasing power may contribute to participants valuing delayed rewards less than immediate rewards.

Ostaszewski, Green, and Myerson (1998) showed that the subjective discounting rate for Polish zloty was much higher than that for the U.S. dollar in 1994 when the inflation rate of zloty was very high, but was about the same in 1996 when the inflation rate of zloty got lower. Ostaszewski et al. (1998) does not fully succeed, however, in showing the effects of inflation because interest and inflation rates cannot be controlled by experimenters. The inflation rate in Poland (about 33% in 1994 and 20% in 1996) was very high even in 1996 compared to that of the United States (about 3% during the same periods). Interest rates in Poland in 1994 (28.8 %) were higher than those in 1996 (20.3%) (International Monetary Fund, 1997).

The nominal interest rate is an exchange rate between present and future money. Saving $100 in a bank account at 5% interest means forgoing spending $100 in the present in exchange for $105 to be received after 1 year. This implies that you value having $105 next year more than having $100 at present.

Subtracting the inflation rate (or expected inflation rate) from the nominal interest rate yields the real interest rate:

$$\text{Real interest rate} = \text{Nominal interest rate} - \text{(Expected) inflation rate} \quad (3)$$

The real interest rate is also important with regard to purchasing power. If the real interest rate is constant, the purchasing power of money in a bank account remains nearly constant even if the nominal interest rate and inflation rate change.

The nominal interest rate determines the objective discounting of delayed reward if the real interest rate is greater than zero. The present value of delayed reward can be calculated from Equation 2 using the nominal interest rate as *k*. In other words, if the sum of an immediate reward and its compound interest for the delay yields the same amount of the delayed reward, such amount of the immediate reward is the present value of delayed reward. If the immediate reward is greater than the present value, the purchasing power of the immediate reward always exceeds the delayed reward, because the real interest is positive, so that participants should choose the immediate reward. If the immediate reward is less than the present value, they should choose delayed reward.

Table 1

Reward Values Over Time Under Three Hypothetical Economics (Experimental Conditions in Experiment 1)

Year	Price	Immediate reward with compound interest: Dollar	Immediate reward with compound interest: Power	Delayed reward: Dollar	Delayed reward: Power
		Economy X: Inflationary condition (inflation: 1%, nominal interest: 1%)			
0	$100.00	$69.89	0.699	-	-
12	$112.68	$78.76	0.699	-	-
24	$126.97	$88.74	0.699	-	-
36	$143.08	$100.00	0.699	$100	0.699
		Economy Y: Zero-inflationary condition (inflation: 0%, nominal interest: 1%)			
0	$100.00	$69.89	0.699	-	-
12	$100.00	$78.76	0.788	-	-
24	$100.00	$88.74	0.887	-	-
36	$100.00	$100.00	1.000	$100	1.000
		Economy Z: Deflationary condition (inflation: -1%, nominal interest: 1%)			
0	$100.00	$69.89	0.699	-	-
12	$88.64	$78.76	0.889	-	-
24	$78.57	$88.74	1.130	-	-
36	$69.64	$100.00	1.436	$100	1.436

Note. Immediate rewards have the same purchasing power as delayed rewards saved for 36 years in Economy X (1% inflation, 1% nominal interest), Economy Y (0% inflation, 1% nominal interest), and Economy Z (-1% inflation, 1% nominal interest). Because the nominal interest rate was the same across the three economies, the immediate reward equal in purchasing power to the delayed reward after the delay was $69.89, regardless of inflation rate.

Table 1 shows immediate rewards that have the same purchasing power as delayed rewards after being saved for a given period in three different hypothetical economies (Economy X, which has 1% inflation and 1% nominal interest rates; Economy Y, which has 0% inflation and 1% nominal interest rates; and Economy Z, which has -1% inflation and 1% nominal interest rates). The prices of items rise in Economy X, stay unchanged in Economy Y, and decrease in Economy Z. Immediate rewards earn compound interest at 1% per annum in all three economies. Note that the amount of the immediate reward in Year 0, the purchasing power of which will be equal to that of the delayed reward ($100) in Year 36, is the same, $69.89, because the nominal interest rate is the same in all three economies. Although the purchasing power of immediate and delayed rewards becomes different over time in the three economies, the purchasing power of the saved immediate reward does not decrease in any of the three economies because the real interest rate in each is not negative. Hence, any immediate reward greater than $69.89 is more valuable in terms of purchasing power than a delayed reward of $100 received after 36 years.

In everyday situations, people make decisions on whether they consume money now or save for later use. So, it is important to note that participants generally have the option, when choosing between immediate and delayed rewards, of saving any immediate rewards in their bank accounts and earning interest. But almost every delay discounting experiment has used hypothetical money and therefore it is possible that participants did not consider saving hypothetical money and earning interest from it.

"Money illusion" is the tendency to think in terms of nominal rather than real monetary value (purchasing power). Shafir, Diamond, and Tversky (1997) using the questionnaire method, showed that participants' judgments were influenced by money illusion in various situations. If participants of delay discounting experiments were influenced by inflation rate, it can be said they were under money illusion.

This study uses a computer game-like task to investigate the effects of interest and inflation rates on delay discounting in human behavior. By using virtual money, the experimenter was able to control the value of immediate and delayed rewards in terms of purchasing power. The value of the items the participants bought with the virtual money was constant, because the items were exchanged at the end of the task for real money (yen) of fixed value (that is, the value of the items did not depend on the amount of virtual money used to buy them).

The purpose of Experiment 1 was to investigate the effect of the inflation rate on delay discounting when the nominal interest rate is constant. Three inflationary conditions were investigated: 1% (inflationary), 0% (zero-inflationary), and -1% (deflationary). The nominal interest rate was constant at 1% across the three conditions. These conditions are the same as those of the hypothetical economies in Table 1, so that the objective discounting of delayed rewards, in terms of purchasing power, would be the same under each condition.

The experiment comprised one practice phase and three experimental phases. One of the three conditions (inflationary, zero-inflationary, and deflationary) was assigned to each of the three experimental phases, and the order in which the three phases were presented to the participants was varied in a balanced manner. Each phase consisted of an initial "game period," a "choice period," and a second game period.

In this task, participants were able to save virtual money in a currency called "moku," earn interest, and buy items during the game periods of the task. The experimenter adjusted the inflation and interest rates during these periods. After participants learned of price changes and changes in expected interest to be earned during the initial game periods, the subjective values of delayed rewards were measured during choice periods. The delayed or immediate rewards chosen in the choice periods were paid as the "bonus" during the second game periods.

Experiment 1

Method

Participants. Eighteen undergraduate students at Waseda University (11 women and 7 men ranging in age from 19 to 21 years) served as participants. All were psychology majors who participated in this study to satisfy a course requirement. All participated with the understanding that they would earn money based on their performance. Participants were informed that their average earnings-per-hour would be on the same order as what undergraduates usually earn at part-time jobs.

None of the participants had previously taken courses in behavior analysis, and none had previously participated in experiments on delay discounting.

Apparatus. Participants worked alone in a sound-attenuating chamber (175 cm high x 85 cm long x 130 cm deep), seated in front of a computer monitor (30.4 cm x 22.8 cm), mouse, and keyboard. An indirect lamp illuminated the chamber. A ceiling-mounted exhaust fan and a ventilator on the floor provided ventilation and masked extraneous sounds. Events were controlled and recorded using an IBM PC-compatible computer with control software written in Delphi7®.

Procedure. Participants were instructed not to bring clocks or mobile phones into the experimental chamber. Participants entered the experimental chamber and seated themselves in front of the computer monitor. Participants were then instructed that during the practice phase, which would take about 10 min, and the three experimental phases, each of which would take about 35 min, they would have opportunities to save virtual money (moku), and to use this virtual money to buy virtual items during the task that would be exchanged for real money (yen) at the end of the task. Participants were then provided with instructions for performing the task and encouraged to buy as many virtual items as possible in order to obtain the maximum amount of real money at the end of the task.

The practice phase was conducted to accustom participants to the task. The circumstances of the experimental phases were mostly similar to those of the practice phase, except that there were more turns during the game periods and more choices presented during the choice period.

After the instructions, the initial game period in the practice phase began. In the game period, the game-flow was partitioned by a "turn," a unit of time in this experiment. At the beginning of each turn, an information window showing turn number, income, interest, and bonus (in moku) was displayed on the monitor for 3 s. The amount of income per turn was two times the item price in the current turn. The amount of interest was the savings times the interest rate. During the initial game period, the bonus was always zero.

After the information window disappeared, the main window of the game period was displayed on the monitor for 8 s. The current turn number was displayed at the top of this window. The amount of savings, the interest rate, and the expected interest to be paid in the next turn were displayed on the left side of the window. The total number of items purchased and the item price were displayed on the right side of the window.

In the first turn, the amount of savings was 1,000 moku. Income, interest, and bonus were added to the amount of savings in subsequent turns. The expected interest was the interest that could be earned in the next turn, calculated by multiplying the current savings and the interest rate. The total number of items purchased was the accumulated number of items bought by participants during the task up to the current turn. The initial item price was calculated according to the inflation rate for the experimental phase such that the price at the beginning of the second game period was 100 moku.

While the main window was displayed, participants could buy items by left-clicking the mouse. When participants bought an item, the item price was subtracted from the savings, the total number of items purchased increased by one, and the expected interest decreased according to the decrease in savings. Participants could buy as many items as they wanted, as long as they had enough in their savings to pay for them. After the main window was displayed for 8 s, the information window was displayed to begin the next turn.

When the fourth turn in the initial game period of the practice phase was finished, a dialog box appeared which said, "The choice period will now begin. Please choose either the alternative on the left or right as pairs of alternatives are presented. Press OK to start."

After clicking the "OK" button, a choice window, in which each pair of alternatives was presented, was displayed on the monitor for 6 s. At the top of the window, the following text appeared: "Which one do you prefer?" The alternatives were presented on two gray square buttons (8.5 cm x 8.5 cm). Each button displayed an amount and a delay before the amount would be received; for example, the text might read "20 moku, to be paid immediately after the end of the choice period" or "100 moku, to be paid 8 turns after the end of the choice period." The button on the left always offered the immediate reward, and the amount of the reward (in moku) varied; the amount on the left button may thus be termed the "variable amount." The button on the right always offered the delayed reward, and the amount of the reward was fixed at 100 moku; the amount on the right button may thus be termed the "standard amount."

After a participant clicked one of the two buttons, the color of the button would change to blue. If the participant clicked another button to change his or her selection, the newly clicked button turned blue, and the previously clicked button reverted to gray. If a participant did not click either button within 6 s, one of the buttons was selected at random automatically.

After the choice window was displayed for 6 s, a confirmation window was displayed on the monitor for 2 s. This window stated the results of the choices the participants had made, displaying text such as, "I will pay you 100 moku 12 turns after the end of the choice period." After this confirmation window disappeared, the choice window was displayed again.

For the practice phase, five choices were presented during the choice period. At the end of the series of five choices, a dialog box appeared which said, "The choice period has ended. Please click OK to start the second game period."

The second game period was a continuation of the initial game period. The amount of savings and the number of items purchased were the same as those at the end of the last turn of the first game period. The item price on the first turn of the second game period was 100 moku. The only difference was that the bonuses were paid at the appropriate turns according to the choices that participants had made during the choice period.

When the "OK" button was clicked to begin the second game period, an information window appeared. The bonuses for rewards that were to be paid immediately after the choice period were totaled and displayed in the information window. For the practice phase, the second game period comprised six turns. When the sixth turn in the second game period ended, a final window appeared showing the value of the items in yen to be paid by the experimenter. The experimenter handed participants the amount in yen as indicated. Participants then left the experimental chamber and sat nearby.

After a 2-min rest period, participants received instructions explaining that both the game and choice periods of the experimental phases would be longer than those of the practice phase, and that the interest rate, item price, and their income would also be different.

As noted above, the settings and procedures of the game periods were mostly the same as those of the practice phase, except that the numbers of turns, the interest rates, and the inflation rates were different. The initial game period of the experimental phases comprised 70 turns. The inflation rates for the three phase conditions were 1% (inflationary), 0% (zero-inflationary), -1% (deflationary). The interest rate for all three conditions was 1%. The item price for the first turn of phases under the inflationary condition was 49 moku, increasing each turn to reach 100 moku at the first turn of the second game period. Similarly, the item price for the first turn of phases under the deflationary condition was 204 moku, decreasing each turn to reach 100 moku at the first turn of the second game period. The item price of phases under the zero-inflationary condition was fixed at 100 moku.

During the choice period of the experimental phases, a random adjusting-amount procedure was used to measure the subjective values of delayed rewards of 3, 6, 12, 24, and 32 turns for participants (Richards, Zhang, Mitchell, & de Wit, 1999). This procedure sets the reward amount and the delays before delayed rewards are received, changing the amounts of immediate rewards according to the choices made by participants. The procedure randomly presents the choices concerning target delays as well as distracter choices so that participants do not become aware that the amounts on offer are being adjusted based on their responses.

In this experiment, rewards of 100 moku delivered after five target delays (3, 6, 12, 24, and 36 turns) were defined as standard amounts. The amounts of the immediate reward alternatives, which were adjusted, were termed variable amounts. The variable amounts were randomly selected from the range of values between the limits used in the random adjusting-amount procedure. These limits included a maximum top limit and a minimum top limit, as well as a maximum bottom limit and a minimum bottom limit. The maximum and minimum top limits for the standard amounts were both 100 moku, and the maximum and minimum bottom limits were 0 moku for the first question. The variable amount for the alternative paired with each standard amount was selected randomly from the range of values between the maximum top limit and maximum bottom limit, in 5 moku increments.

Following the rules of Richards et al. (1999), this range was narrowed according to choices the participants made. If participants chose standard amounts, the top and bottom limits for the next variable amount alternative with which they were presented increased. If the participant chose the variable amount, the top and bottom limits on the next variable amount alternative with which they were presented decreased. If the difference between the maximum top limit and the maximum bottom limit became less than 5 moku, the mean of these limits was considered the subjective value of the standard amount.

The five standard amounts and distracters were selected in random order as alternatives. The probability of selecting a distracter alternative was 15%, and the probability of selecting any of the standard amounts was the same. If one of the standard amounts reached the subjective value, alternatives offering that standard amount did not appear again.

When the subjective values of all of the standard amounts were measured, the choice period ended. However, even if the subjective values of one or more of the standard amounts could not be measured, the choice period ended when the number of alternative pairs reached 110. When this happened, the mean of the maximum top and bottom limits were considered the subjective values of the remaining standard amounts (that is, even though the difference between the limits had not yet become less than 5 moku).

The second game period for the experimental phases began after the choice period. The settings and procedures of the second game period were the same as those of the initial game period except for the number of turns. The second game period comprised 43 turns. The purpose of the second game period was to enable participants to receive the bonus money they earned during the choice period. The total of the immediate rewards (variable amounts) chosen during the choice period was paid in the first turn of the second game period. The total of delayed rewards (standard amounts) chosen during the choice period were paid at the 3rd, 6th, 12th, 24th, and 36th turns, as appropriate.

After the second game period ended, the experimenter handed participants an amount in yen equal to the amount in yen payable displayed on the monitor. A 2-min rest period was inserted between experimental phases. Average earnings for phases under each of the three conditions were ¥482 (inflationary), ¥600 (zero-inflationary), and ¥887 (deflationary), respectively. Average total earnings were ¥1,968.

Results and Discussion

Figure 1 shows the group median subjective values as a function of delay under the deflationary (triangles), zero-inflationary (squares), and inflationary (diamonds) conditions. The curved lines represent the hyperbolic discounting functions (Equation 1), fitted to the median data of deflationary (k = 0.012, R^2 = 0.962), zero-inflationary (k = 0.018, R^2 = 0.991), and inflationary (k = 0.024, R^2 = 0.996) conditions. As Figure 1 shows, the subjective values of delayed rewards decreased as a function of delay under all conditions. The delayed reward under the inflationary condition was discounted more steeply than under the zero-inflationary and deflationary conditions.

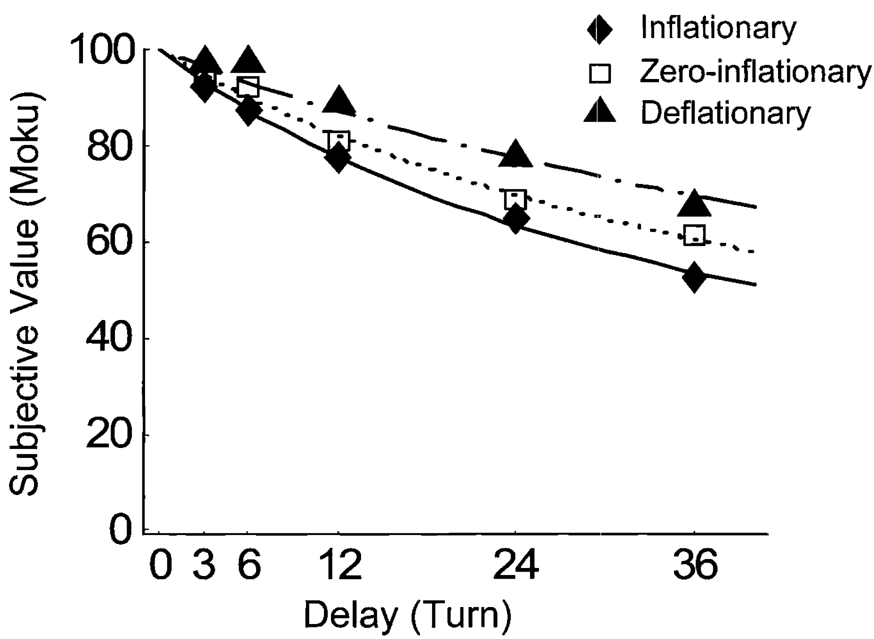

Figure 1. Median subjective values and fitted curves of hyperbolic function ($V = A / 1{+}kD$) for inflationary (diamonds), zero-inflationary (squares), and deflationary (triangles) conditions.

To quantify differences in discounting under the various conditions, the area under the curve of observed subjective values was calculated for each participant under each condition (Myerson, Green, Hanson, Holt, & Estle, 2003; Myerson, Green, & Warusawitharana, 2001). Smaller areas under the discounting curve reflect steeper discounting. The means of the areas under the curve for all participants were 0.656 (inflationary), 0.687 (zero-inflationary), and 0.817 (deflationary). The area under the curve for objective discounting, calculated from the exponential discounting curve at a 1% nominal interest rate, is 0.84. One sample *t* test (two-tailed) showed that the means of the areas for all participants were different from the area of the corresponding curve for objective discounting under the inflationary condition, $t(17) = 3.85$, $p < .01$, and the zero-inflationary condition, $t(17) = 2.87$, $p < .05$. These results suggest that the observed discountings were steeper than objectively optimal to maximize purchasing power.

A repeated measures analysis of variance (ANOVA) on area under the curve showed a significant main effect of inflation rate, $F(2, 34) = 4.03$, $p < .05$. Post hoc, pairwise *t* test with a Bonferroni adjustment revealed that only the means between inflationary and deflationary condition were significantly different, $t(17) = 2.32$, $p < .05$.

These results suggest that inflation rate has an effect on the discounting of delayed rewards, although objectively, the delay discounting behavior that maximizes purchasing power is the same at any inflation rate.

It can be said that the participants were under "money illusion" because their choices between immediate and delayed rewards were not optimal and were influenced by inflation rate. The participants' choices may be, however, influenced by real value of delayed rewards, which depend on inflation rate, without thinking about the compound return of interest. The purchasing power of delayed reward (100 moku) was varied with the inflation rate. For example, the purchasing power of 100 moku after 36 turns was about 0.699 items for inflationary condition, 1 item for zero-inflationary condition, and about 1.436 items for deflationary condition (see Table 1). It is very easy for the participants to think that the purchasing power of delayed reward will decrease in inflationary condition, whereas it will increase in deflationary condition. Moreover, to calculate compound interest for immediate reward after 36 turns is very difficult. Experiment 2 investigated whether the participants were sensitive to nominal interest rate while the inflation rate was constant. Because inflation rate was constant, the purchasing power of delayed reward was constant.

Experiment 2

Although Experiment 1 showed that inflation rate has an effect on discounting behavior, it is possible that the nominal interest rate does not affect delay discounting. Experiment 2 investigated the influence of the nominal interest rate on the discounting of delayed rewards using 0%, 0.5%, and 1.5% nominal interest rates as experimental conditions. The inflation rate in the task was constant at -1% (deflationary), so that the real interest rate was positive even when the nominal interest rate was 0%. If the real interest rate were negative, objective discounting would not depend on the nominal interest rate.

The discounting of delayed rewards will be strong as the nominal interest rate increases. For 0% nominal interest rate, the immediate reward will not increase by saving so that the delayed reward should not be discounted objectively. As the nominal interest rate increase (0.5% and 1.5%), the delayed rewards will be discounted strongly because the immediate rewards will earn more interest by saving.

Method

Participants. Eighteen undergraduate students at Waseda University (10 women and 8 men ranging in age from 19 to 22 years) served as participants. As in Experiment 1, all were psychology majors who participated in this study to satisfy a course requirement. The same instructions that were given to participants in Experiment 1 were given to participants in this experiment prior to participation.

Apparatus. The apparatus employed in Experiment 1 was also employed in this experiment.

Procedure. The procedure was identical to that employed in Experiment 1, except for the following details. The nominal interest rate in the game periods served as the experimental condition. Three nominal interest rates were employed: 1.5%, 0.5%, and 0%. The inflation rate under all three conditions was constant at -1% (deflationary).

Average earnings for each condition were ¥577 (0%), ¥721 (0.5%), and ¥1,110 (1.5%). Average total earnings were ¥2,408.

Results and Discussion

Figure 2 shows group median subjective values as a function of delay for the 0% (triangles), 0.5% (squares), and 1.5% (diamonds) conditions. The curved lines represent hyperbolic discounting functions (Equation 1), fitted to the median data of 0% (k = 0.002, R^2 = 0.485), 0.5% (k = 0.013, R^2 = 0.892), and 1.5% (k = 0.022, R^2 = 0.519) conditions. As Figure 2 shows, the subjective values of delayed rewards decreased as a function of delay under all conditions. The delayed reward under the 1.5% nominal interest rate condition was discounted more steeply than under the 0.5% and 0% condition. Notably, delayed rewards were only slightly discounted under the 0% condition.

The means of area under the curve of observed subjective values under each condition were 0.682 (1.5%), 0.742 (0.5%), and 0.866 (0%). The areas under the curve for objective discounting, calculated from the exponential discounting curve, were 0.774 for the 1.5% condition, 0.915 for the 0.5% condition, and 1 for the 0% condition. One sample t test (two-tailed) showed that the means of area under the curve of observed subjective values were different from the area of the corresponding curve for objective discounting at the 0.5% condition, $t(17) = 3.38$, $p < .01$, and the 0% condition, $t(17) = 3.56$, $p < .01$. Again, these results suggest

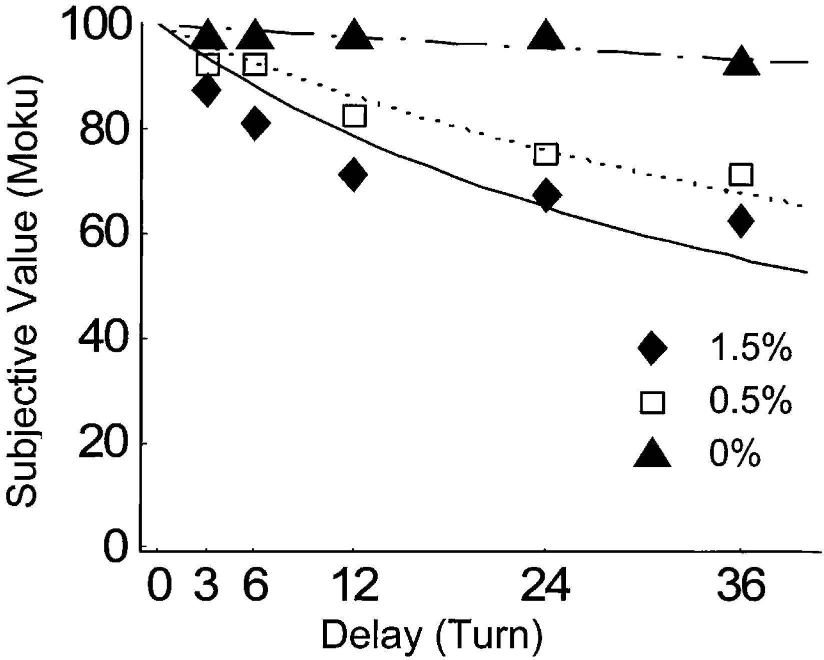

Figure 2. Median subjective values and fitted curves of hyperbolic function ($V = A$ / $1+kD$) for 1.5% (diamonds), 0.5% (squares), and 0% (triangles) conditions.

that the observed discountings were steeper than objectively optimal to maximize purchasing power.

A repeated measures analysis of variance (ANOVA) on area under the curve showed a significant main effect of nominal interest rate, $F(2, 34) = 5.58$, $p < .01$. Post hoc, pairwise t test with a Bonferroni adjustment revealed that the means between 0% and 1.5% condition were significantly different, $t(17) = 2.86$, $p < .05$.

These results suggest that nominal interest rate has an effect on discounting of delayed rewards. The participants recognized the power of compound interest and in delay discounting they paid attention not only to inflation rate, but also to real value (purchasing power). The participants, however, did not correctly calculate how much the immediate reward would increase with nominal interest rate. Their discounting was not optimal as in Experiment 1. The delayed rewards in 0% condition were discounted slightly although objective discounting is not to discount at all. The delayed rewards in 0.5% condition were also discounted too much.

Experiment 3

Experiments 1 and 2 showed that both inflation and nominal interest rates affect subjective delay discounting. The purpose of Experiment 3 was to investigate the effect on delay discounting of different combinations of nominal interest and inflation rates that yield the same real interest rate. The combinations of nominal interest and inflation rates investigated as experimental conditions were, 1% and 3% (inflationary), 0% and 2% (zero-inflationary), 1% and -1% (deflationary); the real interest rate (nominal interest rate minus inflation rate) was thus constant across all three conditions, such that the purchasing power of the amount of money that participants received after completing the task was approximately the same under each of the conditions.

Method

Participants. Eighteen undergraduate students at Waseda University (13 women and 5 men ranging in age from 19 to 20 years) served as participants. As in Experiments 1 and 2, all were psychology majors who participated in this study to satisfy a course requirement. The same instructions that were given to participants in Experiments 1 and 2 prior to participation were given to participants in this experiment.

Apparatus. The apparatus employed in Experiments 1 and 2 was also employed in this experiment.

Procedure. The procedure was identical to that employed in Experiment 1, except for the following details. The combinations of nominal interest and inflation rate in each experimental condition were 3% and 1% (inflationary), 2% and 0% (zero-inflationary), and 1% and -1% (deflationary).

Average earnings for each condition were ¥645 (inflationary), ¥616 (zero-inflationary), and ¥684 (deflationary). Average total earnings were ¥1,946.

Results and Discussion

Figure 3 shows the group median of subjective values plotted as a function of the delay for the deflationary (triangles), zero-inflationary (squares), and inflationary (diamonds) conditions. The curved lines represent hyperbolic discounting functions (Equation 1), fitted to the median data of deflationary ($k = 0.021$, $R^2 = 0.146$), zero-inflationary ($k = 0.021$, $R^2 = 0.408$), and inflationary ($k = 0.037$, $R^2 < 0$) conditions. As Figure 3 shows, the subjective value of delayed rewards decreased as a function of the delay under all conditions. The delayed reward under the inflationary condition was discounted more steeply than under the zero-inflationary and deflationary conditions.

The means of area under the curve of observed subjective values under each condition were 0.590 (inflationary), 0.670 (zero-inflationary), and 0.727 (deflationary). The areas under the curve for objective discounting, calculated from the exponential discounting curve, are 0.616 for the inflationary condition, 0.715 for the zero-inflationary condition, and 0.84 for the deflationary condition. One sample *t* test (two-tailed) showed that only the mean of the area under the curve of observed subjective values under the deflationary condition was different from the area of the corresponding curve for objective discounting, $t(17) = 2.72$, $p < .05$.

A repeated measures analysis of variance (ANOVA) on area under the curve showed a marginally significant main effect of combinations

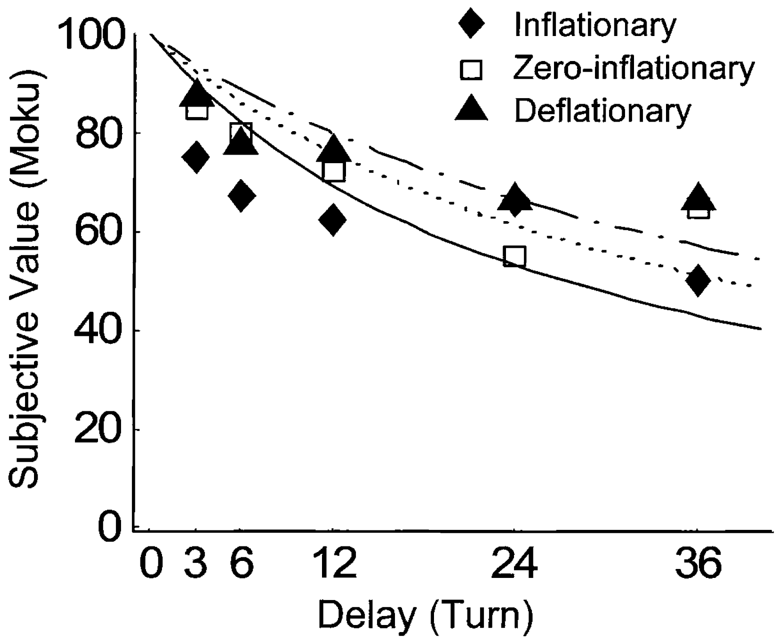

Figure 3. Median subjective values and fitted curves of hyperbolic function ($V = A / 1+kD$) for inflationary (diamonds), zero-inflationary (squares), and deflationary (triangles) conditions.

of nominal interest and inflation rates, $F(2, 34) = 3.56$, $p = 0.05$. Post hoc, pairwise t test with a Bonferroni adjustment showed no significant differences among the means of area under the curve.

These results suggest that different combinations of nominal interest and inflation rates yielding the same real interest rate have an effect on the discounting of delayed rewards, but that the effect is not strong. If the effects of inflation and nominal interest rates were additive, the delayed reward would have been strongly discounted in the inflationary condition in Experiment 3 that simulated high inflation and nominal interest rates. It is possible that the effect of nominal interest rate depends on the inflation rate.

General Discussion

The results of the three experiments suggest that the subjective discounting of delayed rewards is strongly affected both by inflation and interest rates. The inflation rate influenced subjective discounting when the nominal interest rate was constant (Experiment 1), a result that is consistent with the findings of Ostaszewski et al. (1998), even though the objective discounting of delayed rewards was unaffected by inflation rates if participants chose alternatives according to the purchasing power of delayed rewards. The finding that the inflation rate affects discounting is consistent with the "money illusion," the tendency of participants to judge according to nominal value, rather than real value (purchasing power) (Shafir et al., 1997).

The nominal interest rate also affected delay discounting (Experiment 2). This finding suggests that experimenters should pay attention to not only the inflation rate but also the nominal interest rate of the economy in which delay discounting experiments are conducted.

Different combinations of inflation and nominal interest rates that yielded the same real interest rate also had some effect on delay discounting (Experiment 3). The inflation rate, nominal interest rate, and real interest rate are linked, as in Equation 3, so they cannot be controlled independently. However, the results of this study suggest that subjective discounting of delayed rewards may be affected by any two of these rates, independent of the third (that is, even when one of the rates is fixed).

The results of this study have implications for the relationship between individual discounting and market discounting. Long-term interest rates in a given economy are based on official discount rates and the transactions of government bonds in that economy. People buy and sell bonds according to the perceived probability of redemption, expected inflation rate, their expectations regarding short-term interest rates in the future, and so on (James & Webber, 2000). Long-term interest rates can therefore be seen as aggregate measures of expected value of money in the future. Similarly, inflation rates in a given economy depend on the supply/demand balance, the money supply, and other factors. The prices of items are based on transactions of those items, and may therefore be seen as aggregate measures of opinions on the value of the items. In general, macroeconomic factors like interest and inflation rates represent aggregates of microeconomic activities.

The present results, however, show that individual subjective discounting is also affected by macroeconomic factors (interest and inflation rates). Even though macroeconomic conditions are aggregations of microeconomic activities, macroeconomic conditions constitute the economic environment, which in turn influences participants in the economy. Macroeconomic factors may affect subjective discounting in any delay discounting experiment. Participants in economies with high inflation rates may show much higher subjective discounting than those in economies with low inflation rates, as shown in Ostaszewski et al. (1998). Macroeconomic conditions in the countries where delay discounting experiments are conducted must therefore be considered in comparisons of experimental results.

Thus, the results of delay discounting experiments from different countries and times should not be compared lightly; neglecting macroeconomic factors may yield misleading conclusions regarding the behavior of participants. Specifically, participants in experiments in countries with high inflation and interest rates may discount delayed rewards more highly, and may therefore appear to be more impulsive, than those in countries with lower rates.

Subjective and market discount rates are, however, of different magnitudes; subjective discount rates are much higher than market discount rates. Frederick, Loewenstein, and O'Donoghue (2003) summarized the results of 42 delay-discounting experiments from a number of countries and calculated annual subjective discount rates. These ranged from negative to over 55,700% annually. However, the interest rates in the countries in which the experiments were conducted ranged from about 3% to 10% annually.

Moreover, the term structure of subjective discounting is different from that of market discounting. Subjective discount rates are high in the short term and low in the long term. In contrast, long-term interest rates are often higher than short-term interest rates. Thus, the interest rate of a timed certificate of deposit is higher than that of a savings account.

Macroeconomic factors only affect some parameters and outcomes in delay discounting experiments. Interest and inflation rates only seem to affect subjective discounting of monetary rewards. If both immediate and delayed rewards are nonpreservable and participants do not have specific expectations about the price movement of that reward, participants have no reason to consider macroeconomic factors, and base their discounting of the delayed reward only on their temporal preference. Moreover, interest and inflation rates affect delay discounting only over a long period of delay. No one deposits money in a bank account for 3 days for the purpose of earning interest. Except in hyper-inflationary countries, currency does not lose value significantly in 1 month. Interest and inflation rates are significant factors only in experiments with a 3- to 20-year time horizon.

Questions naturally arise concerning the applicability and validity of the present method (using virtual money in a computer game-like task) to real situations. In everyday life, the nominal interest and inflation rates are not constant as in the present task, compound interest does not accumulate as quickly, and prices do not change as fast. Moreover, the consumption styles of most participants are different in real life from their styles in the present task. In real life, people must spend money steadily to consume necessities (such as food, clothing, and rent), whereas in this task, participants do not have to buy items steadily (on the contrary, the most profitable consuming strategy is to save as much money as possible, then to spend the money just before the task is completed).

In the experiments conducted for this study, delay length and the indirect relation between the rewards provided and actual Japanese yen payments may limit the degree to which the delay discounting behavior observed can be generalized. The delays used in this study were much shorter than those employed in other delay discounting experiments. The longest delay in this study, 36 turns of the game, had an actual delay time of only 3 minutes and 36 seconds. The time horizon for the delivery of hypothetical rewards in most delay discounting experiments is more than 10 years.

Moreover, the delayed rewards were virtual money paid in the second game period of the experimental phases, which did not have monetary value until after a phase was completed. Participants bought items using their virtual money, which included both immediate and delayed rewards, and the items were exchanged for yen immediately upon completion of the phases. The delayed rewards were thus not directly connected to yen payments. The short delay lengths and the indirect relation between delayed rewards and incentives may have failed to elicit the same participant time-preferences observed in real-world delay discounting.

Participants in delay discounting experiments might not usually pay attention to economic factors such as interest and inflation rates. The computer game-like task in this study is designed to make participants aware of those factors. Carefully constructed questions are needed to make participants become sensitive to economic factors in usual questionnaire-style studies (Harrison, Lau, & Williams, 2000; Shafir, Diamond, & Tversky, 1997). In addition, the results from participants in a given country at a given time, as is usual in delay discounting experiments, by their very nature, cannot reflect the effects of different economic circumstances.

Although experiments involving computer game-like tasks have limitations, they also have some merits. First, they allow for the experimental control of economic factors such as nominal interest and inflation rates. By changing the parameters of the task, experimenters can model varied economic situations.

Secondly, all immediate and delayed rewards that participants earned were paid. Most delay discounting studies have used hypothetical rewards. Even in studies in which participants have been paid real money, the rewards have often been probabilistic, for example, with one participant chosen randomly to receive only one selected reward.

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