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Maintaining Private and Public Facilities: Theory and Experiment

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Abstract

This paper studies two types of facility maintenance games in the laboratory, in a cross-cultural experiment conducted in Tokyo and Guam. One is called the *one-person maintenance game*, in which only one player makes maintenance investment decisions for a privately owned facility, and the other is called the *two-person maintenance game*, in which two players make maintenance investment decisions for a shared public facility without communication. Both games are characterized by the fact that the durability of the facility depends on each player's decision of costly investment in its maintenance, and that the facility can be enjoyed as long as it is available, i.e., the probability that the game will end or continue depends on each player's decision of costly investment in its maintenance. Our main results are that first, most subjects chose to invest in each experimental round of both games. At the beginning of the two games, the percentage of subjects who are willing to invest is significantly higher among the Tokyo subjects than among the Guam subjects. However, as the game proceeds, the difference in this percentage between the two groups becomes statistically insignificant. Second, in either the one-person game, the two-person game or both, subjective factors (i.e., risk and time preferences) and/or objective factors (i.e., the durability of the facility) play important roles in influencing the investment behaviors of either the Guam subjects, the Tokyo subjects or both. Third, there is a significant difference in the investment ratio between the one-person and two-person games among the Tokyo subjects, but not among the Guam subjects. Finally, we also investigate the factors affecting different behaviors between the two games. The results indicate the possibility of conditional cooperative behavior among the Guam subjects and the possibility of free rider behavior among the Tokyo subjects in the two-person game.

JEL Classification: C71, C72, C91

Keywords: Maintenance Games, Public Good, Free Rider, Risk Preference, Time Preference, Inter-Regional Comparison

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1. Introduction

This paper studies two types of facility maintenance games in the laboratory, in a cross-cultural experiment conducted in Tokyo and Guam. One is called the *one-person maintenance game*, in which only one player makes maintenance investment decisions for a privately owned facility, and the other is called the *two-person maintenance game*, in which two players make maintenance investment decisions for a shared public facility without communication.

Both games are characterized by the fact that the durability of the facility depends on each player's decision to invest in its maintenance costly, and that the facility can be enjoyed as long as it is available, i.e., the probability that the game will end or continue depends on each player's decision of costly investment in its maintenance. The two games model facility maintenance behavior in the real world: the more maintenance investment, the greater the likelihood of long-term facility availability. However, just because you invest in a facility does not mean that the facility will be available indefinitely. There is also the possibility that it will break down naturally despite your maintenance investment. The two games include the possibility of breakdowns.

It is very meaningful to compare the two games to see if there are differences in investment attitudes toward private and public facilities. Because the two-person maintenance game has the structure of two players sharing a non-excludable public good, the free-rider behavior and conditional cooperative behavior commonly observed in public goods game studies may be observed.[1]

It is natural to assume that players' behavior in the one-person and two-person maintenance games depends on their preferences for risk and time. Therefore, we asked subjects to answer a questionnaire measuring individual risk based on Holt and Laury (2002) and a questionnaire measuring time preference based on Gilboa (2010) after playing the two games in the experiment.

In order to investigate how players' preferences for risk and time affect their behavior, we first predict their behavior based on the subgame perfect equilibrium. We then obtain the following predictions: (1) In both one-person and two-person games, once players choose to stop their maintenance investment at some point, they never restart their maintenance investment afterwards, regardless of their risk and time preferences. (2) Since the maintenance investment plays the role of the insurance for the availability of the facility in the future, a player with a more risk-averse preference is more likely to choose to invest in its maintenance costly than a player with a more risk-loving preference. (3) Since players receive the benefits from their costly investment in the future, a player with a more future-oriented preference is more likely to choose to invest in its maintenance costly than a player with a more present-oriented preference. (4) In the two-person game, because of the free-rider

[1] See recent references on infinitely repeated public good games such as Grandjean, Lefebvre, and Mantovani (2022), Vespa (2020), and Aoyagi, Bhaskar, and Fréchette (2019). Dal Bó and Fréchette (2018) analyses a metadata gathered from the previous studies of the repeated prisoner's dilemma games for their survey study.

behavior, players choose to invest in its maintenance costly less frequently than they do in the one-person game.

Based on the experiments of the one-person and two-person maintenance games conducted at Tokyo Institute of Technology and the University of Guam, we observed that (1) Most subjects chose to invest in each experimental round of both games. At the beginning of the two games, the percentage of subjects who are willing to invest is significantly higher among the Tokyo subjects than among the Guam subjects. However, as the game proceeds, the difference in this percentage between the two groups becomes statistically insignificant. (2) Risk preference has a significant effect on the decision of maintenance investment among the Guam subjects in the one-person game but not in the two-person game, while it does not have a significant effect among the Tokyo subjects in both games. (3) Time preference has a marginally significant effect on the decision of maintenance investment among the Guam subjects in the two-person game but not in the one-person game, while it does not have a significant effect among the Tokyo subjects in both games. (4) The ratio of red cards remained in each round capturing the durability of the facility, which reflects objective factors of the game faced by the subjects, has a significant effect on the investment behavior among the Guam subjects in the one-person game but not in the two-person game, while it has a significant effect among the Tokyo subjects in both games. (5) The difference in the investment ratio between the one-person and two-person games is insignificant among the Guam subjects, while the investment ratio is significantly higher in the one-person game than in the two-person game among the Tokyo subjects. The results investigating the factors affecting different behaviors between the two games indicate the possibility of conditional cooperative behavior among the Guam subjects and the possibility of free rider behavior among the Tokyo subjects in the two-person game.

The remainder of the paper is organized as follows. Section 2 describes the one-person and two-person facility maintenance games in our experiment in details. Section 3 explains questionnaires on individual risk and time preferences. Section 4 provides theoretical prediction results that are useful in examining our experimental observations. Section 5 describes our experimental design and procedures. Section 6 explains the experimental results. Section 7 provides the concluding remarks. The appendix contains experimental instructions.

2. Facility Maintenance Games

In this section, we describe the design of the one-person maintenance game and that of the two-person maintenance game in our experiment.

2.1 One-person Maintenance Game

One-person maintenance game is described as a card game which has a feature of the maintenance investment structure for a private facility. In the game, there is only one player who makes the decisions of costly maintenance investment. This card game consists of 40 cards, and there were 40 red cards and 0 black cards at the beginning of the game. Each round follows the procedure described below.

Step 1: Picking a card

At the beginning of each round, the player is asked to pick 1 card among the 40 cards which are put face down.

- If the player picks a black card, the game ends immediately. This situation implies that the facility which the player possesses is broken down, and the player cannot get any payoff from it anymore.
- If the player picks a red card, the player can get 5 tokens. This situation implies that the facility which the player possesses is not broken down here, and the player can still enjoy it. So, these 5 tokens are considered to be the payoff which the player can get from it. Then, the game moves to Step 2.

Step 2: Decision making of costly maintenance investment

The player who picks a red card then needs to decide whether or not to pay 1 token as maintenance investment for the facility. This 1 token is considered to be maintenance cost for the facility. Then the game moves to Step 3.

Step 3: Replacing red cards with black cards

Some red cards are replaced with the same number of black cards here. However, the number of red cards replaced with black cards depends on the decision in Step 2.

- If the player decides to pay 1 token in Step 2, 2 red cards are replaced with 2 black cards.
- If the player decides not to pay any tokens in Step 2, 4 red cards are replaced with 4 black cards.

It is important to note that paying 1 token in Step 2 can decrease the probability of picking a black card in the subsequent rounds. This reflects a real situation where maintenance investment can decrease the possibility of facilities being broken down naturally. This is the end of each round, and the next round starts with Step 1 again.

The game continues until the player picks a black card in Step 1. The payoff of the player in this game is the summation of tokens which the player has received until picking a black card.

2.2 Two-person Maintenance Game

The two-person maintenance game has almost the same structure as the one-person maintenance game. The only difference is that each player is randomly paired with other player at the beginning of the game, and both players decide whether or not to invest for a public facility which they share without any communication. The pair is fixed throughout the game. The same as a one-person game, this card game also consists of 40 cards, and there are 40 red cards and 0 black cards at the beginning of the game. Each round follows the procedure described below.

Step 1: Picking a card

At the beginning of each round, one player in the pair is asked to pick 1 card among the 40 cards which are put face down. The player who picks a card in the first round is randomly determined, and then the two players in the pair alternately pick a card in the subsequent rounds.

- If one player in the pair picks a black card, the game immediately ends for that pair. This situation implies that the facility which these two players share is broken down, and they cannot get any payoff from it anymore.
- If one player in the pair picks a red card, both players can get 5 tokens each. This situation implies that the facility which these two players share is not broken down here, and they can still enjoy it. So, these 5 tokens are considered to be the payoff which both players can get from it. Then, the game moves to Step 2.

Step 2: Decision making of maintenance investment

Both players are asked to decide whether or not to pay 1 token each as maintenance investment for the facility without any communication. This 1 token is considered to be maintenance cost for the facility. Then the game moves to Step 3.

Step 3: Replacing red cards with black cards

Some red cards are replaced with the same number of black cards here. However, the number of red cards replaced with black cards depends on the decisions in Step 2.

- If both players in the pair decide to pay 1 token each, 2 red cards are replaced with 2 black cards.
- If only one person in the pair decides to pay 1 token, 3 red cards are replaced with 3 black cards.
- If nobody in the pair decides to pay 1 token, 4 red cards are replaced with 4 black cards.

It is important to note that paying 1 token in Step 2 can decrease the probability of picking a black card in the subsequent rounds. This reflects a real situation where maintenance investment can decrease the possibility of facilities being broken down. This is the end of each round, and the next round starts with Step 1 again.

The game continues until one player in the pair picks a black card in Step 1. The payoff of each player in this game is the summation of tokens each player has received until one player in the pair picks a black card.

3. Questionnaires on Individual Risk and Time Preferences

As we will see details in the next section, players' preferences for risk and time are expected to have effects on behavior in the one-person and two-person maintenance games. In order to investigate these effects, every subject was asked to answer the following questionnaires to measure individual risk and time preferences after playing the two games in our experiment.

3.1 Risk Preference

Risk preference is an individual preference or attitude toward situations where outcomes are uncertain. In our experiment, a questionnaire to measure risk preference is created based on the questionnaire in Holt and Laury (2002). Participants were asked to make 10 choices between two lotteries with hypothetical rewards: the one is a low-risk lottery where the potential rewards are slightly different, and the other is a high-risk lottery where the potential rewards are more largely different. The instructions and two options in each question were designed as follows. (See Appendix 3 for all questions in the risk preference questionnaire.)

There are 10 red cards in total, ***X*** *red cards and* ***Y*** *black cards. Now, the experimenter shuffles these cards and put them face down. Then you are asked to choose 1 card out of these 10 cards. Which of the following two options would you prefer?*
Option A: To get $40 if you pick a red card. To get $32 if you pick a black card.
Option B: To get $77 if you pick a red card. To get $2 if you pick a black card.[2]

Each of the 10 questions has a different pair of ***X*** and ***Y*** in the following order: (***X***, ***Y***) = (1, 9), (2, 8), (3, 7), (4, 6), (5, 5), (6, 4), (7, 3), (8, 2), (9, 1), (10, 0). Compared to option B, option A has a less difference in the potential rewards when the color of card turns out. In other words, option A is potentially a low-risk lottery, and option B is a high-risk lottery. It is important to note that the expected values of the lotteries differ across each question because the probability of picking a red card gradually increases from question 1 to 10.

More specifically, the expected value of option A is higher than that of option B from question 1 to question 4. However, from question 5 to question 10, the expected value of option B is higher than that of option A. Thus, a risk neutral individual based on the expected utility theory prefers option A to option B from question 1 to 4 and prefers option B to option A from question 5 to 10. We measure individual risk preference by investigating at which question number participants switch their choices from option A to option B. Risk-seeking individuals would switch their choices from option A to option B at a question before question 5. On the other hand, risk-averse individuals would switch their choices from option A to option B at a question after question 5.

Table 3.1 shows the risk-aversion classifications based on lottery choices when the utility function is given by $u(x) = x^{1-\sigma}/(1-\sigma)$ for $x > 0$ with constant relative risk aversion $\sigma \neq 1$, and $u(x) = \ln x$ for $\sigma = 1$. The question number where a participant switches its choice from option A to option B will be used as the person's risk preference variable in our theoretical predictions and regression analysis. The larger this number is, the more risk-averse the participant is.

[2] The amount of reward was changed at the exchange rate of 100 Japanese yen to 1 US dollar at Tokyo.

Table 3.1. Risk-Aversion Classifications Based on Lottery Choices.

Question number where participant switches from safe option A to risky option B	Range of relative risk aversion σ for $u(x) = x^{1-\sigma}/(1-\sigma)$
1 (Always choose risky option B)	$\sigma < -1.72$
2	$-1.72 < \sigma < -0.95$
3	$-0.95 < \sigma < -0.49$
4	$-0.49 < \sigma < -0.15$
5	$-0.15 < \sigma < 0.15$
6	$0.15 < \sigma < 0.41$
7	$0.41 < \sigma < 0.68$
8	$0.68 < \sigma < 0.97$
9	$0.97 \leq \sigma < 1.37$
10	$1.37 < \sigma$
Always choose safe option A	exceeding assumptions

3.2 Time Preference

Time preference is an individual preference which characterizes changes in a subjective value over time. In our experiment, a questionnaire to measure time preference was created based on the questionnaire in Gilboa (2010). Participants were asked to make 10 choices between receiving some amount of reward immediately and receiving a different amount of reward in the future, more specifically, 30 days later. The instructions and two options of an immediate reward and a delayed reward were designed as follows. (See Appendix 4 for all questions in the time preference questionnaire.)

Which of the following two options do you prefer?
Option A: Receiving \$ Z today. (Displaying the experiment date.)
Option B: Receiving \$ W thirty days from today. (Displaying the date of thirty days from the experiment date.) [3]

The reward amount for option A ($= Z$) is fixed at 100 from question 1 to 10, but the reward amount for option B ($= W$) slightly increases from question 1 to 10. Each of the 10 questions has a pair of Z and W in the following order: (Z, W) = (100, 102), (100, 105), (100, 110), (100, 115), (100,

[3] The amount of reward was changed at the exchange rate of 100 Japanese yen to 1 US dollar at Tokyo, just like the risk preference questionnaire.

120), (100, 135), (100, 150), (100, 165), (100, 180), (100, 195). Following the above setup, those who prefer receiving a reward immediately, or those who have a high time discounting rate, continue to choose option A. On the other hand, those who prefer receiving a reward in the future, or those who have a low time discounting rate, continue to choose option B. We measure individual time preference by investigating at which question number participants switch their choices from option A to option B.

Table 3.2 shows the time discount rate classifications based on choices when the discounted reward is given by βW in which β is a time discount rate and W is the reward received in the future. If the reward received today, Z, is preferred to W, then $Z > \beta W$. Conversely, if W is preferred to Z, then $Z < \beta W$. For example, if option A is chosen at question 1, but option B is chosen at question 2, that is, $Z = 100$ is preferred to $W = 102$, but $W = 105$ is preferred to $Z = 100$, then $100/105 < \beta < 100/102$. The question number where a participant switches its choice from option A to option B will be used as the person's time preference variable in our theoretical predictions and regression analysis. The larger this number is, the smaller the individual time discount rate is. In other words, participants are impatient and prefer receiving a reward immediately.

Table 3.2. Time Discount Rate Classifications Based on Choices.

Question number where participant switches from immediate option A to future option B	Range of time discount rate β
1 (Always choose future option B)	$100/102 < \beta \leq 1$
2	$100/105 < \beta < 100/102$
3	$100/110 < \beta < 100/105$
4	$100/115 < \beta < 100/110$
5	$100/120 < \beta < 100/115$
6	$100/135 < \beta < 100/120$
7	$100/150 < \beta < 100/135$
8	$100/165 < \beta < 100/150$
9	$100/180 < \beta < 100/165$
10	$100/195 < \beta < 100/180$
Always choose immediate option A	$0 < \beta < 100/195$

4. Theoretical Predictions

In this section, we present theoretical predictions of facility maintenance games assuming that all players are fully rational and have complete information about the game being played. Since the decision in each round is whether or not to pay 1 token as a costly maintenance investment, the set of choices in each round is denoted by $A = \{Pay, NotPay\}$. A facility maintenance game is an extensive form game with finite rounds, so we can calculate its subgame-perfect equilibrium by backward induction.

4.1 Predictions Based on Expected Number of Tokens

As a benchmark, we first predict players' behavior by assuming that each player's objective is to simply maximize its expected number of tokens. This assumption addresses the case in which each player's coefficient of relative risk aversion and the time discount factor are $\sigma = 0$ and $\beta = 1$, respectively.

4.1.1 One-person Maintenance Game

In the one-person maintenance game, the optimal choice at each round is determined according to the number of red cards. We introduce some notation. Let $E(r)$ denote the maximum expected number of token the player can additionally get at the round when the number of red card is $r \in \{0,2,\ldots,38,40\}$. Since the game ends when $r = 0$, we have $E(r) = 0$ for $r \leq 0$.

Here, we describe how to calculate $E(r)$. If the player chooses Pay, then it can additionally get

$$\frac{r}{40}\{4 + E(r-2)\},$$

and if the player chooses $NotPay$, then it can additionally get

$$\frac{r}{40}\{5 + E(r-4)\}.$$

Hence, we obtain the following recurrence relation:

$$E(r) = max\left\{\frac{r}{40}\{4 + E(r-2)\}, \frac{r}{40}\{5 + E(r-4)\}\right\}.$$

Table 4.1. demonstrates the maximum expected number of token the player can additionally get when the number of red card is $r \in \{0,2,4,\ldots,38,40\}$. The yellow highlighted values in Table 4.1 give the values of $E(r)$. From Table 4.1., we know the prediction of the player's behavior. Observe that choosing Pay gives the values of $E(r)$ for $r \in \{30,\ldots,40\}$, and choosing $NotPay$ gives the values of $E(r)$ for $r \in \{0,\ldots,28\}$. This implies that a player, whose coefficient of absolute risk aversion and time discount rate are $\sigma = 0$ and $\beta = 1$, respectively, will keep choosing Pay until the number of red cards gets 30, and then choosing $NotPay$ until the end of the game.

Prediction 1. In a one-person maintenance game, if $\sigma = 0$ and $\beta = 1$, then
a) A participant keeps choosing Pay when $r > 28$.
b) A participant switches its choice from Pay to $NotPay$ when $r = 28$, and then keeps choosing $NotPay$ when $r < 28$.

Table 4.1. Calculation of $E(r)$

Number of Red Cards	$\frac{r}{40}\{4+E(r-2)\}$ (Choosing Pay)	$\frac{r}{40}\{5+E(r-4)\}$ (Choosing $NotPay$)
r = 0	0	**0**
r = 2	0.2	**0.25**
r = 4	0.425	**0.5**
r = 6	0.675	**0.7875**
r = 8	0.9575	**1.1**
r = 10	1.275	**1.446875**
r = 12	1.634063	**1.83**
r = 14	2.0405	**2.256406**
r = 16	2.502563	**2.732**
r = 18	3.0294	**3.265383**
r = 20	3.632691	**3.866**
r = 22	4.3263	**4.545961**
r = 24	5.127576	**5.3196**
r = 26	6.05774	**6.204874**
r = 28	7.143412	**7.22372**
r = 30	**8.41779**	8.403656
r = 32	**9.934232**	9.778976
r = 34	**11.8441**	11.40512
r = 36	**14.25969**	13.44081
r = 38	**17.3467**	16.00189
r = 40	**21.3467**	19.25969

4.1.2 Two-person Maintenance Game

In the two-person maintenance game, the optimal choice at each round of each player is determined according to the number of red cards and the other player's choice. We introduce some notation. Let $N=\{1,2\}$ be the set of players. For each $i \in N$, let $SPE_i(r)$ denote player i's expected number of tokens i can additionally get in the subgame perfect equilibrium at the round when the number of red card is $r \in \{0,1,2,\dots,38,40\}$. As in the case of the one-person game, when $r=0$, we have $SPE_i(r)=0$ for $r \leq 0$.

Here we describe how to calculate $SPE_i(r)$. Table 4.2 is the payoff table when two players follow the subgame perfect equilibrium after the round when the number of red card is $r \in \{0,1,2,\dots,38,40\}$.

Let $G(r)=(N,(A,A),(v_1^r,v_2^r))$ denote the strategic form game described in Table 4.2. A strategy profile (a_1^*,a_2^*) is a Nash equilibrium of $G(r)$ if

$$v_i^r(a_1^*,a_2^*) \geq v_i^r(a_i\ ,a_{-i}^*) \text{ for each } i \in N \text{ and each } a_i \in A.$$

As we show later, for each $r \in \{0,1,2,\dots,38,40\}$, there is a unique Nash equilibrium (a_1^*,a_2^*) of $G(r)$. Hence, we obtain the following recurrence relation:

$$SPE_i(r)=v_i^r(a_1^*,a_2^*)$$

Table 4.2. Payoff Table of $G(r)$

Player 1 ＼ Player 2	Pay	$NotPay$
Pay	$\frac{r}{40}\{4+SPE_2(r-2)\}$ $\frac{r}{40}\{4+SPE_1(r-2)\}$	$\frac{r}{40}\{5+SPE_2(r-3)\}$ $\frac{r}{40}\{4+SPE_1(r-3)\}$
$NotPay$	$\frac{r}{40}\{4+SPE_2(r-3)\}$ $\frac{r}{40}\{5+SPE_1(r-3)\}$	$\frac{r}{40}\{5+SPE_2(r-4)\}$ $\frac{r}{40}\{5+SPE_1(r-4)\}$

Table 4.3 demonstrates the expected number of tokens each player can additionally get when two players follow the subgame perfect equilibrium after the round when the number of red card is $r \in \{0,1,2,\ldots,38,40\}$. The yellow highlighted values in Table 4.3. show the expected number of tokens each player can additionally get in the subgame perfect equilibrium. From Table 4.3, we know that there is a unique subgame perfect equilibrium. Observe that (Pay, Pay) gives the value of $SPE_i(r)$ for $r = 40$ and $(NotPay, NotPay)$ gives the values of $SPE_i(r)$ for each $r \in \{0,1,2,\ldots,38\}$, which implies that in the unique subgame perfect equilibrium, two players choose Pay at Round 1, and then keep choosing $NotPay$ until the end of the game.

Note that the green highlighted values in Table 4.3. are larger than the yellow highlighted values at the same number of red cards, which can be interpreted as the welfare loss caused by free-ride behavior.

Prediction 2. In a two-person maintenance game, if $\sigma = 0$ and $\beta = 1$, then

a) Two participants choose Pay when $r = 40$.

b) Two participants switch their choices from Pay to $NotPay$ when $r = 38$, and then keep choosing $NotPay$ when $r < 38$.

Table 4.3. Calculation of $SPE_i(r)$

Number of Red Cards	$v_i^r(Pay, Pay)$	$v_i^r(NoTPay, Pay)$	$v_i^r(Pay, NotPay)$	$v_i^r(NotPay, NotPay)$
r = 0	0	0	0	**0**
r = 1	0.1	0.125	0.1	**0.125**
r = 2	0.2	0.25	0.2	**0.25**
r = 3	0.309375	0.375	0.3	**0.375**
r = 4	0.425	0.5125	0.4125	**0.5**
r = 5	0.546875	0.65625	0.53125	**0.640625**
r = 6	0.675	0.80625	0.65625	**0.7875**
r = 7	0.812109375	0.9625	0.7875	**0.940625**
r = 8	0.9575	1.128125	0.928125	**1.1**
r = 9	1.111640625	1.3021875	1.0771875	**1.269140625**
r = 10	1.275	1.48515625	1.23515625	**1.446875**
r = 11	1.449013672	1.6775	1.4025	**1.633671875**
r = 12	1.6340625	1.880742188	1.580742188	**1.83**
r = 13	1.830943359	2.095234375	1.770234375	**2.037470703**
r = 14	2.0405	2.321785156	1.971785156	**2.25640625**
r =15	2.264051514	2.56125	2.18625	**2.487626953**
r = 16	2.5025625	2.814988281	2.414988281	**2.732**
r = 17	2.757241455	3.083972656	2.658972656	**2.990925049**
r = 18	3.0294	3.369432129	2.919432129	**3.265382813**
r = 19	3.320689398	3.6727	3.1977	**3.556622803**
r = 20	3.632691406	3.995462524	3.495462524	**3.866**
r = 21	3.967226971	4.339325977	3.814325977	**4.195235651**
r = 22	4.3263	4.706142542	4.156142542	**4.545960547**
r = 23	4.712260499	5.09795	4.52295	**4.920058112**
r = 24	5.127576328	5.51714139	4.91714139	**5.3196**
r = 25	5.57503632	5.966225342	5.341225342	**5.747022282**
r = 26	6.05774	6.448037773	5.798037773	**6.204874355**
r = 27	6.57924004	6.96573	6.29073	**6.696039225**
r = 28	7.143412049	7.522915597	6.822915597	**7.22372**
r = 29	7.754628438	8.123533908	7.398533908	**7.791591154**
r = 30	8.41779	8.772029419	8.022029419	**8.403655767**
r = 31	9.138483145	9.473383	8.698383	**9.0644304**
r = 32	9.922924613	10.23327292	9.433272923	**9.778976**
r = 33	10.77815508	11.05801601	10.23301601	**10.5530627**
r = 34	11.7121296	11.95476584	11.10476584	**11.3931074**
r = 35	12.73392986	12.931604	12.056604	**12.3063766**
r = 36	13.85379666	13.99775643	13.09775643	**13.3010784**
r = 37	15.08339835	15.16362435	14.23862435	**14.386583**
r = 38	16.43602448	16.44105777	15.49105777	**15.57345203**
r = 40	**19.57345203**	19.386583	18.386583	18.3010784

4.2 Predictions Based on Expected Utility

We next theoretically investigate how players' preferences for risk and time affect their behavior. We ask each participant to answer two questionnaires: one is created by Holt and Laury (2002), which estimates each participant's range of coefficient of relative risk aversion σ for a utility function $u(x) = \frac{x^{1-\sigma}}{1-\sigma}$, in which x denotes the number of tokens. The other is created by Gilboa (2010), which estimates each participant's range of time discount rate β when it maximizes the summation of discounted utilities $\sum_{t=1}^{T} \beta^{t-1} u(x^t)$, in which x^t denotes the number of tokens a player obtained at round t. The aim of this experiment is to compare the theoretical prediction under a given expected utility function $E\left(\sum_{t=1}^{T} \beta^{t-1} \frac{x^{1-\sigma}}{1-\sigma}\right)$, in which σ and β are estimated by the two questionnaires with participant's actual behavior.

4.2.1 One-person Maintenance Game

Given σ and β, we can inductively derive the optimal choice at each round as in the case of $\sigma = 0$ and $\beta = 1$ considered above. We introduce some notation. Let $E^{\sigma,\beta}(r)$ denote the maximum expected utility the player with the expected utility function $E\left(\sum_{t=1}^{T} \beta^{t-1} \frac{x^{1-\sigma}}{1-\sigma}\right)$ can additionally get at the round when the number of red cards is $r \in \{0,2,\ldots,38,40\}$. Since the game ends when $r = 0$, we have $E^{\sigma,\beta}(r) = 0$ for $r \leq 0$.

Here, we describe how to calculate $E^{\sigma,\beta}(0)$. If the player chooses Pay, then it can additionally get

$$\frac{r}{40}\{\frac{4^{1-\sigma}}{1-\sigma} + \beta E^{\sigma,\beta}(r-2)\},$$

and if the player chooses $NotPay$, then it can additionally get

$$\frac{r}{40}\{\frac{5^{1-\sigma}}{1-\sigma} + \beta E^{\sigma,\beta}(r-4)\}.$$

Hence, we obtain the following recurrence relation:

$$E^{\sigma,\beta}(r) = max\left\{\frac{r}{40}\{\frac{4^{1-\sigma}}{1-\sigma} + \beta E^{\sigma,\beta}(r-2)\}, \frac{r}{40}\{\frac{5^{1-\sigma}}{1-\sigma} + \beta E^{\sigma,\beta}(r-4)\}\right\}.$$

Table 4.4 demonstrates when a player with σ and β switches its choice from Pay to $NotPay$. For example, check the number in the first row and the first column is 36. This implies that when $\sigma = -0.95$ and $\beta = 1$, the optimal behavior is to keep choosing Pay when $r > 36$ and then keep choosing $NotPay$ when $r \leq 36$.

Table 4.4 suggests how a player's attitude for risk and time affects its behavior. Regarding risk preferences, as a player becomes more risk-averse, it switches its choice from Pay to $NotPay$ in a later round, which implies that it chooses Pay more frequently. Regarding time preferences, as a player becomes more future-oriented, it switches its choice from Pay to $NotPay$ in a later round, which implies that it chooses Pay more frequently.

Combining Table 4.4 with Tables 3.1 and 3.2, we can also provide a prediction when a participant switched its choice from Pay to $NotPay$, according to its answers to the two questionnaires. For example, suppose that a participant's σ and β are estimated as $-1.7 < \sigma < -0.95$ and $\frac{100}{105} < \beta \leq \frac{1}{102}$, respectively. We then predict from Table 4.4 that it switches its choice from Pay to $NotPay$ when the number of red cards is $r \in \{40,38,36\}$. Table 4.5 exhibits the prediction when a participant is predicted to switches its choice.

These observations are summarized by the following prediction.

Prediction 3. In a one-person maintenance game,

a) The more the number of red cards is, the more frequently Pay is chosen.

b) For each β, the higher σ is, which means that the later a participant switches its choice from safe option A to risky option B in the risk preference questionnaire, the more frequently Pay is chosen.

c) For each σ, the higher β is, which means that the earlier a participant switches its choice from immediate option A to future option B in the time preference questionnaire, the more frequently Pay is chosen.

Table 4.4. When a player switches its choice from Pay to $NotPay$.

$\sigma \setminus \beta$		$\frac{100}{100}$	$\frac{100}{102}$	$\frac{100}{105}$	$\frac{100}{110}$	$\frac{100}{115}$	$\frac{100}{120}$	$\frac{100}{135}$	$\frac{100}{150}$	$\frac{100}{165}$	$\frac{100}{180}$	$\frac{100}{195}$
-1.72		40	40	40	40	40	40	40	40	40	40	40
-0.95		36	36	38	40	40	40	40	40	40	40	40
-0.49		34	34	36	38	38	40	40	40	40	40	40
-0.15		30	30	32	34	36	38	40	40	40	40	40
0.15		28	28	28	30	32	34	38	40	40	40	40
0.41		22	22	22	24	26	28	32	38	40	40	40
0.68		10	10	12	14	14	16	20	24	28	34	38
0.97		2	2	2	2	2	2	2	2	2	2	2
1.37		2	2	2	2	2	2	2	2	2	2	2

Question number where a participant switches its choice from immediate option A to future option B in the time preference questionnaire Question number where a participant switches its choice from safe option A to risky option B in the risk preference questionnaire	1 Always B $\frac{100}{102} < \beta \le 1$	2 $\frac{100}{105} < \beta \le \frac{1}{102}$	3 $\frac{100}{110} < \beta \le \frac{1}{105}$	4 $\frac{100}{115} < \beta \le \frac{1}{110}$	5 $\frac{100}{120} < \beta \le \frac{1}{115}$	6 $\frac{100}{135} < \beta \le \frac{1}{120}$	7 $\frac{100}{150} < \beta \le \frac{1}{135}$	8 $\frac{100}{165} < \beta \le \frac{1}{150}$	9 $\frac{100}{180} < \beta \le \frac{1}{165}$	10 $\frac{100}{195} < \beta \le \frac{1}{180}$	Always A $0 < \beta \le \frac{1}{195}$
1: Always B $\sigma < -1.72$	40	40	40	40	40	40	40	40	40	40	40
2 $-1.72 < \sigma < -0.95$	40～36	40～36	40～38	40	40	40	40	40	40	40	40
3 $-0.95 < \sigma < -0.49$	36～34	38～34	40～36	40～38	40～38	40	40	40	40	40	40
4 $-0.49 < \sigma < -0.15$	34～30	36～30	38～32	38～34	40～36	40～38	40	40	40	40	40
5 $-0.15 < \sigma < 0.15$	30～28	32～28	34～28	36～30	38～32	40～34	40~38	40	40	40	40
6 $0.15 < \sigma < 0.41$	28～22	28～22	30～22	32～24	34～26	38～28	40～32	40～38	40	40	40
7 $0.41 < \sigma < 0.68$	22～10	22～10	24～12	26～14	28～14	32～16	38～20	40～24	40～28	40～34	40～38
8 $0.68 < \sigma < 0.97$	10～2	12～2	14～2	14～2	16～2	20～2	24～2	28～2	34～2	38～2	40～2
9 $0.97 < \sigma < 1.37$	2	2	2	2	2	2	2	2	2	2	40～2
10 $1.37 < \sigma$	2	2	2	2	2	2	2	2	2	2	40～2

Table 4.5 When a participant is predicted to switches its choice from Pay to $NotPay$.

4.2.2 Two-person Maintenance Game

Given σ and β, we can inductively derive the subgame perfect equilibrium as in the case of $\sigma = 0$ and $\beta = 1$ considered above. We introduce some notation. For each $i \in N$, let $SPE_i^{\sigma,\beta}(r)$ denote player i's expected utility Player i with the expected utility function $E\left(\sum_{t=1}^{T} \beta^{t-1} \frac{x^{1-\sigma}}{1-\sigma}\right)$ can additionally get at the round when the number of red card is $r \in \{0,1,2,\ldots,38,40\}$. Since the game ends when $r = 0$, we have $SPE_i^{\sigma,\beta}(r) = 0$ for $r \leq 0$.

Table 4.6 is the payoff table when two players follow the subgame perfect equilibrium after the round when the number of red card is $r \in \{0,1,2,\ldots,38,40\}$.

Table 4.6. Payoff Table of $G^{\sigma,\beta}(r)$

Player 1 ＼ Player 2	Pay	$NotPay$
Pay	$\frac{r}{40}\left\{\frac{4^{1-\sigma}}{1-\sigma} + \beta SPE_2^{\sigma,\beta}(r-2)\right\}$ $\frac{r}{40}\left\{\frac{4^{1-\sigma}}{1-\sigma} + \beta SPE_1^{\sigma,\beta}(r-2)\right\}$	$\frac{r}{40}\left\{\frac{5^{1-\sigma}}{1-\sigma} + \beta SPE_2^{\sigma,\beta}(r-3)\right\}$ $\frac{r}{40}\left\{\frac{4^{1-\sigma}}{1-\sigma} + \beta SPE_1^{\sigma,\beta}(r-3)\right\}$
$NotPay$	$\frac{r}{40}\left\{\frac{5^{1-\sigma}}{1-\sigma} + \beta SPE_2^{\sigma,\beta}(r-3)\right\}$ $\frac{r}{40}\left\{\frac{4^{1-\sigma}}{1-\sigma} + \beta SPE_1^{\sigma,\beta}(r-3)\right\}$	$\frac{r}{40}\left\{\frac{5^{1-\sigma}}{1-\sigma} + \beta SPE_2^{\sigma,\beta}(r-4)\right\}$ $\frac{r}{40}\left\{\frac{5^{1-\sigma}}{1-\sigma} + \beta SPE_1^{\sigma,\beta}(r-4)\right\}$

Let $G^{\sigma,\beta}(r) = (N, (A, A), (v_1^{\sigma,\beta,r}, v_2^{\sigma,\beta,r}))$ denote the strategic form game described in Table 4.6. Let (a_1^*, a_2^*) be a Nash equilibrium of $G^{\sigma,\beta}(r)$. We then obtain the following recurrence relation:

$$SPE_i^{\sigma,\beta}(r) = v_i^{\sigma,\beta,r}(a_1^*, a_2^*) \text{ for each } i \in N.$$

Table 4.7 demonstrates when two players with σ and β switch their choices from Pay to $NotPay$ in the subgame perfect equilibrium. Observe that there may be two subgame perfect equilibria. For example, when $\sigma = 0.68$ and $\beta = 1$, since $G^{\sigma,\beta}(24)$ is described as in Table 4.8, both (Pay, Pay) and $(NotPay, NotPay)$ are Nash equilibria of $G^{\sigma,\beta}(24)$. Hence, there are two subgame perfect equilibria in which; (1) two players choose $(NotPay, NotPay)$ when $r = 24$, which implies that they switch their choices from Pay to $NotPay$ when $r = 24$; and (2) two players choose (Pay, Pay) when $r = 24$, which implies that they switch their choices from Pay to $NotPay$ when $r = 22$.

Table 4.7. When two players switch from Pay to $NotPay$

$\sigma \setminus \beta$	$\frac{100}{100}$	$\frac{100}{102}$	$\frac{100}{105}$	$\frac{100}{110}$	$\frac{100}{115}$	$\frac{100}{120}$	$\frac{100}{135}$	$\frac{100}{150}$	$\frac{100}{165}$	$\frac{100}{180}$	$\frac{100}{195}$
-1.72	40	40	40	40	40	40	40	40	40	40	40
-0.95	40	40	40	40	40	40	40	40	40	40	40
-0.49	40	40	40	40	40	40	40	40	40	40	40
-0.15	40 or 38	40	40	40	40	40	40	40	40	40	40
0.15	36	36 or 38	38	40	40	40	40	40	40	40	40
0.41	32	32	34 or 32	36 or 34	38 or 36	40 or 38	40	40	40	40	40
0.68	24 or 22	24	26 or 24	26	28	30	36 or 34	40	40	40	40
0.97	2	2	2	2	2	2	2	2	2	2	2
1.37	2	2	2	2	2	2	2	2	2	2	2

Table 4.8. Payoff table of $G^{\sigma,\beta}(24)$

Player 1 ＼ Player 2	Pay	$NotPay$
Pay	5.78, 5.78	5.54, 5.77
$NotPay$	5.77, 5.54	5.56, 5.56

As with the case of one-person games, players' attitudes for risk and time affect their behavior. Regarding risk preferences, as players become more risk-averse, they switch their choices from Pay to $NotPay$ in a later round. Regarding time preferences, as players become more future-oriented, they switch their choices from Pay to $NotPay$ in a later round. In addition, comparing the numbers of red cards in Table 4.6. with those in Table 4.4., we observe that for each σ and each β, in two-person games players switch their choices from Pay to $NotPay$ in an earlier round than they do in one-person games.

Combining Table 4.7 with Tables 3.1 and 3.2, we can also provide a prediction when two participants switch their choices from Pay to $NotPay$, according to their answers to the two questionnaires. Table 4.9 exhibits when two participants are predicted to switch their choices. Note that when there exist two subgame perfect equilibria, our prediction, provided as a range of the number of red cards, contains both equilibria.

These observations are summarized by the following prediction.

Prediction 4. In the two-person maintenance game,

a) The more the number of red cards is, the more frequently Pay is chosen.

b) For each β, the higher σ is, which means that the later participants switch their choices from safe option A to risky option B in the risk preference questionnaire, the more frequently Pay is chosen.

c) For each σ, the higher β is, which means that the earlier participants switch their choices from immediate option A to future option B in the time preference questionnaire, the more frequently Pay is chosen.

d) Participants switch their choices from Pay to $NotPay$ in earlier rounds than they do in the one-person game, so that they choose Pay less frequently than they do in a one-person game.

Question number where a participant switches its choice from immediate option A to future option B in the time preference questionnaire Question number where a participant switches its choice from safe option A to risky option B in the risk preference questionnaire	1 Always B $\frac{100}{102} < \beta \le 1$	2 $\frac{100}{105} < \beta \le \frac{1}{102}$	3 $\frac{100}{110} < \beta \le \frac{1}{105}$	4 $\frac{100}{115} < \beta \le \frac{1}{110}$	5 $\frac{100}{120} < \beta \le \frac{1}{115}$	6 $\frac{100}{135} < \beta \le \frac{1}{120}$	7 $\frac{100}{150} < \beta \le \frac{1}{135}$	8 $\frac{100}{165} < \beta \le \frac{1}{150}$	9 $\frac{100}{180} < \beta \le \frac{1}{165}$	10 $\frac{100}{195} < \beta \le \frac{1}{180}$	Always A $0 < \beta \le \frac{1}{195}$
1: Always B $\sigma < -1.72$	40	40	40	40	40	40	40	40	40	40	40
2 $-1.72 < \sigma < -0.95$	40	40	40	40	40	40	40	40	40	40	40
3 $-0.95 < \sigma < -0.49$	40	40	40	40	40	40	40	40	40	40	40
4 $-0.49 < \sigma < -0.15$	40～38	40	40	40	40	40	40	40	40	40	40
5 $-0.15 < \sigma < 0.15$	40～36	40～36	40～38	40	40	40	40	40	40	40	40
6 $0.15 < \sigma < 0.41$	38～32	38~32	40～32	40～34	40～36	40～38	40	40	40	40	40
7 $0.41 < \sigma < 0.68$	32～22	34～24	36～24	38～26	40～28	40～30	40～34	40	40	40	40
8 $0.68 < \sigma < 0.97$	24～2	26～2	26～2	28～2	30～2	36～2	40～2	40～2	40～2	40～2	40～2
9 $0.97 < \sigma < 1.37$	2	2	2	2	2	2	2	2	2	2	40～2
10 $1.37 < \sigma$	2	2	2	2	2	2	2	2	2	2	40～2

Table 4.9 When participants are predicted to switches their choices from Pay to $NotPay$.

5. Experimental Design and Procedures

Our experiment studies the one-person and two-person maintenance games. In order to check whether there is an order effect between these games, we consider the following two treatments. In Treatment 1-2, the one-player game is played first, followed by the two-player game, whereas the two-player game is played first, followed by the one-player game in Treatment 2-1.

We conducted two sessions in each of Treatments 1-2 and 2-1 at Tokyo Institute of Technology during November and December 2019 and at the University of Guam during February 2020. We recruited the student subjects by campus-wide advertisement at Tokyo and by announcements during classes at Guam. These students were informed that there would be an opportunity to earn money in a research experiment. None of them had prior experience in an economic experiment. Twenty subjects participated in each session (eighty separate subjects in total) in Tokyo. Eighteen subjects participated one session in each of Treatments 1-2 and 2-1, sixteen subjects did another session in Treatments 1-2, and twenty-two subjects did another session in Treatments 2-1 (seventy-four separate subjects in total) in Guam. No subject attended more than one session.

The subjects in each session were seated at partitioned desks in a relatively large room. Each subject received a tablet device and written instructions including an explanation on the rules of the two types of maintenance games and how to play the games by using the tablet device. See Appendices 1 and 2 for the instructions for our experiment.

The pairings in the two-person game were anonymous and determined in advance by experimenters. Each subject was informed that experimenters randomly chose the pairings, which were fixed throughout the session. Each subject could not know which person the subject was paired with. After playing the two types of maintenance games, the subjects answered two questionnaires: the risk preference questionnaire first and then the time preference questionnaire.[4]

No information, or decisions, regarding the other subjects were shown on the tablet device.[5] No communication among the subjects was allowed, and we declared that the experiment would be stopped if we observed any communication among the subjects. We observed no such communication throughout the experimentation.

The sessions in Tokyo were conducted in Japanese, and the sessions in Guam were conducted in English. The instructions and questionnaires were translated from Japanese to English by the authors

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[4] After the questionnaires on risk and time preferences, the subjects were also asked to fill out the questionnaire of Zimbardo Time Perspective Inventory (ZTPI) in Guam, which measures individual time perspective toward past, present, and future temporal flames based on a subjective time scale (Zimbardo et al, 1999). We used the Japanese translation of the ZTPI by Shimojima et al (2012) in Tokyo. In this research, we conduct theoretical predictions and regression analyses by using the results of the questionnaires for risk and time preferences, based on an economic model, but not the result of the psychological ZTPI questionnaire.

[5] For the two-person game only, the decisions of the other subject paired with one subject were displayed on that subject's tablet device.

and the translations were proofread by a native English professor specializing in Speech Communication.[6] The exchange rate used to translate payoffs from Tokyo to Guam was $1 = 100 Yen = 20 experimental points. The reward of experiment was determined depending on the performances of the two types of maintenance games. Each session took approximately 100 minutes to complete. The mean reward per subject was $23.98 at Tokyo and $22.06 at Guam.

All subjects were asked to answer a pre-experiment questionnaire on personal attributes, such as age, gender, and cultural background, before the experiment days. The answers are briefly summarized in Table 5.1.

Table 5.1. Summarized information of participants at Guam and Tokyo

	Guam	Tokyo
Participants	74	80
Age range (years)	18 - 61	18 - 26
Mean age (years)	21.7	21.0
Female (%)	56.6	16.3
Guam (%)	68.4	
Saipan (%)	9.2	
Micronesia (%)	7.9	
Philippines (%)	5.2	
Japan (%)		100.0
Others (%)	9.2	

Note: The question of the cultural background is "Where have you spent most of your life?". "Others" in the table includes China, India, Hawaii, Rota, and Palau.

6. Results

6.1 Descriptive evidence

6.1.1 Risk and time preferences

In the post-experimental questionnaire, all the subjects were asked to make ten choices between two lotteries with hypothetical rewards for eliciting their risk preferences. Recall that the one is a low-risk lottery (Option A) where potential rewards are slightly different, and the other is a high-risk lottery (Option B) where potential rewards are more largely different. Figure 6.1 shows the question numbers and the distribution of how subjects change their choices, more precisely, the proportions of choosing Option A.[7] The gray dash line in the figure represents how a risk-neutral individual switches its choice

[6] We thank Professor Daniel Dolan at Waseda University for proofreading the translations.

[7] There were 11 Tokyo subjects and 17 Guam subjects who behaved irrationally by choosing Option A again after switching from A to B. The data of these subjects were excluded from the following analyses.

between Option A and Option B, based on the expected utility theory, which predicts that an individual with risk neutral preference should choose Option A in the first four questions, and then switch to Option B from the fifth question and remain that choice until the final question. From the figure, it seems that the Guam subjects are more risk-neutral than the Tokyo subjects. However, the result of the Wilcoxon rank-sum test indicates that there is no statistical difference in the risk preference between the subjects of the two universities ($p > 0.10$).

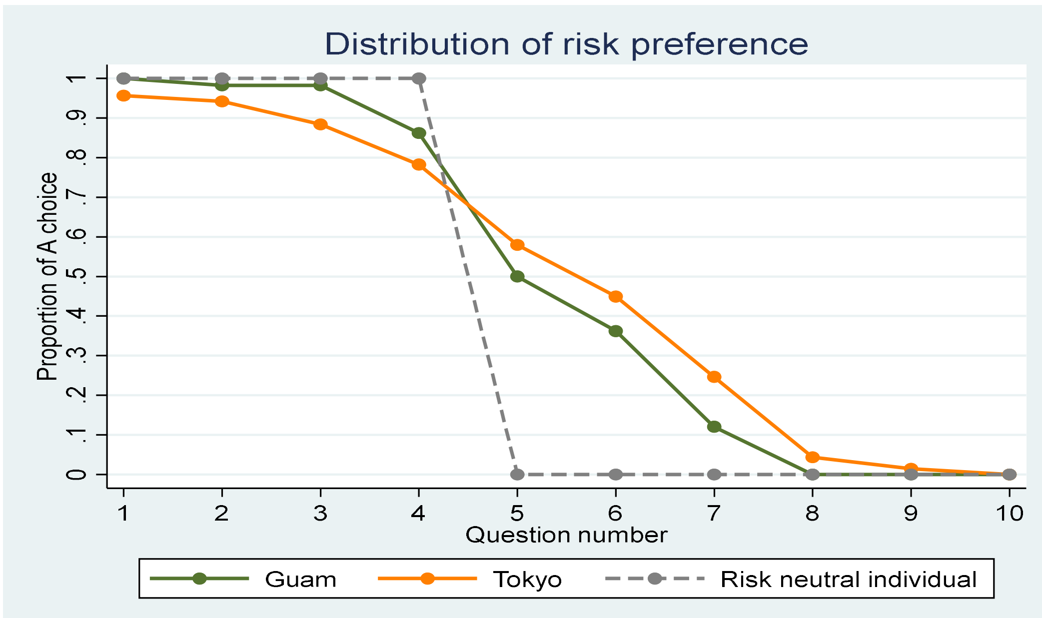

Figure 6.1. Distribution of risk preference

With respect to eliciting subjects' time preferences, we asked them to make ten choices between receiving some amount of reward immediately (Option A) and receiving the different amount of reward in thirty days later (Option B). Figure 6.2 shows the question numbers and the distribution of how subjects change their choices, more precisely, the proportions of choosing Option A. As shown from the figure, the proportion of choosing Option A in the earlier questions is higher in the Guam subjects than in the Tokyo subjects. This difference in the time preference is statistically significant by conducting the Wilcoxon rank-sum test ($p = 0.0152$).

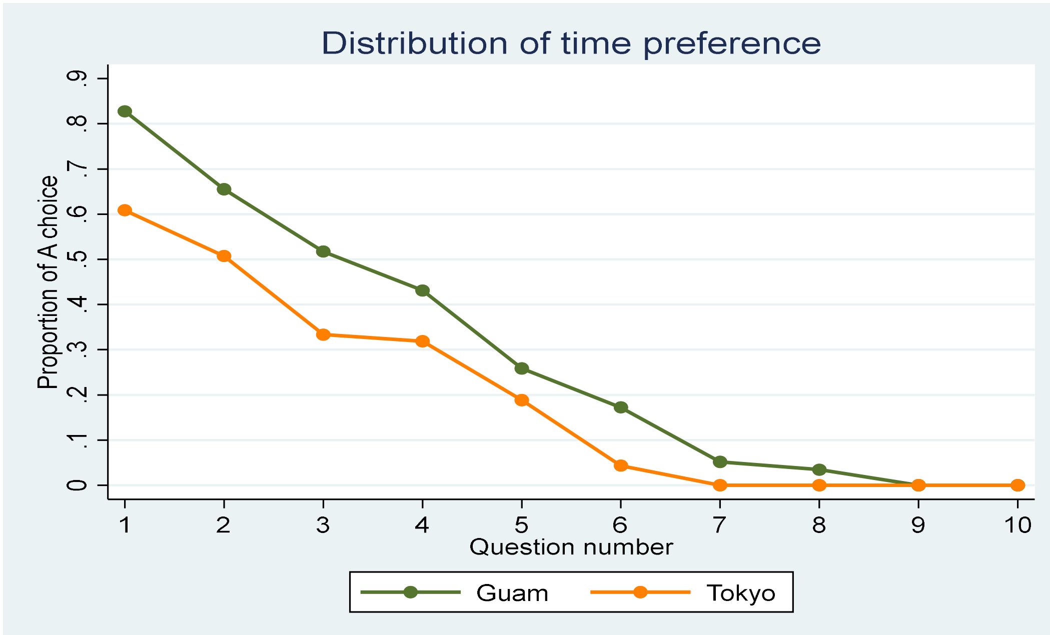

Figure 6.2. Distribution of time preference

6.1.2 Investment ratio in one-person and two-person maintenance games

In this subsection, we investigate whether the subjects' investment behaviors in one-person and two-person maintenance games are consistent with the benchmark theoretical predictions based on a risk-neutral ($\sigma = 0$) and patient ($\beta = 1$) individual.

One-person game

The ratio of maintenance investment in one-person game for the subjects from the two universities is plotted in Figure 6.3. The gray dash line indicates the benchmark theoretical prediction of the investment decision when $\sigma = 0$ and $\beta = 1$ (i.e., investing in the first six rounds and not investing afterwards). As shown in the figure, the behavior of Tokyo subjects seems closer to that of the theoretical prediction when $\sigma = 0$ and $\beta = 1$ in the earlier rounds than the Guam subjects. However, regardless of the university the subjects attended, most of them who remained after the seventh round still chose to invest, which is inconsistent with the theoretical prediction. Based on the regression results presented in the later subsections, we do not find an order effect between Treatment 1-2 and Treatment 2-1. Therefore, we pool the data from the two treatments in the following empirical analyses. Using a two-sided test for proportion, we find that from the first round to the fifth round, the ratio of investment is significantly higher for the Tokyo subjects than for the Guam subjects (all the p values are smaller than 0.05). Besides, in the remaining rounds after the sixth, there is no significant difference in the investment ratio between the subjects of the two universities.

Summing up the above evidence, we obtain the following results.

Result 1. In the one-person maintenance game,

a) Regardless of which university they are from, most subjects are willing to invest in each round, which supports the theoretical prediction when $\sigma = 0$ and $\beta = 1$. In short, subjects tend to invest in the first six rounds (Prediction 1a).

b) The high investment ratios observed in the later rounds for both the Tokyo and Guam subjects is inconsistent with the theoretical prediction of not investing after the seventh round (Prediction 1b) when $\sigma = 0$ and $\beta = 1$.

c) At the beginning of the game, the percentage of subjects who are willing to invest is significantly higher among the Tokyo subjects than among the Guam subjects. However, as the game proceeds, the difference in this percentage between the two groups becomes statistically insignificant.

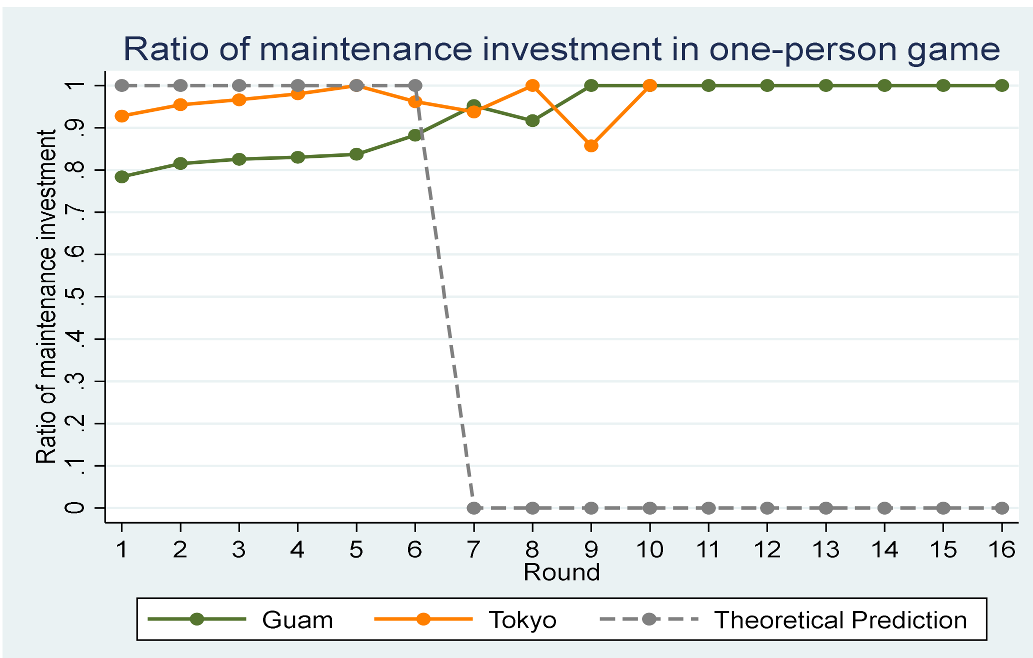

Figure 6.3. Ratio of maintenance investment in one-person game

Two-person game

Figure 6.4 plots the ratio of maintenance investment in two-person game. The benchmark theoretical prediction based on a risk-neutral ($\sigma = 0$) and future-orient ($\beta = 1$) individual (i.e., the gray dash line) suggests that subjects should invest in the first round and then choose not to invest afterwards. Similar to what was observed from the one-person game, most of the subjects who remained after the second round still invested, which is inconsistent with Prediction 2b. In the first four rounds, the investment ratio of the Tokyo subjects is significantly higher than that of the Guam subjects (two-sided test for proportion, all p values are smaller than 0.05). Besides, in the remaining rounds after the fifth, there is no significant difference in the investment ratio between the two university subjects.[8]

Summing up the above evidence, we obtain the following results.

Result 2. In the two-person maintenance game,

a) Regardless of which university they are from, most subjects are willing to invest in each round, which supports the theoretical prediction when $\sigma = 0$ and $\beta = 1$. In short, subjects tend to invest in the first round (Prediction 2a).

b) The high investment ratios observed in the later rounds for both the Tokyo and Guam subjects is inconsistent with the theoretical prediction of not investing after the second round (Prediction 2b) when $\sigma = 0$ and $\beta = 1$.

c) At the beginning of the game, the percentage of subjects who are willing to invest is significantly higher among the Tokyo subjects than among the Guam subjects. However, as the game proceeds, the difference in this percentage between the two groups becomes statistically insignificant.

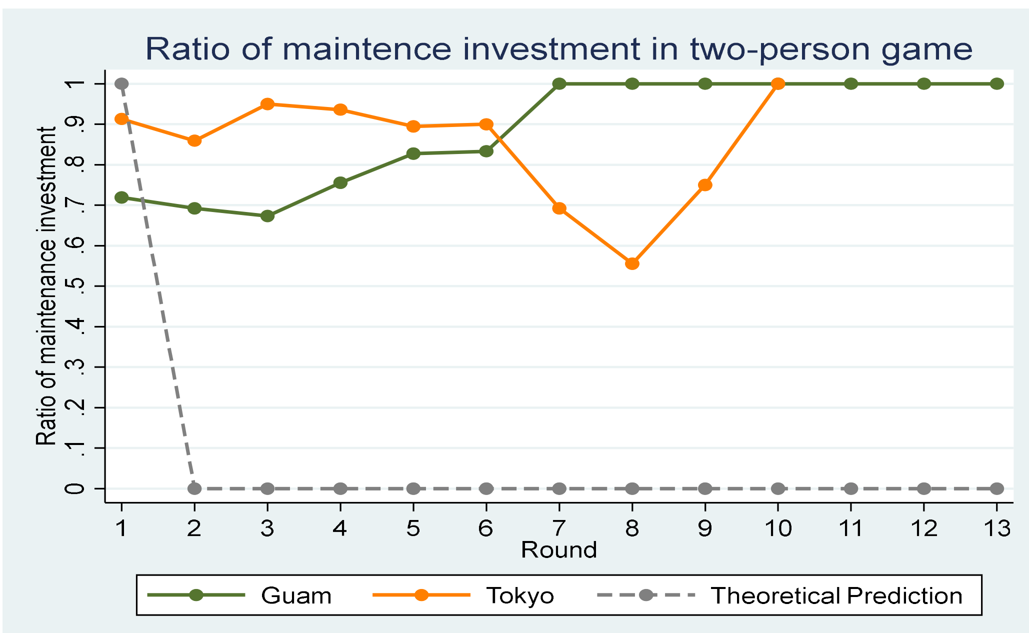

Figure 6.4. Ratio of maintenance investment in two-person game

[8] The investment ratio of the Tokyo subjects is significantly lower than that of the Guam subjects in the seventh, eighth, and ninth rounds indeed. However, the sample size is too small to ensure the validity of the statistical test.

The high investment ratios observed in the later rounds in both one-person and two-person games might be attributed to the fact that the game ended earlier for subjects with lower investment motivation. We will carefully examine how the dropped-out subjects affect the results later. In addition, we will examine whether our experimental results are consistent with the theoretical predictions when risk and time preferences are taken into account in the following subsections.

6.2 Regression analysis of investment decisions in one-person game

6.2.1 Results of heteroskedastic probit model

Table 6.1 reports the regression results of one-person game based on a heteroskedastic probit model. In the regression, the experimental round is treated as the heteroskedastic variable, because the length of the games differs among subjects. The dependent variable is subjects' binary response of whether to invest for the purpose of maintenance. Among the independent variables presented in Table 6.1*, Order* is a dummy variable denoted as 1 for Treatment 1-2 and 0 for Treatment 2-1, which is used to investigate whether there is an order effect between the two treatments. *Tokyo* and *Male* are dummy variables for Tokyo subjects and male subjects, respectively. *Risk* and *Time* refer to subjects' risk and time preferences measured by their chosen question numbers, respectively, which reflects subjective factors of the subjects. *Redrate* is the ratio of red cards remained in each round when making the investment decision. This variable reflects objective factors of the game faced by the subjects. In addition, *Risk_Tokyo*, *Time_Tokyo*, *Male_Tokyo*, and *Redrate_Tokyo* are the interaction terms of *Tokyo* with *Risk*, *Time*, *Male*, and *Redrate*. It should be noted that the interaction terms of any single variable (e.g., *Risk*, *Time*, *Male*, and *Redrate*) with the university dummy of *Tokyo* only capture the effects of these single variables caused by the Tokyo subjects compared to those caused by the Guam subjects, but not the pure effects of the Tokyo subjects. The pure ones should be the sums of the coefficients of the interaction terms and each corresponded single variable.

Based on the results presented in Table 6.1, we obtain the following results.

Result 3. In the one-person maintenance game,

a) The ratio of red cards remained is a common factor affecting the investment decision-making among the subjects of both universities. The more the number of red cards remained, the higher the probability of choosing to invest, which supports Prediction 3a. The magnitude of its effect is higher among the Tokyo subjects than among the Guam subjects.

b) Risk reference has a significant effect on the decision of maintenance investment among the Guam subjects but not among the Tokyo subjects. The more risk-averse Guam subjects are, the more they are likely to invest, which supports Prediction 3b.

c) Time preference has no significant effect on the decision of maintenance investment among the subjects of both universities, which does not support Prediction 3c.

d) The variable of male is estimated to be significantly negative for the Tokyo subjects and insignificant for the Guam subjects, which indicates that female Tokyo subjects are more likely to invest.

Table 6.1. Heteroskedastic probit regression on the investment decision in one-person game

	Coefficients	Chi-squared tests for	
Order	-0.0484		
Tokyo	3.2074***		
Risk	0.0937**		
Risk_Tokyo	-0.1280**	*Risk*+*Risk_Tokyo*=0	chi2(1)=1.00
Time	0.0155		
Time_Tokyo	0.0370	*Time*+*Time_Tokyo*=0	chi2(1)=3.15*
Male	0.1980		
Male_Tokyo	-3.6755***	*Male*+*Male_Tokyo*=0	chi2(1)=567.19***
Redrate	0.8026***		
Redrate_Tokyo	1.5595***	*Redrate*+*Redrate_Tokyo*=0	chi2(1)=25.95***
Constant	-0.8587***		
Observations	637		

Notes: Standard errors are clustered at the subject level. *z* values and clustered standard errors are omitted for saving space. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

6.2.2 Robustness check

In the above heteroskedastic probit regression, although we tried to control the heteroskedastic effect of each subject's experimental round by treating it as a heteroskedastic variable, the existence of a so-called selection bias due to early and unexpected termination of the experiment might still be a potential problem in the heteroskedastic probit regression. Therefore, we use three methods here to check whether the selection bias is a problem in our analysis. The first one is to compare the average number of the experimental round between the subjects who always invested and those who did not. The second and third ones are running a Heckman probit regression with sample selection and a number of probit regressions based on different ratios of red card remained, respectively, for which the purpose is to investigate whether the results are different from those obtained from the heteroskedastic probit model.

With respect to the result of the first method, the average number of the experimental round in one-person game (resp. two-person game) is 6.168 (resp. 5.782) for the subjects who always invested and 5.742 (resp. 5.729) for those who did not. The results based on a two-sided t test exhibit that in both games there are no significant differences in the number of the experimental round between the two types of subjects (both p values are larger than 0.10). This indicates that even if the subjects who tended to choose investment behavior survived longer, the effect would not have been large enough to make a significant difference in the number of experimental rounds.

Table 6.2. Heckman probit regression with sample selection in one-person game

	Investment		Selection
Order	-0.0653	*Redrate*	7.5606**
Tokyo	0.5636***	*Redrate_Tokyo*	-0.2706
Risk	0.0520**	*Constant*	-5.0161*
Risk_Tokyo	-0.0515**		
Time	0.0026		
Time_Tokyo	0.0054		
Male	0.0208		
Male_Tokyo	-0.1969**		
Constant	0.4587***		
Chi-squared tests for			
Risk+*Risk_Tokyo*=0	chi(1)=0.00	*Redrate*+*Redrate_Tokyo*=0	chi(1)=4.17**
Time+*Time_Tokyo*=0	chi(1)=0.37		
Male+*Male_Tokyo*=0	chi(1)=2.91*		
Observations	763		

Notes: Standard errors are clustered at the subject level. z values and clustered standard errors are omitted for saving space. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Regarding the second method, the Heckman probit model with sample selection includes two probit regressions – the selection regression and the investment regression. The dependent variable in the selection regression is defined as a dummy variable that equals to 1 if the experimental behavior could be observed and 0 if not. Since the experimental behavior could be observed until the black card appeared, this variable equals to 1 in the rounds with the appearance of red card and 0 in the rounds with the appearance of black card and afterwards. The independent variables in the selection regression are *Redrate* and its interaction terms with *Tokyo*. It should be noted that *Redrate* here is recoded as the ratio of red cards remained until and including the round when the black card appeared and 0 for a latent round after that. In other words, *Redrate* corresponds to the selection probability at each round.

In addition, the dependent variable in the investment regression is the same as that in the heteroskedastic probit model. The Heckman probit regression results presented in Table 6.2 indicate that the effects of the red card ratio separately by the Guam and Tokyo subjects are all statistically significant in the selection regression.[9] In addition, risk preference is significant for Guam subjects and male is significant for Tokyo subjects in the investment regression, while time preference is insignificant for both university subjects. These results are similar to those reported as Results 3a-3d.

Table 6.3. Probit regression on the investment decision in one-person game by different red card ratios

	Redrate=0.90	*Redrate*=0.85	*Redrate*=0.80
Order	-0.5671	0.0395	-0.8403
Tokyo	5.9464***	10.2986***	4.5109***
Risk	0.2795*	0.5600***	0.0541
Risk_Tokyo	-0.2514	-0.7725***	0.0072
Time	0.0628	0.2089	0.0568
Time_Tokyo	0.1186	0.0078	-0.0224
Male	0.3008	6.1242***	0.1367
Male_Tokyo	-4.3110***	-10.3970***	-4.1628***
Constant	-0.5851	-3.2380**	1.1885
Tests for			
Risk+*Risk_Tokyo*=0	chi(1)=0.11	chi(1)=6.34**	chi(1)=0.25
Time+*Time_Tokyo*=0	chi(1)=2.61	chi(1)=9.06***	chi(1)=0.09
Male+*Male_Tokyo*=0	chi(1)=91.47***	chi(1)=39.99***	chi(1)=76.31***
Observations	105	87	69

Notes: Standard errors are clustered at the subject level. *z* values and clustered standard errors are omitted for saving space. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 6.3 reports the results of probit regressions based on *Redrate*=36/40=0.90, *Redrate*=34/40=0.85, and *Redrate*=32/40=0.80. It should be noted that the selection among samples with the same *Redrate* (= the probability of selection) is not biased, because *Redrate* in round *n* is determined by the outcome in round *n-1* and independent of any actions in round *n*. Put differently, regressions among the sample with a constant *Redrate* is immune to the selection bias. The factors that significantly affect subjects' investment behavior in at least two cases are risk preference for Guam

[9] See the results of *Redrate* and *Redrate*+*Redrate_Tokyo*=0 in Table 6.2.

subjects and male for Tokyo subjects, while time preference is insignificant in most of the cases. These results are also similar to those reported as Results 3b-3d.

Summing up the above discussions, we conclude that selection bias issue due to early and unexpected termination of the experiment seems not a problem to bias our heteroskedastic probit regression results. Therefore, in the analysis on the investment decision in two-person game, we only rely on the heteroskedastic probit regression.

6.3 Regression analysis of investment decisions in two-person game

Table 6.4. Heteroskedastic probit regression on the investment decision in two-person game

	Coefficients	Chi-squared tests for	
Order	0.0440		
Tokyo	-1.3279*		
Risk	0.0517		
Risk_Tokyo	-0.0590	*Risk*+*Risk_Tokyo*=0	chi2(1)=0.03
Time	0.0609*		
Time_Tokyo	-0.0573	*Time*+*Time_Tokyo*=0	chi2(1)=0.01
Male	0.0993		
Male_Tokyo	-0.0025	*Male*+*Male_Tokyo*=0	chi2(1)=0.25
Redrate	-0.6786		
Redrate_Tokyo	2.5979***	*Redrate*+*Redrate_Tokyo*=0	chi2(1)=11.76***
Pay_Pay	1.1661***		
Pay_Pay_Tokyo	-0.2003	*Pay_Pay*+*Pay_Pay_Tokyo*=0	chi2(1)=4.63**
Pay_Nopay	0.3758*		
Pay_Nopay_Tokyo	0.0394	*Pay_Nopay*+*Pay_Nopay_Tokyo*=0	chi2(1)=1.20
Nopay_Pay	0.3571		
Nopay_Pay_Tokyo	-0.5395	*Nopay_Pay*+*Nopay_Pay_Tokyo*=0	chi2(1)=0.54
Constant	-0.2939		
Observations	470		

Notes: Standard errors are clustered at the subject level. z values and clustered standard errors are omitted for saving space. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 6.4 presents the results of Heteroskedastic probit regression on the investment decision in two-person game. In addition to the same independent variables of one-person game, we added the variables related to the behaviors of each subject and the subject paired with in the previous round.

These variables are: *Pay_Pay* defined as 1 if both a subject and the subject paired with invested in the previous round, and 0 if not; *Pay_Nopay* defined as 1 if a subject invested but the subject paired with did not in the previous round, and 0 if not; *Nopay_Pay* defined as 1 if a subject did not invest but the subject paired with did, and 0 if not; *Pay_Pay_Tokyo*, *Pay_Nopay_Tokyo*, and *Nopay_Pay_Tokyo* are the interaction terms of *Pay_Pay*, *Pay_Nopay*, and *Nopay_Pay* with *Tokyo*.

Based on the results presented in Table 6.4, we obtain the following results.

Result 4. In the two-person maintenance game,
a) The ratio of red cards remained has a significant effect on the Tokyo subjects' investment behavior but not on the Guam subjects' behavior. The more the number of red cards remained, the higher the probability of Tokyo subjects choosing to invest, which supports Prediction 4a.
b) Risk preference is insignificant for the subjects of both universities, which does not support Prediction 4b.
c) While time preference is insignificant for the Tokyo subjects, it is significantly estimated for the Guam subjects with an opposite direction as Prediction 4c predicts. This result is inconsistent with Prediction 4c.
d) The fact that a subject invested (no matter whether the subject paired with invested or not) in the previous round has a significantly positive effect on its investment decision for the Guam subjects, while only the fact that both a subject and the subject paired with invested in the previous round significantly affect the investment decision-making for the Tokyo subjects.

6.4 Difference in investment ratio between the one-person and two-person games

Table 6.5. Statistical tests on investment ratios between the one-person and two-person games

	Mean investment ratio		Difference	*t* test	signed-rank test
	One-person	Two-person			
Guam	0.769	0.714	0.055	*p*=0.3041	*p*=0.1319
Tokyo	0.950	0.884	0.066	*p*=0.0857	*p*=0.0417

In this subsection, we apply both a two-sided *t* test and Wilcoxon signed-rank test to compare whether there are differences in the subjects' investment ratios between the one-person and two-person games. Each subject's average investment ratios in both games are used in the tests. Based on the results presented in Table 6.5, we obtain the following results.

Result 5. Regarding the difference in investment ratio between the one-person and two-person games,
a) There is no significant difference among the Guam subjects, which does not support Prediction 4d.

b) Among the Tokyo subjects, the investment ratio is significantly higher in the one-person game than in the two-person game, which supports Prediction 4d.

Table 6.6. Random-effect panel regression on differences in the investment decision between two games

	Coefficients	Chi-squared tests for	
Risk	-0.0379		
Risk_Tokyo	0.0368	*Risk*+*Risk_Tokyo*=0	chi(1)=0.00
Time	0.0144		
Time_Tokyo	-0.0280	*Time*+*Time_Tokyo*=0	chi(1)=0.57
Male	-0.0770		
Male_Tokyo	0.1371	*Male*+*Male_Tokyo*=0	chi(1)=0.35
Redrate	0.7173		
Redrate_Tokyo	3.1296*	*Redrate*+*Redrate_Tokyo*=0	chi(1)=5.65**
Pay_Pay	0.4419*		
Pay_Pay_Tokyo	-0.2372	*Pay_Pay*+*Pay_Pay_Tokyo*=0	chi(1)=1.50
Pay_Nopay	0.1558		
Pay_Nopay_Tokyo	-0.1040	*Pay_Nopay*+*Pay_Nopay_Tokyo*=0	chi(1)=0.10
Nopay_Pay	0.2168*		
Nopay_Pay_Tokyo	-0.3108	*Nopay_Pay*+*Nopay_Pay_Tokyo*=0	chi(1)=0.23
Constant	-0.2195		
Observations	328		

Notes: *z* values and clustered standard errors are omitted for saving space. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

As stated in Prediction 4d, in the two-person game, we predict that subjects switch their choices from Pay to $NotPay$ in an earlier round than they do in the one-person game. That is, as the game proceeds, some subjects choose different choices between the one-person game and two-person game. For example, if $\sigma = 0$ and $\beta = 1$, when the number of red cards is $30 \leq r \leq 38$, while a subject is predicted to choose Pay in the one-person game, it is also predicted to choose $NotPay$ in the two-person game. Thus, as the number of red cards is decreasing, we observe more frequently the behavior changes between the one-person and the two-person games.

Since our experimental design is a within-subject one, we can investigate which factors might influence subjects' behavior changes between the one-person and two-person games. We use a random-effect panel regression to examine this issue. The dependent variable is defined as the difference of the investment behavior between the two games in each round, and its value is calculated by subtracting the value of the investment behavior (i.e., 0 or 1) in the one-person game from that in the two-person game (i.e., 0 or 1). Consequently, the values of the dependent variable are –1, 0, and 1, of which –1 means that a subject did not invest in the two-person game but invested in the one-person game, 0 denotes that there was no difference in one's investment behavior between the two games, and 1 stands for a subject investing in the two-person game but not investing in the one-person game. The independent variables are those used in the above analyses. In addition, it should be noted that given that subjects' experimental rounds might differ in the two games, we only used data of the two games for the shorter rounds. For example, if a subject finished the one-person game in the third round and the two-person game in the fifth round, we only used three rounds' data of both games (i.e., from the first round to the third round).

Based on the random-effect panel regression results presented in Table 6.6, we obtain the following results.

Result 6. Regarding the factors affecting the behavior changes between the one-person and two-person games,
a) Among the Guam subjects, the fact that the subject paired with had invested in the previous round has a significant effect, regardless of whether a subject themselves had invested. This indicates the possibility of conditional cooperative behavior among the Guam subjects in the two-person game.
b) Among the Tokyo subjects, the difference in the ratio of red cards remained has a significant effect. This indicates the possibility of free-rider behavior among the Tokyo subjects in the two-person game.

7. Concluding Remarks

One important issue is worthy of noting. The *Tokyo* dummy in the regression is always estimated to be strongly significant at 1% level in the one-person game (see Tables 6.1, 6.2, and 6.3), while it is estimated to be marginally significant at 10% level in the two-person game (see Table 6.4). On one hand, the latter means that besides the common factors controlled in the two games (i.e., *Redrate*, *Risk*, *Time*, and *Male*), the significant effects of previous behaviors of a subject and/or the subject paired with (i.e., *Pay_Pay*, *Pay_Nopay*, and *Nopay_Pay*) help us explain the differences in the investment behavior of the two-person game between the Guam and Tokyo subjects, which results that the significance of *Tokyo* dummy is reduced in the two-person game. However, on the other hand, the former indicates that there should be some unobserved factors other than those controlled (i.e., *Redrate*, *Risk*, *Time*, and *Male*) to explain the differences in the investment behavior of the one-person game between the Guam and Tokyo subjects. Thus, in future studies, we aim to investigate what these unobserved factors are.

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Appendices

A1. Experimental Instructions for Treatment 1-2

Today, we will conduct two experiments, Experiment A and Experiment B.

Instructions for Experiment A (the one-person maintenance game)

In this experiment, you cannot talk to anyone but the experimenter. If there is any other talking, the experiment will be stopped at that point. If you have any questions, please ask the experimenter by raising your hand.

Overview for Experiment A

In this experiment, you will make decisions described below.

1. At the beginning of each round, you are asked to pick 1 card among 40 cards which are put face down. There are 40 red cards and 0 black cards in the first round.
2. If you pick a black card, the experiment ends.
3. If you pick a red card, you will receive 5 tokens.
4. Then you will decide whether or not to pay 1 token out of the 5 tokens which you received.
5. If you decide to pay 1 token, 2 red cards out of those 40 cards will be replaced with 2 black cards.
6. If you decide not to pay any token, 4 red cards out of those 40 cards will be replaced with 4 black cards.
7. This experiment continues until you pick a black card.

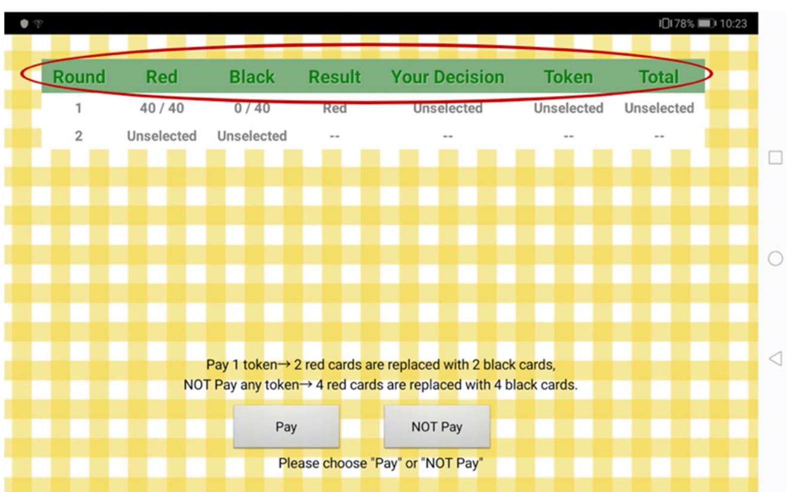
This experiment is performed on a tablet app.

Procedures for Experiment A

We explain the procedures for the experiment. **Please do not take any actions until the experimenter tells you to start the experiment.**

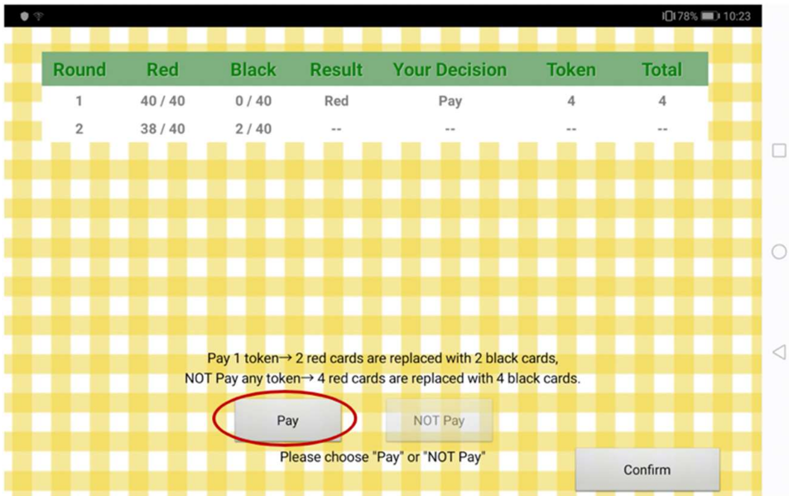
1. Please turn on the tablet and swipe up or down to unlock it.
2. Please open the "**Game for Solo**" app on the top left of the screen.
3. The following screen will appear when you open the app. **When the experimenter tells you to start the game**, please press the "Start Game" button.

4. Once you press the “Start Game” button, the game will start. Please tap the screen to proceed to the game.
5. Please pick 1 card out of the 40 cards. When you tap the card, a “Confirm” button will appear in the lower right corner. Please press the button to check the color of the card you picked. If you picked a black card, the game ends immediately. If you picked a red card, you will receive 5 tokens.
6. Please press the “Confirm” button in the lower right corner to go to the next screen.
7. You will then see a table. The information in the table, from left to right, is as follows. “Round” means the number of rounds; “Red”, the number of red cards / total number of cards; “Black”, the number of black cards / total number of cards; “Result”, the color of the card you picked; “Your Choice”, your decision to Pay or NOT Pay; “Token”, the difference between the tokens you earned in this round and the tokens you paid in this round; “Total”, the total tokens you have earned so far.

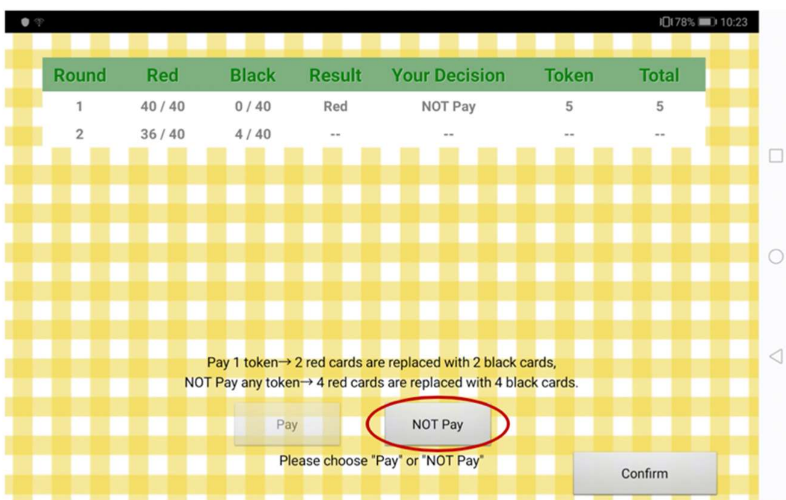


8. If you picked a red card, you will decide whether or not to pay 1 token.

9. If you choose "Pay", you will pay 1 token from the tokens you have earned. Then, <u>2 red cards</u> out of those 40 cards will be replaced with <u>2 black cards</u>.



10. If you choose "NOT Pay", you will not pay any token. Then, <u>4 red cards</u> out of those 40 cards will be replaced with <u>4 black cards.</u>



11. Please choose "Pay" or "NOT Pay".

12. After you decide whether or not to pay 1 token, please press the "Confirm" button in the lower right corner to continue to the next round.

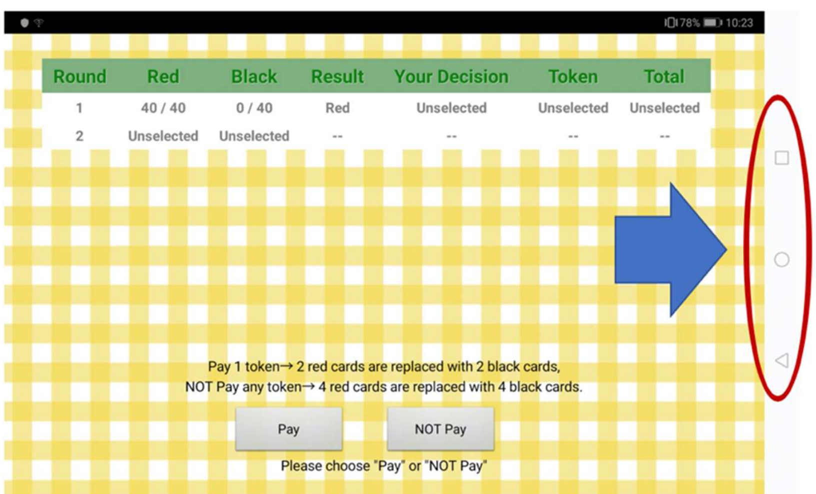
13. If you pick a black card, **please be sure to press the "Save Data" button at the bottom right corner.**

14. The game continues until you pick a black card.

Please do not touch the tablet after pressing the "Save Data" button.

Notes:

- **Please do not make unnecessary taps such as unnecessarily repetitive taps.**
- **Please do not press the △, ○, □ buttons at the bottom of the tablet (vertical screen mode) or right end of the tablet (horizontal screen mode).**



Honorarium

Your score of experiment A is the total amount of tokens you have when the game ends. Your total honorarium in USD in experiments A and B is calculated as follows.

Your total honorarium
= (Score of Experiment A + Score of Experiment B) × 0.05 + 20 [USD][10]

The score of experiment B will be explained after experiment A.

You will have 3 minutes to look at the instruction sheet. Then the experiment will start. If you have any questions, please raise your hand. **Please do not talk to any other participants.**

Instructions for Experiment B (the two-person maintenance game)

In this experiment, you cannot talk to anyone but the experimenter. If there is any other talking, the experiment will be stopped at that point. If you have any questions, please ask the experimenter by raising your hand.

Overview for Experiment B

In this experiment, you will be paired with one of the other participants and make decisions described below.

1. At the beginning of each round, one person in each pair will be asked to pick 1 card among 40 cards which are put face down. There are 40 red cards and 0 black cards in the first round.
2. The person who picks a card in the first round is randomly determined. Then two persons in a pair alternately pick a card.
3. If one person in a pair picks a black card, the experiment ends for that pair.
4. If one person in a pair picks a red card, both in the pair receive 5 tokens each.
5. Each person in the pair is asked to decide whether or not to pay 1 token out of the 5 tokens which he or she received.
6. If both in the pair decide to pay 1 token each, 2 red cards out of those 40 cards will be replaced with 2 black cards.
7. If only one person pays 1 token, 3 red cards out of those 40 cards will be replaced with 3 black cards.

[10] This explanation is for Guam. The honorarium at Tokyo was explained as follows:
Your total honorarium = (Score of Experiment A + Score of Experiment B) × 5 + 2200 [Japanese Yen].
The show-up fee at Tokyo (= $22) was set larger than at Guam (= $20), considering the difference in minimum wages between Tokyo and Guam at the time of the experiment.

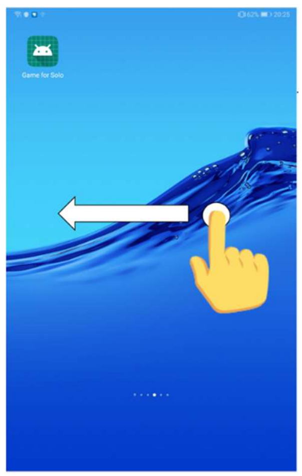
8. If nobody decides to pay any token, 4 red cards out of those 40 cards will be replaced with 4 black cards.
9. This experiment continues until one person in the pair picks a black card.

This experiment is performed on a tablet app.

Procedures for Experiment B

We explain the procedures for the experiment. **Please do not touch the tablet until the experimenter tells you to do so.**

1. Please turn on the tablet and swipe up or down to unlock it.
2. When you see the screen below, please swipe left to move the screen.

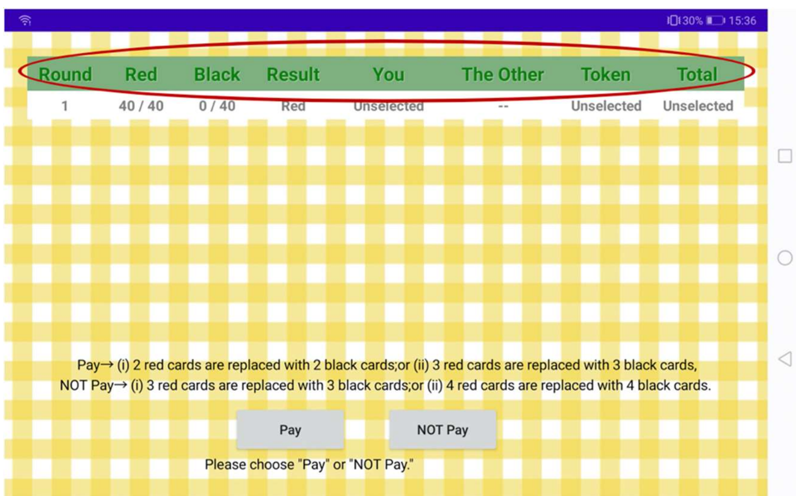


3. Please open the "**Game for Duo**" app on the top left of the screen.
4. The following screen will appear when you open the app. **When the experimenter tells you to start the game**, please press the "Start Game" button.

5. The experiment starts when the experimenter tells you to start the game. Please tap the screen to

proceed to the game.

6. You will be paired with one of the other persons, who is chosen randomly.
7. One person in each pair will be asked to pick a card from a set of 40 cards. Please pick 1 card out of the 40 cards on your turn. After you tap the card, the "Confirm" button will appear in the lower right corner. Please press the button to check the color of the card you picked.
8. If either person in a pair picked a black card, the game for that pair ends immediately. If either person in the pair picked a red card, both persons will receive 5 tokens.
9. Please press the "Confirm" button in the lower right corner to go to the next screen.
10. You will then see a table. The information in the table, from left to right, is as follows. "Round" means the number of rounds; "Red", the number of red cards / total number of cards; "Black", the number of black cards / total number of cards; "Result", the color of the card either person in the pair picked; "You", your decision to Pay or NOT Pay; "The Other", the other person's decision to Pay or NOT Pay; "Token", the difference between the tokens you earned in this round and the tokens you paid in this round; "Total", the total tokens you have earned so far.

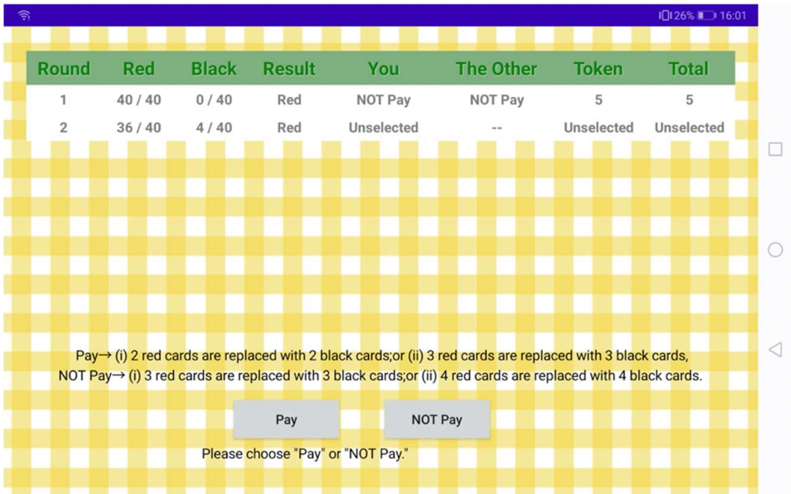


11. If either person in the pair picked a red card, each person will decide whether or not to pay 1 token.
12. If you choose "Pay", you will pay 1 token from the tokens you have earned. If you choose "NOT Pay", you will not pay any token.
13. If both persons in the pair choose "Pay", <u>2 red cards</u> out of those 40 cards will be replaced with <u>2 black cards.</u>

14. If you choose “Pay” and the other person chooses “NOT Pay”, 3 red cards out of those 40 cards will be replaced with 3 black cards.

15. If you choose “NOT Pay” and the other person chooses “Pay”, 3 red cards out of those 40 cards will be replaced with 3 black cards.

16. If both persons in the pair choose “NOT Pay”, <u>4 red cards</u> out of those 40 cards will be replaced with <u>4 black cards.</u>

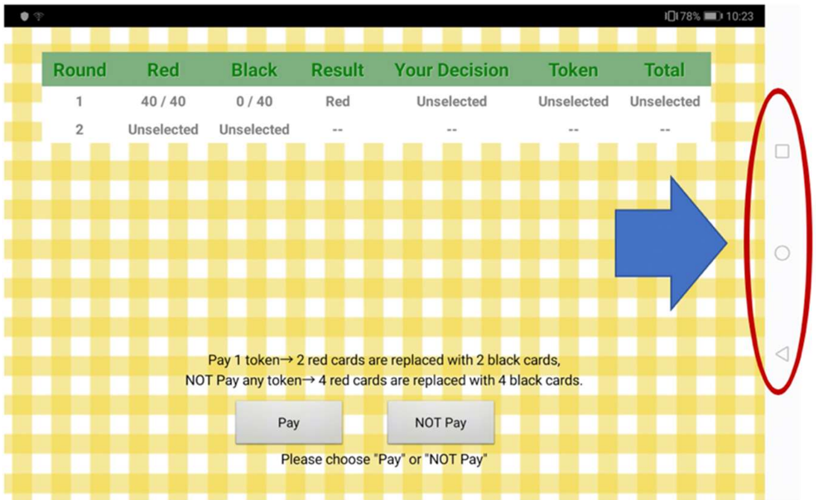


17. The game continues until one person in the pair picks a black card.

<u>Please do not touch the tablet after pressing the “Save Data” button.</u>

<u>Notes:</u>

- **<u>Please do not make unnecessary taps such as unnecessarily repetitive taps.</u>**
- **<u>Please do not press the △, ○, □ buttons at the bottom of the tablet (vertical screen mode) or right end of the tablet (horizontal screen mode).</u>**



The way how to make a pair

You will be paired with one of the other participants randomly. The person you will be paired with does not change throughout the game. You cannot know who you will be paired with and vice versa.

Honorarium

Your score of experiment B is the total amount of tokens you have when the game ends. Your total honorarium in USD in experiments A and B is calculated as follows.

Your total honorarium

= (Score of Experiment A + Score of Experiment B) × 0.05 + 20 [USD]

You will have 3 minutes to look at the instruction sheet. Then the experiment will start. If you have any questions, please raise your hand. **Please do not talk to any other participants.**

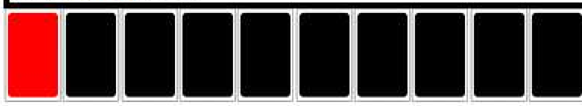
A2. Experimental Instructions for Treatment 2-1

Today, we will conduct two experiments, Experiment X and Experiment Y.

Experiment X was conducted first, followed by Experiment Y. The instructions for Experiment X were the same as for Experiment B (the two-person maintenance game) and the instructions for Experiment Y were the same as for Experiment A (the one-person maintenance game).

A3. Risk preference questionnaire

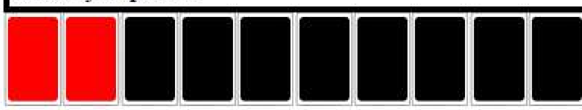
(1)
There are 10 cards in total, 1 red card and 9 black cards.
Now, the experimenter shuffles these cards and put them face down.
Then you are asked to choose 1 card out of these 10 cards. Which of the following two options would you prefer?



○ Option A : To get $40 if you pick a red card. To get $32 if you pick a black card
○ Option B : To get $77 if you pick a red card. To get $2 if you pick a black card

---

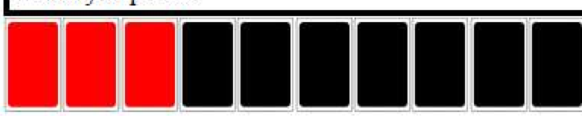
(2)
There are 10 cards in total, 2 red cards and 8 black cards.
Now, the experimenter shuffles these cards and put them face down.
Then you are asked to choose 1 card out of these 10 cards. Which of the following two options would you prefer?



○ Option A : To get $40 if you pick a red card. To get $32 if you pick a black card
○ Option B : To get $77 if you pick a red card. To get $2 if you pick a black card

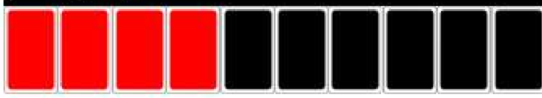
---

(3)
There are 10 cards in total, 3 red cards and 7 black cards.
Now, the experimenter shuffles these cards and put them face down.
Then you are asked to choose 1 card out of these 10 cards. Which of the following two options would you prefer?



○ Option A : To get $40 if you pick a red card. To get $32 if you pick a black card
○ Option B : To get $77 if you pick a red card. To get $2 if you pick a black card

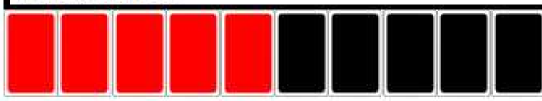
(4)
There are 10 cards in total, 4 red cards and 6 black cards.
Now, the experimenter shuffles these cards and put them face down.
Then you are asked to choose 1 card out of these 10 cards. Which of the following two options would you prefer?



- ○ Option A : To get $40 if you pick a red card. To get $32 if you pick a black card
- ○ Option B : To get $77 if you pick a red card. To get $2 if you pick a black card

---

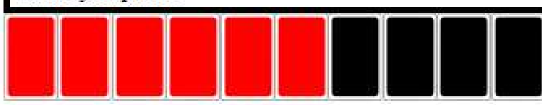
(5)
There are 10 cards in total, 5 red cards and 5 black cards.
Now, the experimenter shuffles these cards and put them face down.
Then you are asked to choose 1 card out of these 10 cards. Which of the following two options would you prefer?



- ○ Option A : To get $40 if you pick a red card. To get $32 if you pick a black card
- ○ Option B : To get $77 if you pick a red card. To get $2 if you pick a black card

---

(6)
There are 10 cards in total, 6 red cards and 4 black cards.
Now, the experimenter shuffles these cards and put them face down.
Then you are asked to choose 1 card out of these 10 cards. Which of the following two options would you prefer?

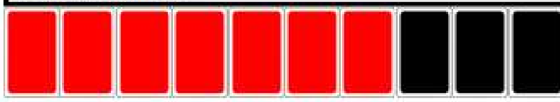


- ○ Option A : To get $40 if you pick a red card. To get $32 if you pick a black card
- ○ Option B : To get $77 if you pick a red card. To get $2 if you pick a black card

---

(7)
There are 10 cards in total, 7 red cards and 3 black cards.
Now, the experimenter shuffles these cards and put them face down.

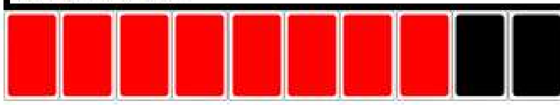
Then you are asked to choose 1 card out of these 10 cards. Which of the following two options would you prefer?



○ Option A : To get $40 if you pick a red card. To get $32 if you pick a black card
○ Option B : To get $77 if you pick a red card. To get $2 if you pick a black card

---

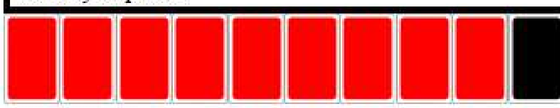
(8)
There are 10 cards in total, 8 red cards and 2 black cards.
Now, the experimenter shuffles these cards and put them face down.
Then you are asked to choose 1 card out of these 10 cards. Which of the following two options would you prefer?



○ Option A : To get $40 if you pick a red card. To get $32 if you pick a black card
○ Option B : To get $77 if you pick a red card. To get $2 if you pick a black card

---

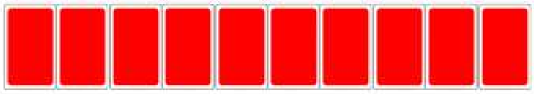
(9)
There are 10 cards in total, 9 red cards and 1 black card.
Now, the experimenter shuffles these cards and put them face down.
Then you are asked to choose 1 card out of these 10 cards. Which of the following two options would you prefer?



○ Option A : To get $40 if you pick a red card. To get $32 if you pick a black card
○ Option B : To get $77 if you pick a red card. To get $2 if you pick a black card

---

(10)
There are 10 cards in total, 10 red cards and 0 black cards.
Now, the experimenter shuffles these cards and put them face down.
Then you are asked to choose 1 card out of these 10 cards. Which of the following two options would you prefer?



○ Option A : To get $40 if you pick a red card
○ Option B : To get $77 if you pick a red card

Send

A4. Time preference questionnaire

(1)
Which of the following two options do you prefer?

○ Option A
Receiving $100 today. (February, 21, 2020)

○ Option B
Receiving $102 thirty days from today. (March, 22, 2020)

(2)
Which of the following two options do you prefer?

○ Option A
Receiving $100 today. (February, 21, 2020)

○ Option B
Receiving $105 thirty days from today. (March, 22, 2020)

(3)
Which of the following two options do you prefer?

○ Option A
Receiving $100 today. (February, 21, 2020)

○ Option B
Receiving $110 thirty days from today. (March, 22, 2020)

---

(4)
Which of the following two options do you prefer?

○ Option A
Receiving $100 today. (February, 21, 2020)

○ Option B
Receiving $115 thirty days from today. (March, 22, 2020)

(5)
Which of the following two options do you prefer?

○ Option A
Receiving $100 today. (February, 21, 2020)

○ Option B
Receiving $120 thirty days from today. (March, 22, 2020)

---

(6)
Which of the following two options do you prefer?

○ Option A
Receiving $100 today. (February, 21, 2020)

○ Option B
Receiving $135 thirty days from today. (March, 22, 2020)

(7)
Which of the following two options do you prefer?

○ Option A
Receiving $100 today. (February, 21, 2020)

○ Option B
Receiving $150 thirty days from today. (March, 22, 2020)

---

(8)
Which of the following two options do you prefer?

○ Option A
Receiving $100 today. (February, 21, 2020)

○ Option B
Receiving $165 thirty days from today. (March, 22, 2020)

(9)
Which of the following two options do you prefer?

○ Option A
Receiving $100 today. (February, 21, 2020)

○ Option B
Receiving $180 thirty days from today. (March, 22, 2020)

---

(10)
Which of the following two options do you prefer?

○ Option A
Receiving $100 today. (February, 21, 2020)

○ Option B
Receiving $195 thirty days from today. (March, 22, 2020)

Send