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Mostafa E. Shahen
School of Economics and Management, Kochi University of Technology

Koji Kotani
School of Economics and Management, Kochi University of Technology
Research Institute for Future Design, Kochi University of Technology

Tatsuyoshi Saijo
Research Institute for Humanity and Nature
Research Institute for Future Design, Kochi University of Technology
School of Economics and Management, Kochi University of Technology

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School of Economics and Management
Research Institute for Future Design
Kochi University of Technology

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Mostafa E. Shahen[*,†] Koji Kotani[*,†,‡,§,¶] Tatsuyoshi Saijo[*,†,‡,‖]

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Abstract

The intergenerational sustainability dilemma (ISD) is a situation where the current generation chooses to maximize (sacrifice) its own benefits without (for) considering future generations, compromising (maintaining) intergenerational sustainability (IS) (Kamijo et al., 2017, Shahrier et al., 2017b). Despite its importance, little is known about how individuals behave under the ISD and affect IS. We design a one-person ISD game (ISDG) with a strategy method in which a queue of individuals is organized as a generational sequence. Each individual is asked to choose, in 36 situations, either (i) an unsustainable option that yields a payoff, X, at an irreversible cost to future generations, D, or (ii) a sustainable option that yields a payoff, $(X - D)$, that imposes no cost on future generations; in each situation, the histories of previous generations' choices and the payoff structures of X & D are varied. As a potential resolution for the ISD, we institute a future ahead and back (FAB) mechanism, whereby each individual is asked, first, to take the position of the next generation and request what she wants the current generation to choose and, second, to make the actual decision from the original position. Our results show that individuals are likely to choose the unsustainable option when the proportion of previous generations that chose the unsustainable option is high or when $\frac{X}{D}$ (the IS index) is low. However, the FAB treatment is effective at preventing individuals from choosing the unsustainable option even in such situations. Overall, the results suggest that some new institutions, such as FAB mechanisms, which induce people to take the standpoint of future generations, may be necessary to avoid intergenerational unsustainability, especially when IS default risk becomes high.

Keywords: Intergenerational sustainability dilemma; future ahead and back mechanism; intergenerational sustainability index

[*]Research Institute for Future Design, Kochi University of Technology
[†]School of Economics and Management, Kochi University of Technology
[‡]Urban Institute, Kyusyu University
[§]College of Business, Rikkyo University
[¶]Corresponding author, e-mail: kojikotani757@gmail.com
[‖]Research Institute for Humanity and Nature

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Nomenclature

DG Dictator game

FAB Future ahead and back

IS Intergenerational sustainability

ISD Intergenerational sustainability dilemma

ISDG Intergenerational sustainability dilemma game

SD Standard deviation

1 Introduction

The survival of the human race on Earth depends on whether we can maintain intergenerational sustainability (IS). However, human actions in recent decades have caused several environmental problems through rapid economic growth, threatening IS for generations to come (Dietz, 2003, Greenhalgh, 2005, Ehrlich et al., 2012, Steffen et al., 2015, Shahrier et al., 2017b, Steffen et al., 2018). This is described by the "intergenerational sustainability dilemma" (ISD), which is a situation where the current generation chooses to maximize (sacrifice) its own benefits without (for) considering future generations, compromising (maintaining) intergenerational sustainability (IS) (Kamijo et al., 2017, Shahrier et al., 2017b). A main feature in ISD is its unidirectional nature, as the current generation affects future generations, but the opposite is not true. Thus, ISD can be considered to have a similar structure to a dictator game (DG) in which a dictator unidirectionally affects a recipient. In this unidirectional setting, the current generation (or the dictator) can prioritize its own benefits without considering future generations (or receivers). Thus, today IS faces serious threats exemplified by the emergence of climate change, the allocation of natural resources and the accumulation of public debt. This paper addresses how individuals behave under the ISD.

The DG has been widely studied by economists for the last few decades (Bohnet and Frey, 1999, Dana et al., 2006, Bardsley, 2007, List, 2007, Ekeli, 2009, Thompson, 2010, Macro and Weesie, 2016, Koch et al., 2017). The stake represents the economic factor in the DG and is observed to be an influential factor in the allocations between the dictator and a receiver (Hoffman et al., 1996, Cherry et al., 2002, List and Cherry, 2008, Novakova and Flegr, 2013, Raihani et al., 2013). Engel (2011) reviews 440 DG papers in a meta-study, identifying that the stake usually falls between $0\,\$$ and $130\,\$$, and an increase in the stake reduces dictators' willingness to give. Other researchers have focused on how information on the allocations of other dictators affects a dictator's allocation in the DG (Hoffman et al., 1994, Cason and Mui, 1998, Fehr and Schmidt, 1999, Bolton and Ockenfels, 2000, Diekmann, 2004, Herne et al., 2013). Ben-Ner et al. (2004) find that information about the allocations of other dictators leads a dictator to divide the allocation in a similar way to how other dictators make their allocations. In short, previous studies have shown that the economic factor and information about other dictators' allocation influence allocations in the DG.

Many scholars have applied an experimental approach in examining group behaviors regarding IS. Fischer et al. (2004) implement a common pool resource experiment with university students to investigate individual decisions in a group, demonstrating that the existence of subsequent groups motivates individuals to sustain resources. Hauser et al. (2014) conduct an online intergenerational goods experiment under a voting mechanism using a general subject pool and find that voting could reduce the exploitation of resources by restraining defectors when a majority of subjects are prosocial. Sherstyuk et al. (2016) examine the efficiency of a dynamic externality game in the laboratory, identifying that resolving the dynamic externalities becomes more challenging in intergenerational settings than in settings with infinitely lived decision makers. They also claim that access to information on the history of previous generations' decisions may improve the negative externalities.

Kamijo et al. (2017) design and implement an ISD game (ISDG) in the laboratory with a student pool to understand group behaviors in the ISD. They find that, within a group of three individuals, the introduction of an individual who is asked to play the role of deputy for future generations, called an imaginary future person, enhances IS. Shahrier et al. (2017b,a) conduct an ISDG field experiment using a subject pool drawn from the general public in urban and rural areas of Bangladesh, showing that rural groups choose sustainable options more often than do urban groups, as the majority of rural people are prosocial. Moreover, they find that inducing subjects to take and understand the standpoint of the next generation before making their decision, an institution called the future ahead and back mechanism, improves IS.[1] Overall, group behaviors in IS are mainly affected by social preferences, access to information about the decisions of previous generations (i.e., history) and institutions or environments for group decisions.

Past studies suggest that individual behaviors in the DG and group behaviors in the ISD are

[1] Shahrier et al. (2017b,a) note that introducing an imaginary future person in a group is not effective at maintaining IS with a general subject pool of Bangladeshi people in the ISDG field experiments. Therefore, they institute and design a future ahead and back mechanism.

influenced by not only people's social preferences of prosociality but also information about the allocations of other dictators and the decisions of previous generations, respectively. We call such information the retrospective factor for decisions in the ISD. On the other hand, how the current generation affects future generations also alters people's behaviors in the ISD. We call this effect of the current generation's choice on future generations the prospective factor for decisions in the ISD. How individuals behave in response to the retrospective and prospective factors in the ISD has not been systematically studied, although this issue is crucial for designing our societies to be intergenerationally sustainable. To this end, we design and institute a one-person ISD game (ISDG) with a strategy method in which a queue of individuals is organized as a generational sequence. Each individual is asked to choose either (i) an unsustainable option that yields payoff X, imposing an irreversible cost on future generations of D, or (ii) a sustainable option that yields payoff $(X - D)$, without imposing any cost on future generations, in 36 situations where the histories of previous generations' choices (the retrospective factor) and the payoff structures of $\frac{X}{D}$ (the prospective factor, i.e., the IS index) are varied. As a potential resolution of the ISD, we introduce a future ahead and back (FAB) mechanism whereby first, each individual is asked to take the position of the next generation and to request what she wants the current generation to choose and second, she makes the actual decision from the original position.

The economic factor and information about how other dictators make their allocations in the DG have been established to affect the allocations between a dictator and a receiver along with people's social preferences. Likewise, the economic factor (i.e., $\frac{X}{D}$) and histories of previous generations' decisions in the ISD are hypothesized to affect the allocations of the decisions made by the current generation between herself and the next generation, consequently influencing subsequent generations and IS.[2] However, there is a distinction between the DG and the ISDG in that a dictator unidirectionally affects only one receiver, while the current generation unidirectionally affects not only the next generation but also all subsequent generations. To the best of our knowl-

[2]The ratio in ISD is interpreted to represent how many generations can enjoy the positive amount of resources before reaching the "devastating consequence" of resource extinction (i.e., $X = 0$), when all the current and subsequent generations keep choosing unsustainable options. Therefore, it is very important and can be considered similar to an idea of the "tipping point" in the ecological system (Westley et al., 2011, Steffen et al., 2015, 2018).

edge, no previous research has systematically addressed and examined individual behaviors under various situations of the ISD. Given this state of affairs, the novelties of this research lie in (i) characterizing how individuals with different social preferences behave in response to the economic (the prospective) factor and history of previous generations' decisions (the retrospective factor) under the ISD and (ii) evaluating how effective an FAB mechanism that induces people to take the standpoint of future generations is at maintaining IS.

2 Methods and materials

2.1 Experimental setup

We administered a one-person intergenerational sustainability dilemma game (ISDG), social value orientation (SVO) game and questionnaires to collect data on individual behaviors, social preferences and sociodemographic information from subjects.

One-person intergenerational sustainability dilemma game (One-person ISDG)

We designed and implemented a one-person ISDG, which possesses similar structures to those of the ISDG played by a group of three people in Kamijo et al. (2017) and Shahrier et al. (2017b). A one-person ISDG is organized by queuing a sequence of consecutive generations, and each generation is represented by one person. A generation is asked to make a choice between an unsustainable option A and a sustainable option B. If a generation chooses option A, she receives a payoff of X tokens (hereafter, we skip mentioning "tokens"), and the next generation faces the decision environment where the payoffs associated with options A and B uniformly decrease by D. If a generation chooses option B, she receives a payoff of $X - D$, and the next generation has the same decision environment as the current one, where the payoffs associated with options A and B never decrease. An essential feature of the game is that the current generation affects subsequent generations, while the opposite is not true.

The 1st generation always starts a one-person ISDG with option $A = 3600$ and option $B =$

$3600 - D$ in any situation. Suppose that a subject is the 1st generation and plays the game with $D = 900$ in a specific situation. The 1st generation receives 3600 if she chooses option A, and the 2nd generation plays the game with options $A = 2700$ and $B = 1800$. When the 1st generation chooses option B, she receives 2700 and the 2nd generation plays the game with options $A = 3600$ and $B = 2700$. Next, suppose that a subject is the 5th generation and plays the game with $D = 300$ in another situation, given a history that the 1st and 3rd (2nd and 4th) generations chose option A (B). In this case, the 5th generation faces the decision environment where the payoffs associated with options A and B are 3000 ($= 3600 - 2D = 3600 - 2 \times 300$) and 2700, respectively, noting that the two previous generations choose option A. Therefore, the 5th generation receives 3000 if she chooses option A, and the 6th generation plays the game with options $A = 2700$ and $B = 2400$. If the 5th generation chooses option B, she receives 2700, and the 6th generation plays the game with options $A = 3000$ and $B = 2700$.

[Table 1 about here.]

A strategy method is applied to create 35 different one-person ISDG situations that each subject uniformly goes through. To this end, the history of previous generations' choices, the payoff of X that a generation can receive, a payoff difference of D between options A and B and the ratio between X and D (i.e., $\frac{X}{D}$) are parametrized under the assumptions that the 1st generation always starts the one-person ISDG with options $A = 3600$ and $B = 3600 - D$ and that the value of D remains the same in each situation. Table 1 summarizes the 35 different situations in the one-person ISDG, listing the associated percentages of previous generations that choose unsustainable option A in history, ranging from 0 to 1; the payoff X that a generation can receive, ranging from 0 to 3600; the difference D, ranging from 100 to 1800; and the ratio between X and D, ranging from 0 to 36. Although table 1 contains the percentage of previous generations in history for each situation that chose option A as a summary, a subject is shown a whole history of how each previous generation chose between options A or B, displayed by a sequence of human-shaped icons with different colors in each situation, as in the appendix.

Figure 1 displays a scatter plot for the distribution of the 35 situations over the percentage of previous generations who choose option A and the ratio between X and D, where each plot corresponds to one situation in table 1. In this experimental design, the history of the sequence for each situation and the ratio between X and D for each situation can be interpreted as the retrospective and prospective factors because they represent what happened in the past as well as what will happen to the subsequent generations in the sequence for each situation, respectively. Specifically, the history of the sequence for each situation is interpreted as the retrospective factor, while the ratio of $\frac{X}{D}$ is interpreted as the prospective factor, representing how many generations in the sequence can receive a positive payoff of X for each situation when each generation keeps choosing option A. We call the ratio of $\frac{X}{D}$ the intergenerational sustainability index (i.e., IS index) in the one-person ISDG. The parametrization is made to widely vary the retrospective (history) and prospective ($\frac{X}{D}$) factors as well as to minimize the correlation among the factors in the one-person ISDG with a strategy method, reflecting figure 1 ($r = 0.099, P = 0.56$). For example, the 23rd situation in table 1 consists of a history in which $70\,\%$ of previous generations chose option A, $X = 1500$ and $D = 300$, implying that the current generation is 11th and there are 10 previous generations. Concretely, the history consists of 7 previous generations (i.e., 1st, 2nd, 4th, 6th, 8th, 9th and 10th) that chose option A and of 3 previous generations (i.e., 3rd, 5th, 7th) that chose option B, as shown in figure 2. In this case, the payoffs associated with options A and B that the 11th generation faces are 1500 ($= 3600 - 7D = 3600 - 7 \times 300$) and 1200, respectively.

[Figure 1 about here.]

Figure 2 shows the screens of the game, which are designed following Strombach et al. (2015). In each situation, a subject observes the screen of the game when she is asked to decide between options A and B. Here, we take the 23rd situation as an example. The first screen in figure 2 notifies the subject of the situation number (i.e., the 23rd situation), and the second screen presents the history, options and associated payoffs for the current and next generations. At the top of the second screen, human-shaped icons represent the generations in each situation, and the dotted and striped icons represent the current and subsequent generations, respectively. The gray and light gray icons represent the previous generations in history who chose options A and B, respectively, while the black icons represent the subsequent generations to come after the next generation. In the middle of the screen, the options for the current and next generations are presented next to the white and striped icons, respectively.

[Figure 2 about here.]

In addition to these 35 situations of the one-person ISDG, each subject plays one binding situation whose decision environments evolve over generations according to how previous generations have chosen and how the current generation chooses, being passed to the subsequent generations within the sequence to determine the real payment to subjects. In the binding situation, the 1st generation starts the game with option $A = 3600$, where one value of D is randomly picked from the four possible values of 300, 600, 900 and 1200. Once it is picked, the value of D remains the same for the $1\text{st}, 2\text{nd}, \ldots$ generations in the sequence for the binding situation. The binding situation is continued as long as the value of X is strictly positive and ends when it becomes zero or negative for some generation in the sequence. Therefore, the payoff structures in the decision environment faced by each generation in the sequence for the binding situation are different, while the 35 situations in table 1 are uniformly played by all subjects. We call the series of experimental procedures in which each subject plays the one-person ISDG in 36 situations the basic ISDG treatment.

Building upon the basic ISDG treatment, we apply the future ahead and back (FAB) mechanism for the one-person ISDG in 36 situations, which is hereafter called the FAB treatment. In the FAB treatment, we ask each subject to go through the following steps in each situation. As the 1st step, each subject is asked to imagine that she is in the next generation. From the standpoint of the next generation, she is asked to make a request about the choice that she wants the previous generation to choose between options A and B. As the 2nd step, the subject is asked to return to her original (actual) position in the sequence, and she makes her final and actual decision by choosing one option, A or B, for that situation. For instance, if a subject is the 5th generation in the sequence for one situation, then she is asked to imagine herself in the position of the 6th generation in the sequence and to make a request about the choice that she wants the 5th generation in the sequence to make. After that, she is asked to return to her original position in the sequence (i.e., the 5th generation) and make her final and actual choice for that situation.

Each subject was randomly assigned to either the basic ISDG treatment or the FAB treatment and played the one-person ISDG with a strategy method in 36 different situations, consisting of the 35 situations in table 1 and a single binding situation. The orders of the 36 situations that each subject went through in the one-person ISDG were randomly shuffled to avoid order effects. The experimenters offered the following explanation to the subjects: "One situation out of the 36 situations shall be chosen for the actual experimental payment, following a certain rule. Because you do not know in advance which situation shall be chosen for the payment, please be serious and considerate about a choice in each situation that may affect the subsection subjects, because they will play after you." However, in reality, to simplify the experimental procedures, the experimenters predetermined that the choices and outcomes in the binding situation would only be used to determine the experimental payment of each subject and to affect the subsequent subjects. In the one-person ISDG, one experimental token was calculated and exchanged as 1.5 JPY, and subjects were paid 3000 JPY (≈ 27.8 USD) on average.

Social value orientation

Subjects' social preferences are proxied by their social value orientations (SVOs), which were identified using the triple dominance measure (Van Lange et al., 1997). This measure consists of 9 items, each of which contains three choices. For each item, subjects must make one choice over how to divide an amount of money between herself and a stranger. For example, each subject faces the following three options: A: you get 500 and the other gets 100, B: you get 500 and the other gets 500 and C: you get 560 and the other gets 330. A competitive subject is likely to choose option A, maximizing the gap between her own and the stranger's points $(500 - 100 = 400)$. A prosocial subject has high chances of choosing option B, as it maximizes the joint benefit $(500 + 500 = 1000)$. An individualistic subject chooses option C by maximizing her payoff without considering the other (Van Lange et al., 2007). A subject's type, i.e., individualistic, competitive or prosocial, is identified by her choices in the SVO game. When a subject makes 6 consistent choice for the same orientation (i.e., individualistic, competitive or prosocial) out of the 9 items, then she is considered to have that orientation or otherwise is "unidentified." Subjects were randomly paired for the computation of their payoffs based on their performance, and they were paid on average 500 JPY (≈ 4.7 USD) in the SVO game.

Experimental procedures

Our experiments were conducted at experimental laboratories at Kochi University of Technology. The experiment comprised 27 sessions, each involving $4 \sim 5$ subjects, for a total of 108 subjects (55 females and 53 males; average age $= 20.4$).[3] The subjects were volunteer undergraduate students in various fields such as engineering and social science; each subject participated in only one session and was paid in total 4000 JPY (≈ 37 USD) on average (i.e., the one-person ISDG payoff (3000 JPY), the SVO game payoff (500 JPY) and a fixed participation fee (500 JPY)). The time of each session varied between the basic ISDG and FAB treatments. One session in the basic ISDG treatment consisted of two parts and took approximately 75 minutes. In the first part, subjects completed the one-person ISDG for 40 minutes. In the second part, they completed the SVO game and questionnaires for 35 minutes. One session in the FAB treatment also consisted of two parts and took approximately 90 minutes. In the first part, subjects completed the one-person ISDG for 55 minutes—a longer duration than that of the basic ISDG treatment due to the additional procedures in the FAB (see the 1st and 2nd steps of the FAB treatment within the dashed-line box in figure 3). In the second part, they complete the SVO game and questionnaires for 35 minutes.

Figure 3 shows the procedures for the one-person ISDG, SVO game and questionnaire in one session for the basic ISDG and FAB treatments. Upon arriving to the meeting room, each subject picked a lottery number that determined her experimental ID. Then, the subjects were taken to

[3] The observations of 9 subjects in the FAB treatment and 2 subjects in the basic ISDG treatment were dropped because of missing responses in the one-person ISDG, which made the number of subjects in the FAB treatment lower than that in the basic ISDG treatment

two different designated rooms based on their experimental IDs. In the basic ISDG treatment, each subject read the experimental instructions and listened to an oral presentation made by an experimenter about the basic one-person ISDG. We use neutral terminologies in the explanations and avoid using terms such as "generations," "sustainable" and "unsustainable." Then, each subject completed the 36 situations of the basic one-person ISDG treatment in a shuffled order. Each subject made her decision by choosing between options A and B in each of the situations. When a subject finished making the decisions in all 36 situations, she was informed of the situation number that corresponded to the binding situation, which determined her final payoff from the one-person ISDG. Then, subjects moved to a different room to complete the SVO game and fill out the questionnaires. After that, the subjects moved to a payment room, where the payment for the SVO game was calculated by randomly pairing subjects together.

In the FAB treatment, each subject read the experimental instructions and listened to an oral presentation made by an experimenter. Then, each subject completed the 36 situations of the ISDG with the FAB treatment as shown in figure 3. In each situation, the subject was asked to imagine that she was in the position of the next generation in the sequence. From that position, she made a request to the previous generation on which choice she wanted the previous generation to make. After that, she returned to her original position in the sequence and made her final decision between options A and B. After each subject finished making her requests and decisions in all 36 situations, the subject was informed about the situation number that corresponded to the binding situation, which determined her final payoff from the one-person ISDG. Then, subjects moved to a different room to experience the SVO game and fill out a questionnaire. After that, subjects moved to a payment room, where the payment for the SVO game was calculated by randomly pairing subjects together.

[Figure 3 about here.]

Figure 4(a) shows the screens that a subject observes while playing the basic ISDG and FAB treatments. The screens for the basic ISDG treatment are displayed and two screens presented in each situation. The first screen presents the situation number and appears for 3 seconds. After that, the second screen appears for 15 seconds and presents the history of the previous generations' choices at the top of the screen and the options available for the current and subsequent generations in the middle. We call the second screen the "one-person ISDG screen." During the time in which the second screen is displayed, each subject makes her decision by entering the character "A" or "B" in another computer display served as a response device. A subject has to go through the above processes by observing the first and second screens in each situation, and the one-person ISDG is continued until she finishes making the decisions in all 36 situations.

Figure 4(b) presents a series of screens that a subject faces for each situation under the FAB treatment in the one-person ISDG. The first screen presents the situation number for 3 seconds. The second screen is displayed to notify the subject that she should imagine herself in the position of the next generation in the sequence and make a request about which choice she wants the previous generation to make between options A and B. Then, the next screen is the same screen as the second screen in the basic ISDG treatment (i.e., the one-person ISDG screen), and this screen is displayed for 10 seconds. At that time, the subject must make a request of the previous generation by entering the character "A" or "B" in another computer display served as a response device. After that, another notice screen appears for 3 seconds to let the subject know that she must return to her original position. The one-person ISDG screen appears one more time for 10 seconds to present the one-person ISDG choices to the subject, and she makes her final choice from her original position in the current generation. Subjects make their final choice by entering "A" or "B" in the response device, while the request they have made as the next generation kept visible on the display of the response devise. As in the basic ISDG treatment, a subject has to go through the above processes by observing a series of screens in each situation, and the one-person ISDG is continued until she finishes making the decisions in all 36 situations.

[Figure 4 about here.]

3 Results

Table 2 presents the summary statistics of experimental results for the basic one-person ISDG (basic ISDG) and the future ahead and back (FAB) treatments. The number of subjects who participated in the basic ISDG and FAB treatments is 55 and 42 subjects, among which the number of prosocial subjects are 30 and 14, respectively. Each subject went through the 36 situations of the one-person ISDG in both treatments, generating a total number of observations of 1980 $(= 55 \times 36)$ and 1512 $(= 42 \times 36)$ in the basic ISDG and the FAB treatment, respectively. Approximately $33.7\,\%$ and $44.5\,\%$ of the generational choices are option B in the basic ISDG and FAB treatments, implying that the percentages choosing option A are $66.3\,\%$ and $55.5\,\%$, respectively. These results appear to suggest that the FAB treatment is effective at inducing subjects to choose the sustainable option. To statistically confirm the difference, we run a chi-square test with the null hypothesis that the frequencies of the observations of subjects choosing options A and B between the basic ISDG and the FAB treatments are the same, and the null hypothesis is rejected at the $1\,\%$ significance level ($\chi^2 = 42.4, P < 0.01$).

[Table 2 about here.]

Figure 5(a) shows the frequency distributions of the percentage per subject of the choice of option B in the 36 situations under the basic ISDG and FAB treatments; the percentage represents the number of situations in which the subject chooses option B divided by 36 (one subject goes through 36 situations and is asked to choose between options A and B in each situation). Figure 5(a) demonstrates that the distribution under the basic ISDG treatment is skewed to the left, as the peak of the distribution is around $0\,\%$ to $10\,\%$, indicating that a considerable portion of subjects do not choose option B at all or only around $10\,\%$ of the time. On the other hand, the distribution under the FAB treatment is flattened, with more concentration of around $50\,\%$ as well as a reduction in the peak's height at $0\,\%$. We also draw the corresponding boxplots in figure 5(b) for the same distributions under the basic ISDG and FAB treatments, corroborating that the location parameters, such as medians and quantiles, for the percentage of choices of option B per subject in the FAB treatment are generally higher than those in the basic ISDG. We also run a Mann-Whitney test with the null hypothesis that the distributions of the percentage of choices of option B per subject between the basic ISDG and FAB treatments are the same. The null hypothesis is rejected at the $10\,\%$ significance level ($z = -1.79, P = 0.072$), implying that subjects are more likely to choose option B in the FAB treatment than in the basic ISDG treatment.

[Figure 5 about here.]

Table 3 displays the percentages of choices of option B for prosocial and proself subjects in each of the basic ISDG and FAB treatments by pooling observations from subjects. The percentages of choices of option B made by prosocial subjects under the basic ISDG and FAB treatments ($44.72\,\%$ and $55.56\,\%$) are higher than those made by proself subjects ($20.44\,\%$ and $38.99\,\%$). The result suggests that prosocial subjects tend to choose option B more than proself subjects, which is consistent with the literature (Gintis et al., 2003, Camerer and Fehr, 2006). At the same time, the percentages of choices of option B made by prosocial and proself subjects under the FAB treatments ($55.56\,\%$ and 38.99) are higher than those under the basic ISDG treatment ($44.72\,\%$ and $20.44\,\%$). We run a chi-square test with the null hypothesis that the frequency distributions of choosing option B among prosocial and proself subjects are the same between the basic ISDG and FAB treatments. The result rejects the null hypothesis at the $1\,\%$ level ($\chi^2 = 129.6, P < 0.01$), demonstrating that the FAB treatment appears to be effective at inducing subjects to choose option B, irrespective of subjects' value orientations.

[Table 3 about here.]

To quantitatively characterize the marginal impact of subjects' SVO and the prospective and retrospective factors on subjects' choices in the one-person ISDG, panel logit regressions are applied to our experimental data. In the regressions, a dummy variable capturing the subject's binary choice between options A and B in each situation is specified as the dependent variable, taking a choice for option A as the base group. On the other hand, the SVO, the percentage of option A

in the sequence history, FAB treatment & the IS index ($\frac{X}{D}$) in each situation and the interaction terms of these variables are specified as the independent variables. Since one subject provides 36 observations in our experiment, the data are considered to possess a panel-data structure, where a panel unit is a subject and a time unit is one situation out of the 36. Since a time-invariant independent variable (the SVO) is included as one of the independent variables in the analysis, we apply a random-effects panel logit regression (Wooldridge, 2010, 2019). With these model specifications, we not only estimate the model but also calculate the marginal effect of an independent variable on the likelihood of a subject choosing option B (Wooldridge, 2010). Table 4 summarizes the estimation results and the associated marginal probabilities from the three panel logit regressions.

In model 1 of table 4, we consider the basic independent variables, consisting of the prosocial dummy, the percentage of option A choices in the sequence history, the FAB treatment dummy and the IS index, finding that all the coefficients and marginal probabilities of these variables are statistically significant at $1\,\%$ level. All the independent variables have a positive relationship with the probability of choosing option B except the percentage of option A choices in the sequence history. More specifically, subjects in the FAB treatment (prosocial subjects) are $15.8\,\%$ ($22.4\,\%$) more likely to choose option B than those in the basic ISDG treatment (proself subjects), while an increase of one unit in the IS index leads subjects to choose option B more often by $0.2\,\%$. On the other hand, subjects are $0.97\,\%$ less likely to choose option B as the percentage of option A choices in the sequence history increases by $10\,\%$. These results indicate that prosociality and the FAB treatment are effective at maintaining IS, which is in line with previous studies on group behaviors. For example, Hauser et al. (2014) indicate that a group tends to be sustainable when a majority are prosocial individuals, while Kamijo et al. (2017), Shahrier et al. (2017b) and Timilsina et al. (2019) show that the introduction of some mechanisms can have positive effects on group behaviors for IS.

In models 2 and 3, we include interaction terms for the FAB treatment dummy & IS index and the FAB treatment dummy & the percentage of option A choices in the sequence history. The estimation results remain qualitatively the same as those in model 1, while the interaction term of the FAB treatment dummy & IS index (FAB treatment dummy & percentage of option A choices in history) is statistically significant at the $1\,\%$ level (insignificant) with a negative sign in models 2 and 3 (in model 3). The results suggest that subjects behave differently under the basic ISDG and FAB treatments in response to the IS index, while they do not respond to the percentage of option A choices in the sequence history. Specifically, subjects tend to choose option A as the IS index decreases, reflecting the result of model 1 in table 4. However, the results associated with the interaction terms in models 2 and 3 suggest that the FAB treatment prevents subjects from choosing option A in response to a decrease in the IS index, making the treatment effective as sustainability becomes endangered.[4]

[Table 4 about here.]

To quantitatively demonstrate how subjects behave differently under the basic ISDG and FAB treatments, we calculate the predicted probabilities of a subject choosing option B over the IS index in each treatment based on the estimation result of model 2 in table 4.[5] Because the interaction term of the FAB treatment dummy & IS index is estimated to be negative in model 2, the predicted probabilities under the FAB treatment should be larger than those under the basic ISDG treatment as the IS index decreases. Figure 6 displays the predicted probabilities over the IS index under basic ISDG and FAB treatments represented by the solid and dashed lines, respectively. As seen in figure 6, the trajectories over the IS index are clearly different between the basic ISDG and FAB treatments. The predicted probability under the basic ISDG (solid line) increases in the IS index ranging from 0.27 to 0.41, while that under FAB (dashed line) is almost flat or only slightly decreases in the IS index ranging from 0.47 to 0.44. These results in figure 6 confirm that subjects tend to choose option A under the basic ISDG when the IS index of a prospective factor is low. However, the introduction of the FAB can induce subjects to consistently or stably choose option B irrespective of the values of the IS index.

[4] We apply several other models including different specifications and other interaction terms as robustness checks, yielding qualitatively similar results to those in models $1, 2$ and 3 of table 4.

[5] The predicted probabilities are calculated by changing the IS index, holding other independent variables fixed at the sample means.

[Figure 6 about here.]

Next, we characterize how subjects respond to the retrospective and prospective factors in the ISD within a single framework. To this end, two heat maps are drawn to present the predicted probabilities of choosing option B under the basic ISDG and FAB treatments on the domain of the percentage of option A choices in the sequence history and the IS index (figure 7). The predicted probabilities are calculated based on the estimation results in model 3 of table 4.[6] The vertical (horizontal) axis represents the percentage of option A choice in the sequence history (IS index), and it varies from 0 to 1 (from 0 to 36). The density of the black color in each location of the domain reflects the predicted probability of choosing option B; the darker the color, the higher is the predicted probability. The scale, ranging from $23\,\%$ to $52\,\%$, is shown on the right-hand side in figure 7.

The predicted probabilities under the basic ISDG in figure 7 corroborate that subjects are more likely to choose option A as the IS index (the percentage of option A in history) becomes lower (higher), consistent with the results in table 4 and figure 6. This is quite intuitive in the sense that people in the current generation tend to give up being sustainable when previous generations chose such unsustainable options that it may be too late or the situation faced by the current generation too grave for sustainability to be improved. However, the predicted probabilities under the FAB treatment in figure 7 show that subjects tend to choose option B stably and consistently, being more invariant against changes in either the IS index or the percentage of option A in history than the probabilities in the basic ISDG. In fact, the predicted probabilities under the FAB treatment range from $40\,\%$ to $52\,\%$, demonstrating that asking subjects to take the position of the next generation fundamentally affects their choices between options A and B in response to the retrospective and prospective factors in the ISD. Overall, the regression results in table 4, figures 6 and 7 establish that people react to the retrospective and prospective factors in an intuitive way under the basic ISDG, implying that people in the current generation choose unsustainability if previous genera-

[6] The predicted probabilities are calculated in the same way as in figure 6 by holding other independent variables fixed at the sample means. In addition, as a robustness check, they are calculated based on the estimation results in model 2. We confirm that they remain qualitatively the same as in figure 7.

tions betray them and it seems too late for the current situation to be made sustainable. However, the FAB treatment is demonstrated to prevent people from making such choices.

[Figure 7 about here.]

Some behavioral scientists and economists have recently emphasized the importance of analyzing economic, cognitive and noncognitive factors to characterize human behaviors at the individual and group levels in a single framework (see, e.g., Borghans et al., 2008, Izuma et al., 2010, Lindqvist and Vestman, 2011, Acharya et al., 2018, Chen et al., 2019). Our experiments are considered to systematically examine individual behaviors in response to these factors under the ISD in the sense that prospective and retrospective factors and social preferences are known to correspond to economic and noncognitive factors, respectively (Borghans et al., 2008). Overall, the results are interpreted to demonstrate that the economic factors of the IS index and the percentage of option A choices in the sequence history as well as social preferences have impacts on individual behaviors in the ISD in an intuitive way, consistent with the literature on the dictator and other games. In particular, a social preference of prosociality is identified as one influential factor in subjects choosing the sustainable option in the ISDG, and a similar result is consistently confirmed in common pool resource and public goods games (Hauser et al., 2014, Kamijo et al., 2017, Shahrier et al., 2017b, Timilsina et al., 2017). However, people's social preferences are claimed to be determined at young ages by the culture and social norms of societies, remaining fixed when they become adults. Therefore, these preferences are considered impossible to change with policy or external interventions (Ockenfels and Weimann, 1999, Brosig-Koch et al., 2011, Carlsson et al., 2014).

An important question here is why and how the FAB mechanism affects individual behaviors in the ISD. Although we admit that there are several possible explanations, we conjecture that the FAB mechanism affects a cognitive factor in human-decision processes (Konow, 2000). In particular, Cooper (2007) argues that some dissonance in human cognition, that is, cognitive dissonance, may influence human decisions when individuals experience two or more different psychological and/or economic representations in a decision-making situation, such as a social dilemma where two representations conflict with one another regarding interests and payoffs. Since the FAB mechanism requires each individual to experience or role-play two representations of the current and future generations where each generation's interest conflicts, we argue that cognitive dissonance in subjects' decision-making processes might have been triggered and augmented to enhance sustainable choices over the outcomes observed in the basic ISDG.

Another possible explanation is that the FAB mechanism might affect not only cognitive factors but also noncognitive factors in human decision-making processes. Some economists, psychologists and neuroscientists demonstrate that empathy is a primary factor in characterizing prosocial behaviors in several different games and settings and is known to play a part in cognitive and noncognitive factors (Batson et al., 1988, Snow, 2000, de Vignemont and Singer, 2006, Decety and Ickes, 2009, Mathur et al., 2010, Tusche et al., 2016). In economics, Andreoni and Rao (2011) and Andreoni et al. (2017) demonstrate that prosocial donations are increased in the DG by letting one subject role-play both the dictator and the receiver. They argue that empathy from the dictator to the receiver is enhanced by such role-playing and is a key means of promoting prosocial behaviors. Furthermore, psychologists argue that empathy can be a main factor in a person making decisions to the benefit of others or engaging in prosocial behaviors even at a personal cost (Batson et al., 1988). In the ISDG, choosing the sustainable option is equivalent to benefiting others at a personal cost. Thus, the FAB mechanism may be considered to enhance the empathy of the current generation through its role-playing of the next generation in the ISD.

Democracy and capitalism have become two major social institutions that have been adopted by many countries in the world over the last few decades. However, some social scientists argue that these institutions are not future-oriented but present-oriented in their nature (Wolf, 2008, Saunders, 2014). The decision-making processes under democracy and capitalism rarely require people to take the standpoint of future generations, even for intergenerational problems such as climate change and government debt, and the decisions end up being mostly made from the current generation's standpoint (Milinski et al., 2006, Ekeli, 2009, Christiano, 2010, Mulgan, 2011, Steffen et al., 2015, Hansen and İmrohoroğlu, 2016, Steffen et al., 2018). Our findings imply that

IS problems will worsen in the absence of a new mechanism to affect people's cognitive and/or noncognitive processes. They also suggest that the FAB mechanism is one approach to nudge the current generation toward being more future-oriented by asking her to role-play future generations and send a request to the current generation. We believe that institutionalization of the FAB mechanism is one possible resolution of the ISD, affecting people's cognitive and noncognitive factors by propagating an idea of "putting oneself in future generations' shoes" at the individual, household and society levels. Introducing the FAB mechanism will be more likely to lead to better outcomes for sustainability than introducing nothing.

4 Conclusion

This paper has addressed the intergenerational sustainability dilemma (ISD) and how individuals behave under the ISD. We hypothesize that the economic factor (the prospective factor, i.e., the IS index) and histories of previous generations' behaviors (i.e., the retrospective factor) affect the decisions made by the current generation that impact herself and future generations in the ISD. To examine the hypothesis, a basic one-person ISD game (ISDG) treatment was designed and implemented with a strategy method in a laboratory experiment. In addition, the future ahead and back (FAB) mechanism was instituted as a possible solution for the ISD. The experimental results in the basic ISDG treatment show that people are more likely to choose the unsustainable option as sustainability is increasingly endangered (i.e., the IS index is low and/or the percentage of previous generations that chose the unsustainable option is high). In other words, people are said to react to retrospective and prospective factors in an intuitive way, in that no one chooses to be sustainable after previous generations have betrayed the current generation or if it appears too late to do anything about the current situation. On the other hand, the FAB mechanism is identified to positively influence individual behaviors for maintaining sustainability even in such an endangered situation. We argue that a possible explanation for the effectiveness of the FAB mechanism is an increase in cognitive dissonance and/or the associated empathy toward future generations.

Finally, we note some limitations and future avenues of research. Our research does not address the detailed processes and channels of how and why the FAB mechanism affects individual behaviors in the ISD. To address these issues, two approaches can be suggested: (i) a neuropsychological approach and (ii) qualitative and deliberative interviews. The neuropsychological approach should allow the collection of various psychological scales and neuroimages to examine the possible processes and channels engaged when individuals make decisions under the FAB mechanism in the ISDG. In this way, a specific factor that influences individual behaviors may be identified (Vanderwolf, 1998, Watkins and Goodwin, 2019). Qualitative interviews and deliberative approaches have already been used by some economists and psychologists (Corbin and Strauss, 2014, Schulz et al., 2014, Rand, 2016, Palfrey et al., 2017). Individual interviews or group deliberations are conducted to clarify how individuals and groups reach decisions. Specifically, qualitative content analyses and text mining can be applied to untangle the detailed changes in individual behaviors that occur under the FAB mechanism in the ISDG. These caveats notwithstanding, it is our belief that this paper is an important first step in understanding individual behaviors in the ISD and suggests a possible mechanism to enhance sustainability.

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List of Tables

Table 1: The 35 situations that each subject plays in one-person ISDG

Situations	% of option A in history	X	D	$\frac{X}{D}$	# of generations in history	Current generation		
						Position[1]	Option A	Option B
1	0	3600	1800	2	0	1	3600	1800
2	0	3600	1200	3	5	6	3600	2400
3	0	3600	900	4	7	8	3600	2700
4	0	3600	300	12	0	1	3300	3300
5	0	3600	100	36	9	10	3600	3500
6	0.25	2700	900	3	4	5	2700	1800
7	0.25	1800	300	6	8	9	1800	1500
8	0.25	3400	200	17	4	5	3400	3200
9	0.33	0	1200	0	9	10	0	-1200
10	0.33	1200	600	2	12	13	1200	600
11	0.5	0	1800	0	4	5	0	-1800
12	0.5	0	900	0	8	9	0	-900
13	0.5	1200	1200	1	4	5	1200	0
14	0.5	2400	600	4	4	5	2400	1800
15	0.5	2400	600	4	4	5	2400	1800
16	0.5	2400	300	8	8	9	2400	2100
17	0.5	3400	200	17	2	3	3400	3200
18	0.5	3200	100	32	8	9	3200	3100
19	0.63	2600	200	13	8	9	2600	2400
20	0.67	1200	1200	1	3	4	1200	0
21	0.67	3000	300	10	3	4	3000	2700
22	0.67	2600	100	26	15	16	2600	2500
23	0.7	1500	300	5	10	11	1500	1200
24	0.7	2200	100	22	20	21	2200	2100
25	0.75	0	300	0	16	17	0	-300
26	0.75	900	900	1	4	5	900	0
27	0.75	1800	600	3	4	5	1800	1200
28	0.75	3300	100	33	4	5	3300	3200
29	0.78	0	200	0	23	24	0	-200
30	1	1800	1800	1	1	2	1800	0
31	1	1800	900	2	2	3	1800	900
32	1	2400	1200	2	1	2	2400	1200
33	1	3300	300	11	1	2	3300	3000
34	1	3000	200	15	3	4	3000	2800
35	1	3500	100	35	1	2	3500	3400

[1] This represents current generation position in a situation. For example, in situation number 23, the number of generations in history is 10, thus current generation position is the 11th generation.

Table 2: Summary statistics

	Basic ISDG treatment	FAB treatment
Total No. of subjects	55	42
No. of prosocial subjects	30 (55 %)	14 (33 %)
No. of proself subjects	25 (45 %)	28 (67 %)
No. of situations per subject	36	36
Total number of observations	1980	1512
Observations of choosing option A	1313 (66.3 %)	839 (55.5 %)
Observations of choosing option B	667 (33.7 %)	673 (44.5 %)

Table 3: The percentages of choices of option B made by prosocial and proself subjects in the basic ISDG and FAB treatments

	Percentages of choices of option B		
	Basic ISDG treatment	FAB treatment	Overall
Prosocial	$44.72\,\%$ ($\approx\frac{483}{1080}$)	$55.56\,\%$ ($\approx\frac{280}{504}$)	$48.17\,\%$ ($\approx\frac{763}{1584}$)
Proself	$20.44\,\%$ ($\approx\frac{184}{900}$)	$38.99\,\%$ ($\approx\frac{393}{1008}$)	$30.24\,\%$ ($\approx\frac{577}{1908}$)
Subtotal	$33.69\,\%$ ($\approx\frac{667}{1980}$)	$44.51\,\%$ ($\approx\frac{673}{1512}$)	$38.37\,\%$ ($\approx\frac{1340}{3492}$)

Table 4: Panel logit models with a dummy variable of the binary choice between options A and B as the dependent variable, with the choice of option A is the base group

	Model 1		Model 2		Model 3	
	Coefficients	Marginal effects[1]	Coefficients	Marginal effects	Coefficients	Marginal effects
Prosocial[2]	1.410^{***}	0.224^{***}	1.431^{***}	0.225^{***}	1.431^{***}	0.225^{***}
	(0.369)	(0.058)	(0.371)	(0.058)	(0.371)	(0.058)
% of option A in history[3]	-0.615^{***}	-0.097^{***}	-0.602^{***}	-0.095^{***}	-0.599^{***}	-0.095^{***}
	(0.131)	(0.021)	(0.131)	(0.021)	(0.175)	(0.021)
FAB treatment[4]	1.001^{***}	0.158^{***}	1.337^{***}	0.159^{***}	1.341^{***}	0.159^{***}
	(0.370)	(0.059)	(0.381)	(0.058)	(0.405)	(0.058)
IS index $\left(\frac{X}{D}\right)^5$	0.014^{***}	0.002^{***}	0.028^{***}	0.002^{***}	0.028^{***}	0.002^{***}
	(0.003)	(0.0006)	(0.005)	(0.0006)	(0.005)	(0.0006)
FAB $\times$ IS index			-0.032^{***}	-	-0.032^{***}	-
			(0.008)	-	(0.008)	-
FAB $\times$ % of option A in history					-0.007	-
					(0.265)	-
Observations	3492		3492		3492	
Wald χ^2	51.98^{***}		68.43^{***}		68.44^{***}	

***, **, * significant at the 1 %, 5 % and 10 % levels, respectively.
Standard errors in parentheses.

1 Calculated at the same means of the independent variables.

2 Prosocial is a dummy variable for SVO, taking 1 if the subject is categorized as prosocial and 0 otherwise.

3 % of choice A in history is the percentage of option A choices in the sequence history, taking a value from 0 to 1 reflecting the ratio of the number of previous generations that chose option A to the total number of previous generations in the sequence history for each situation.

4 FAB treatment is a dummy variable taking 1 if the subject is in the FAB treatment and 0 otherwise.

5 IS index is an ordered categorical variable for the ratio of $\frac{X}{D}$, taking a value from 0 to 36.

List of Figures

Figure 1: Scatter plot for the distribution of the 35 situations in our game

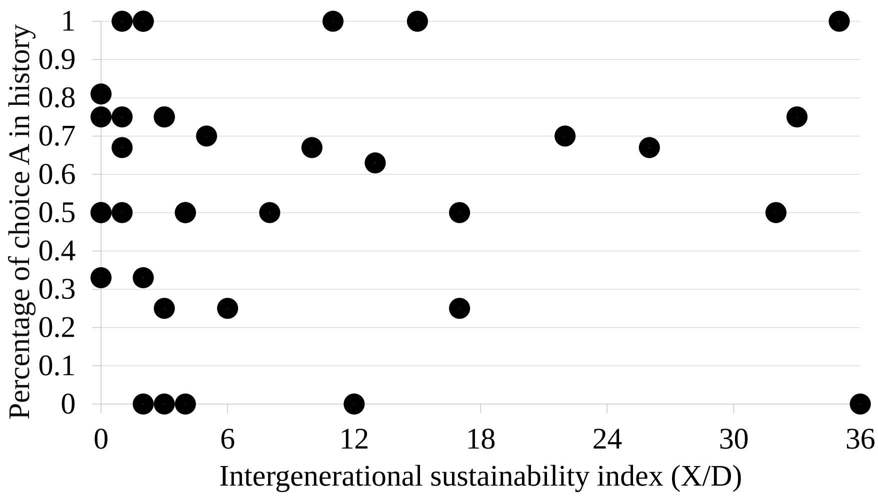
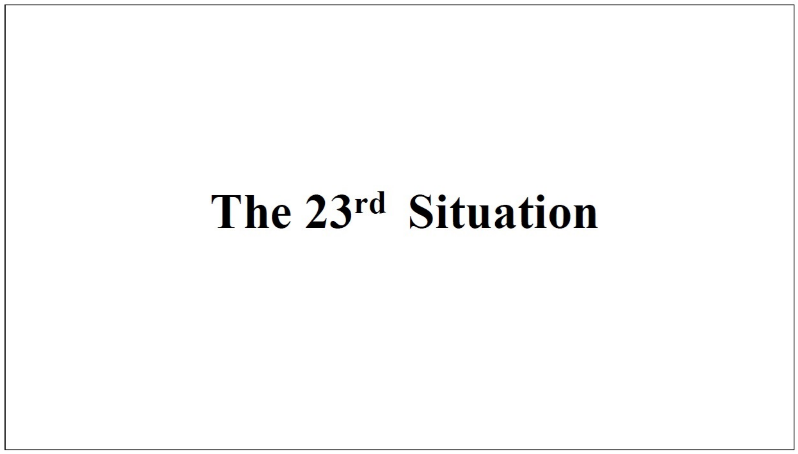


Figure 2: The 23rd situation of the one-person ISDG as seen by each subject

(a) The first screen



(b) The second screen

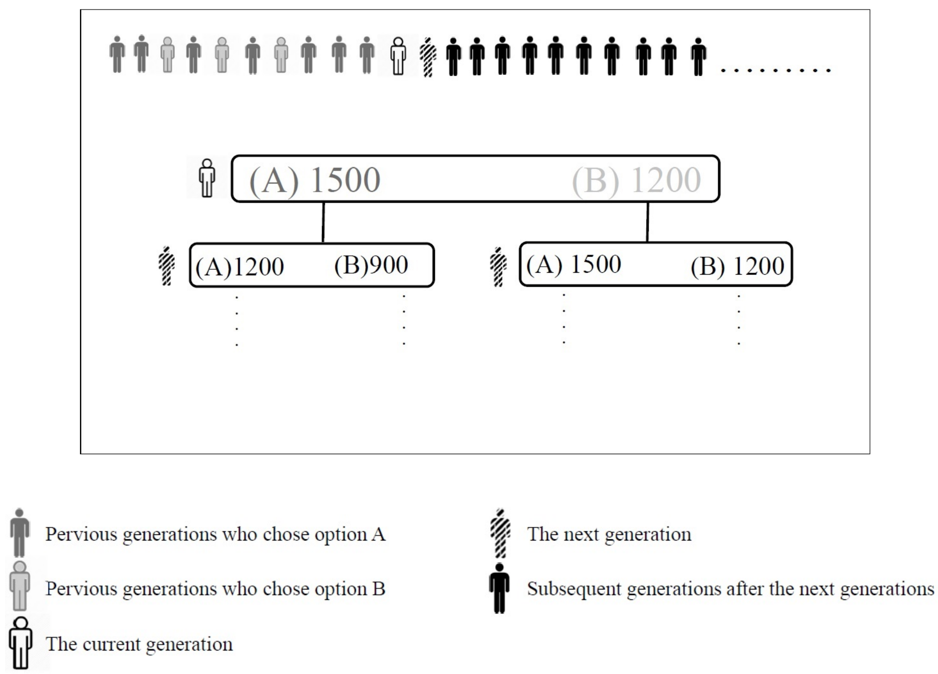


Figure 3: Procedures of the one-person ISDG, SVO game and questionnaire in one session

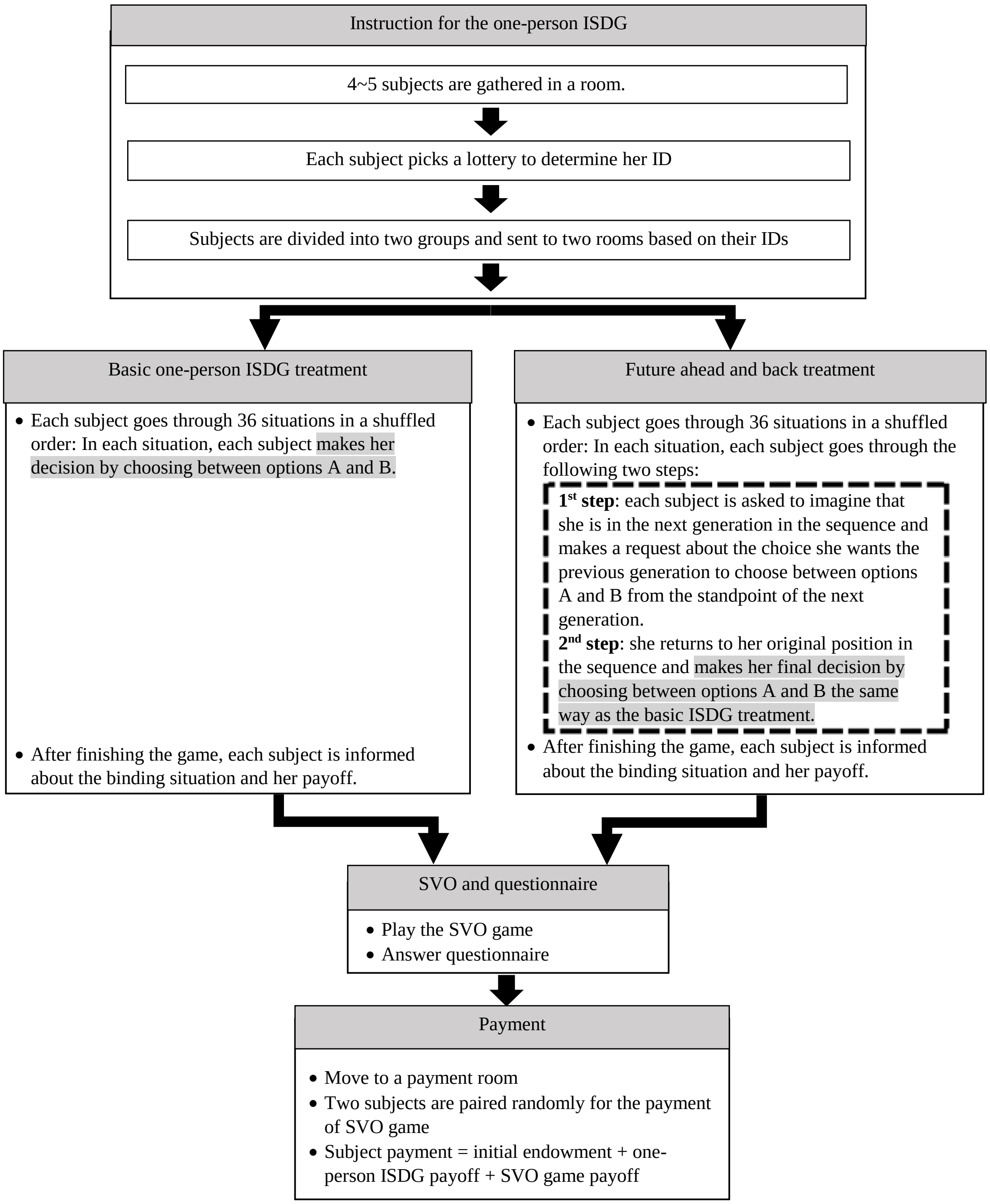
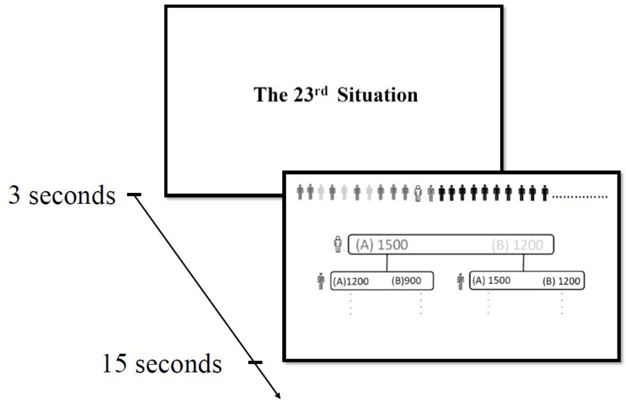


Figure 4: The screen of the ISDGs as seen by each subject in chronological order

(a) One-person ISDG situation for the basic ISDG treatment



(b) One-person ISDG situation for the FAB treatment

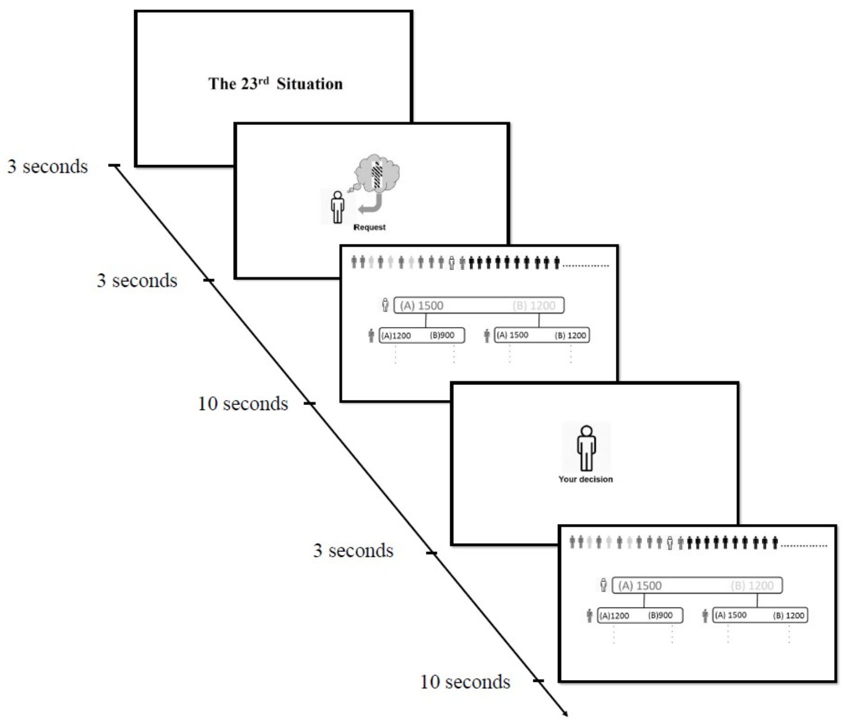
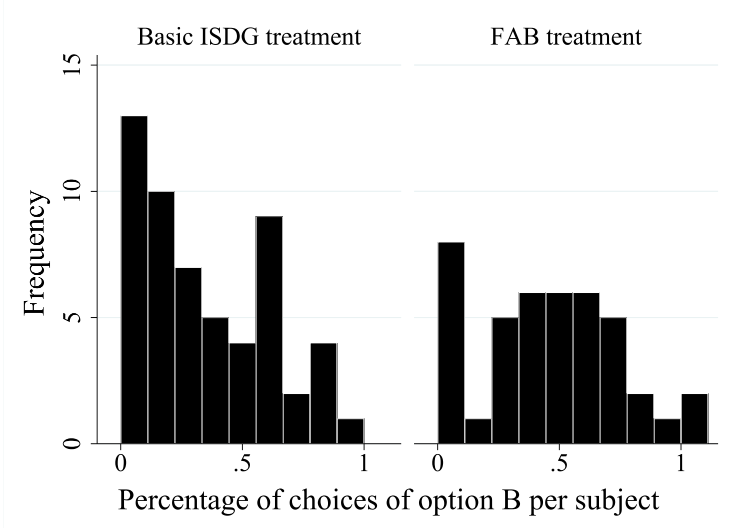


Figure 5: The distribution of the percentage of choices of option B per subject in the basic ISDG and FAB treatments

(a) Frequency distribution of the percentage of choices of option B per subject in the basic ISDG and FAB treatments



(b) Boxplot of the percentage of choices of option B per subject in the basic ISDG and FAB treatments

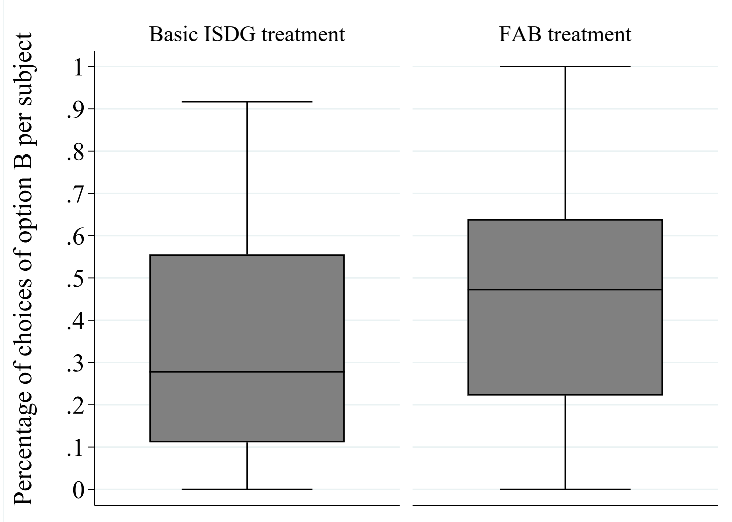


Figure 6: Predicted probability of choosing option B for subjects in the basic ISDG and FAB treatments

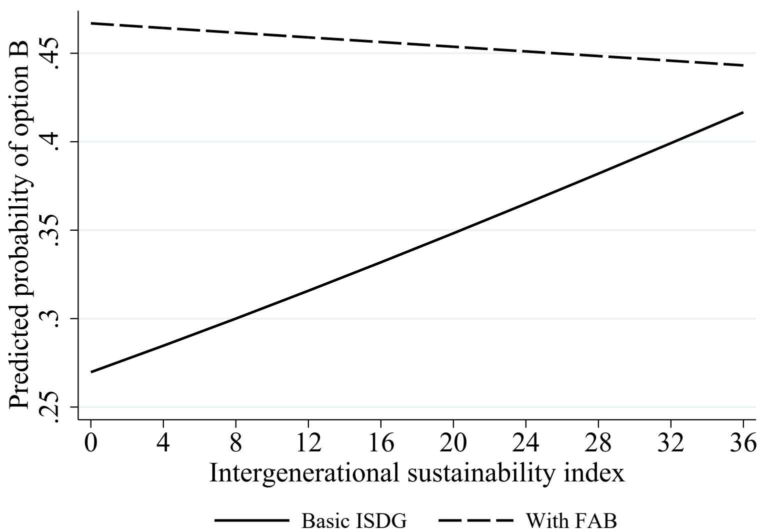


Figure 7: Heat map of the predicted probability of choosing sustainable option B on the domain of the percentage of option A choices in the sequence history and $\frac{X}{D}$