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PREFERENCE FOR RANDOMIZATION AND VALIDITY OF RANDOM INCENTIVE SYSTEM UNDER AMBIGUITY: AN EXPERIMENT

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Preference for randomization and validity of random incentive system under ambiguity: An experiment*

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Abstract

The random Incentive System (RIS) is a standard method to incentivize participants in economic experiments. However, recent theoretical studies point out the possibility of its failure under ambiguity. We propose a modification of RIS, named *independent RIS* (I-RIS), to improve its reliability. We conducted an experiment to evaluate the performances of the standard RIS and I-RIS in direct and indirect manners. Whereas a nonnegligible fraction of participants are not consistent with the reversal-of-order axiom, a majority of ambiguity averse and seeking participants are. This implies that participants with nonneutral ambiguity attitudes may not report truthful preferences when RIS is used. However, randomization attitudes do not explain inconsistent choices under RIS. In addition, we did not find significant differences in performance between RIS and I-RIS. These results suggest that preferences for randomization, which is driven by nonneutral ambiguity attitudes, do not cause the failure of RIS.

Keywords: Random Incentive System, Ambiguity, Incentive Compatibility

JEL Code: C91, D81

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1 Introduction

The random Incentive System (RIS) is a standard method to incentivize participants in economic experiments (Azrieli et al. 2018). However, recent theoretical studies point out the possibility of its failure when participants are concerned about ambiguity (Bade 2015, Kuzmics 2017, and Oechssler and Roomets 2014). They argue that participants may view the whole experiment as a single decision problem and exploit randomness in RIS to hedge ambiguity. If their conjecture holds, it is difficult to experimentally investigate choice behavior under ambiguity.

We propose a variation of RIS, named *independent RIS (I-RIS)* in which choice alternatives in different choice situations suffer ambiguity from independent ambiguity sources. In addition, we posit a preference condition, which is a variation of the compound independence axiom of Segal (1990), which guarantees that I-RIS is incentive compatibility. This preference condition is satisfied by, for example, maxmin expected utility with independent multiple priors (Gilboa and Schmeidler, 1989).

To test the performance of the standard RIS and I-RIS empirically, we conducted an experiment in which we elicit participants' preferences under ambiguity and relate them to behavior under RIS. Our experiment consists of two parts, which are conducted two weeks apart. In the first part, participants face a series of lotteries and report willingness-to-pay (WTP) for each, which allows us to elicit participants' attitudes toward ambiguity, randomization, and reversal of uncertainty resolution order. In the second part, participants face two *identical* binary choice problems under ambiguity. If RIS is incentive compatible, participants should choose the same lottery twice in the second part. If a participant chooses different lotteries (we call such choices, inconsistent choices), instead, we conclude s/he does not report his or her preferences truthfully.

There are two treatments in the second part, correlated (COR) and independent (IND), corresponding to the two versions of RIS. In the COR treatment, just one ball is drawn at the end of the experiment to determine participants' earnings as is normally done in RIS. The IND treatment, instead, employs I-RIS. Namely, in the IND treatment, one ball is drawn *independently for each lottery.* We are interested in whether the observed frequencies of inconsistent choices are the same in the COR and IND treatments, as well as the relationship between participants' randomization attitudes and frequencies of inconsistent choices.

Based on an online experiment conducted with 192 students of Osaka University in February 2021, we did not find a statistically significant difference (we employed a 5% significance level throughout the paper) in the frequencies of inconsistent choices between the IND and COR treatments. Thus, at least, in the simple setting considered in our experiment, the two versions of RIS deliver practically the same outcome. Moreover, preferences for randomization, which are elicited in the first part, do not explain the inconsistent choices. These results suggest that the interaction of the randomness of RIS and ambiguity aversion is not the source of inconsistent choices.

In Section 2, we review the theoretical and experimental literature that are related to the performance of RIS. In Section 3, we propose I-RIS and argue that it is incentive compatible if an appealing preference condition is satisfied. In Section 4, we describe our hypotheses and the experiment, and we report the results. In Section 5, we discuss our experimental results. Section 6 concludes.

2 Theoretical and experimental background

In this section, we review the theories that motivate our experiment and related experimental studies.

2.1 Random incentive system

Usually, experimenters want to elicit participants' preferences multiple times in one experiment. One simple method to incentivize participants to report truthfully is paying all chosen alternatives. However, if the experiment involves complementary goods, and if participants view the whole experiment as a single decision problem, the choice in each choice situation may be different from the one that would be observed when that choice situation was the only one presented.

The random incentive system is a more common incentive scheme that works as follows:[1]

1. The experimenter randomly and privately select a choice situation that will be used for compensation.
2. A participant reports his/her best-preferred alternative in each choice situation.
3. The alternative that the participant reported as his/her best-preferred one in the choice situation selected by the experimenter are paid to him/her.

The remarkable part of this scheme is that only one choice situation is used for compensation. False reports are expected to decrease under this scheme compared with the case when an experimenter pays all chosen alternatives because participants cannot obtain a set of complementary goods.

Even under RIS, participants may view the whole experiment as a single decision problem. When a participant chooses $f_1, \ldots, f_N$ in N choice situations, the RIS generates a lottery over $f_1, \ldots, f_N$. Holt (1986) points out that when a participant's preferences do not satisfy the independence axiom, RIS is not incentive compatible.[2] Karni and Safra (1987) also conducts a similar analysis in the context of the preference reversal phenomenon. Many authors, for example, Cubitt et al. (1998), Cox et al. (2014), Harrison and Swarthout (2014), Cox et al.

[1] Baillon et al. (2019) recommend determining the choice situation used for compensation at the beginning of the experiment, which we follow throughout this paper.

[2] He implicitly assumes that the participant reduces two-stage lotteries to one-shot ones.

(2015), Brown and Healy (2018), and Freeman et al. (2019) conduct experiments to determine whether such a concern exists. All of these authors consider the case in which choice alternatives are objective lotteries.

The arguments of Holt (1986) and Karni and Safra (1987) also apply to preferences for ambiguity because they are typically nonlinear. Recently, Oechssler and Roomets (2014), Bade (2015), and Kuzmics (2017) prove it is impossible to elicit ambiguity preferences using RIS in different settings. A common assumption Bade (2015) and Kuzmics (2017) posit is that all acts are defined on a common state-space. Oechssler and Roomets (2014), who focus on the α-maxmin expected utility model, consider the case where the state-space has a product structure. However, their specific assumption on multiple priors makes the situation the same as those of Bade (2015) and Kuzmics (2017). As we see in Section 3, if their assumptions are violated, our modification of RIS may be incentive compatible even if participants' preferences are ambiguity nonneutral.[3]

2.2 Preference conditions

Azrieli et al. (2018) show that RIS is essentially the only incentive compatible preference elicitation scheme when a preference condition, called *monotonicity*, is the only assumption the experimenter imposes. The monotonicity condition of Azrieli et al. (2018) states that if $f_1, \ldots, f_N$ are the best-preferred choices in each choice situation, then the lottery generated from these choices through RIS is the best one that is given in this manner. As Azrieli et al. (2018) show, monotonicity is violated when a participant's preferences are nonlinear and satisfies the reversal-of-order axiom. The reversal-of-order axiom, which was proposed by Anscombe and Aumann (1963), states that the participant ignores the order of uncertainty resolutions of multistage lotteries.[4] To introduce the reversal-of-order axiom formally, let Ω be a state space and call $f : \Omega \to \Delta\mathbb{R}$ an act, which stands for a lottery that gives a

[3]Oechssler and Roomets (2014) recognize this point. See footnote 9 of that paper.
[4]See also Seo (2009) for implication of this axiom for ambiguity attitudes.

random monetary outcome conditional on states.[5] Let $\mathcal{F}$ be the set of all acts. For acts f and g, and $\alpha \in [0,1]$, let $\alpha f \oplus (1-\alpha)g$ be the state-wise mixture of f and g.[6] Next, for acts f and g, let $\alpha f + (1-\alpha)g$ be an objective lottery that gives f with probability α and gives g with probability $1-\alpha$. A preference relation $\succeq$ satisfies the reversal-of-order axiom if $\alpha f \oplus (1-\alpha)g \sim \alpha f + (1-\alpha)g$ for all f, g and α.

To see that nonlinearity of preferences and the reversal-of-order axiom imply failure of RIS, consider an Ellsberg-type experiment. Let $\Omega = \{R, B\}$ be the state-space that represents Ellsberg urn with red and black balls. An experimenter is interested in a participant's preferences for bets on ball colors R and B, and bets on the results of a toss of a fair coin, H (for heads) and T (for tails). The experimenter asks the participant which of R or H, and B or T s/he prefers, using the RIS that assigns a probability of 1/2 to each choice situation. Typical ambiguity averse choices in this setting are $H \succ R$ and $T \succ B$. Suppose the participant's preferences are such ones. By reporting these preferences, RIS generates a lottery $\frac{1}{2}H + \frac{1}{2}T$, which reduces to an objective lottery that wins with a probability of 1/2. However, choosing R and B in each situation, the randomness of RIS generates the lottery $\frac{1}{2}R + \frac{1}{2}B$, which provides exposure to R or B, each with probability 1/2. If the participant's preferences satisfy the reversal-of-order axiom, $\frac{1}{2}R + \frac{1}{2}B \sim \frac{1}{2}R \oplus \frac{1}{2}B$ holds. But $\frac{1}{2}R \oplus \frac{1}{2}B$ is an objective lottery that wins with probability 1/2, which is the same as the one that is given when reporting the true preferences. Then, the participant may as well report preferences $R \succeq H$ and $B \succeq T$. That is, the randomization provided by RIS hedges ambiguity. As this example shows, the reversal-of-order axiom is related to the performance of RIS. Therefore, empirically testing this axiom is important. Recently, Oechssler et al. (2019) confirm that the reversal-of-order axiom holds at the population level.

In the example above, the preferences $\frac{1}{2}R \oplus \frac{1}{2}B \succ R, B$, together with the reversal-of-

[5]Here, $\Delta\mathbb{R}$ denotes for the set of Borel probability measures over $\mathbb{R}$.

[6]For $p, q \in \Delta\mathbb{R}$, let $\alpha p \oplus (1-\alpha)q \in \Delta\mathbb{R}$ be the objective lottery defined by $[\alpha p \oplus (1-\alpha)q](B) = \alpha p(B) + (1-\alpha)(B)$ for $B \subset \mathbb{R}$. The act $\alpha f \oplus (1-\alpha)g$ is defined by $[\alpha f \oplus (1-\alpha)g](\omega) = \alpha f(\omega) \oplus (1-\alpha)g(\omega)$.

order axiom, imply $\frac{1}{2}R + \frac{1}{2}B \succ R, B$. The latter nonlinear preferences for lotteries over ambiguous bets are the causes of the failure of RIS in the example. In this paper, we say $\succeq$ is *randomization seeking* if $f \sim g$ and $\lambda f + (1-\lambda)g \succ f$ is observed for some f and g. Similarly, we say $\succeq$ is *randomization averse* if $f \sim g$ and $pf + (1-p)g \prec f$ for some f and g. If $\lambda f + (1-\lambda)g \sim f$ for any $f \sim g$ for any f and g, we say $\succeq$ is *randomization neutral*.[7]

Even if participants' preferences do not satisfy the reversal-of-order axiom, they may be randomization nonneutral. In such a case, again, RIS fails. Saito (2015) and Ke and Zhang (2020) study utility models that accomodate decision makers who believe that ex ante randomization hedges ambiguity to some extent, but not as much as a state-wise mixture. Their models predict the correlation of ambiguity aversion and randomization seeking. However, Dominiak and Schnedler (2011) do not find a significant correlation of this kind.

2.3 Random choice

Nonneutral ambiguity attitudes are not the only potential cause of preferences for randomization. Wheres the models of Saito (2015) and Ke and Zhang (2020) assume that a decision maker has stable beliefs and random choices under ambiguity are driven by the motivation of hedging ambiguity, Lu (2019) views belief itself as random. The preferences of the participants of our experiment may not be stable, as in the model of Lu (2019). In this paper, however, we insist on the view that they have stable beliefs and their seemingly random choices are driven by the purpose of hedging ambiguity. This is because the theoretical papers that point out the possible failure of RIS under ambiguity share this view.

[7] The definitions of randomization attitudes are essentially the same as those of Eichberger et al. (2016), although they use a different setup.

3 Independent random incentive system

In this section, we propose a variant of RIS, in which choice alternatives in different choice situations depend on different state spaces. We provide a preference condition that guarantees the incentive compatibility of our incentive scheme. It states that participants do not hedge ambiguity by stochastically choosing alternatives that depend on different state spaces.

3.1 Setup

First, we formally introduce choice alternatives that appear in experiments on ambiguity. For any topological space Y, let ΔY denote for the set of Borel probabilities over Y. Let X be the outcome space, which is a compact metrizable set. Let $S_1, \ldots, S_K$ be finite state spaces and let $\Omega = \prod_{k=1}^{K} S_k$. Each S_k is interpreted as a different ambiguity source. An act is a mapping $f : \Omega \to \Delta X$ and we denote the set of all the acts as $\mathcal{F}$.[8] A random act $P \in \Delta\mathcal{F}$ is a probability over $\mathcal{F}$. Let $\succeq$ be a continuous weak order over $\Delta\mathcal{F}$, which is interpreted as preferences of a decision maker (DM, henceforth). A second-order random act $\mathcal{P} \in \Delta(\Delta\mathcal{F})$ is a probability over $\Delta\mathcal{F}$. Each $x \in X$ is identified with $f_x \in \mathcal{F}$ such that $f_x(\omega) = x$ for all ω. Each $f \in \mathcal{F}$ is identified with the degenerate probability $\delta_f \in \Delta F$. Each $P \in \Delta\mathcal{F}$ is identified with the degenerate probability $\delta_P \in \Delta(\Delta\mathcal{F})$.

3.2 Incentive scheme

Next, we develop a framework to describe experiments on ambiguity and incentive schemes following Azrieli et al. (2020). Let $\mathcal{D} = \{D_1, \ldots, D_N\}$ be a list of choice situations in the experiment, where D_n is a compact subset of $\Delta\mathcal{F}$. That is, participants report his/her best-preferred alternatives from each D_l. This setup covers several kinds of experiments. For example, the Becker–DeGroot–Marschak (BDM) method (Becker et al., 1964) to elicit

[8]The set $\mathcal{F}$ is endowed with the product topology.

the WTP for an act generates a distribution over the act and some amounts of money, conditional on a reported WTP. In this case, a participant chooses random acts. Another example is an experiment in which a participant faces a finite set of acts. Such an experiment is also accommodated in this setup because an act is identified with the random act that gives the former with probability one.

Under ambiguity, RIS may fail partly because choice alternatives in different choice situations depend on a common ambiguity source. In order to avoid this pitfall, we consider the choice situations in which this is not the case. For $I \subset \{1, \ldots, K\}$, let $S_I = \prod_{k \in I} S_k$ and denote typical elements of S_I as s_I, s'_I, etc. Let $S_{-I} = \prod_{k \notin I} S_k$. We denote $\mathcal{F}_I = \{f \in \mathcal{F} | f(s_I, s_{-I}) = f(s_I, s'_{-I})$ for any $s_I \in S_I, s_{-I}, s'_{-I} \in S_{-I}\}$.

Definition 1. $\mathcal{D} = \{D_1, \ldots, D_N\}$ is *independent* if there exists a partition $\{I_1, \ldots, I_N\}$ of $\{1, \ldots, K\}$ and $D_n \subset \Delta \mathcal{F}_{I_n}$ for each n.

Given $\mathcal{D}$, the DM reports her choices $m = (m_1, \ldots, m_N) \in M := \prod_n D_n$. The mechanism we consider randomly pays one of $m_1, \ldots, m_N$. If a participant views the whole experiment as a single decision problem, s/he would manipulate reports to obtain better outcomes. To capture such underlying preferences, assume $\succeq$ extends to a relation $\succeq^*$ over $\Delta(\Delta \mathcal{F})$, which is also a continuous weak order. Whereas $\succeq$ represents the *true preferences* the experimenter is concerned about, $\succeq^*$ dictates the *ovserved choices.*

Definition 2 (Random incentive system)**.** An RIS is a mapping $\varphi : M \to \Delta(\Delta \mathcal{F})$ such that there exists a full-support probability $\lambda \in \Delta \mathcal{D}$ and

$$\varphi(m)(P) = \sum_{n;\, m_n = P} \lambda(D_n)$$

holds for any $m \in M$ and $P \in \bigcup_{n=1}^{N} D_n$.

For D_n and $\succeq$, let $\arg\max_{\succeq} D_n = \{P \in D_n | \, P \succeq Q$ for all $Q \in D_n\}$. Define $\arg\max_{\succeq^*} \varphi(M) =$

$\{\varphi(m)|\varphi(m) \succeq \varphi(m') \text{ for all } m' \in M\}$.[9] We say RIS is incentive compatible if the reported best-preferred items are actually the best-preferred ones in each choice situation. That is,

Definition 3 (Incentive compatibility)**.** RIS is incentive compatible if $\varphi(m) \in \arg\max_{\succeq^*} \varphi(M)$ implies $m_n \in \arg\max_{\succeq} D_n$ for all n.

3.3 Preference condition

Next, we propose a condition that restricts the relationship between $\succeq$ and $\succeq^*$. For second-order random acts $\mathcal{P}_1, \ldots, \mathcal{P}_l$ and $\alpha_1, \ldots, \alpha_L \geq 0$ with $\sum_{l=1}^{L} \alpha_l = 1$, define the mixture $\sum_{l=1}^{L} \alpha_l \mathcal{P}_l \in \Delta(\Delta\mathcal{F})$ by $(\sum_{l=1}^{L} \alpha_l \mathcal{P}_l)(G) = \sum_{l=1}^{L} \alpha_l \mathcal{P}_l(G)$ for any Borel sets $G \subset \Delta\mathcal{F}$.[10] This operation also applies to first-order random acts because they are identified with degenerate second-order random acts.

Condition 1. For any $I, I' \subset \{1, \ldots, K\}$, $P, Q \in \Delta\mathcal{F}_I$, $R \in \Delta\mathcal{F}_{I'}$, and $\alpha \in (0, 1]$, if $I \cap I' = \emptyset$,

$$P \succeq Q \Leftrightarrow \alpha P + (1-\alpha)R \succeq^* \alpha Q + (1-\alpha)R.$$

This condition has three implications. First, $\succeq$ and $\succeq^*$, restricted to $\Delta\mathcal{F}$, coincide (for the case $\alpha = 1$). Second, for any $P, Q \in \Delta\mathcal{F}_I$, the preference $P \succeq^* Q$ does not reverse when ambiguity-free lottery $R \in \Delta X$ is mixed (for the case $I' = \emptyset$); $\alpha P + (1-\alpha)R \succeq^* \alpha Q + (1-\alpha)R$. Third, the DM does not hedge ambiguity by randomly choosing random acts that depend on different ambiguity sources. The third implication is related to the DM's perception about how ambiguity sources correlate.

To clarify, consider an experiment in which the experimenter uses two Ellsberg urns that contain red and black balls. Here, the two urns are different ambiguity sources; $S_k = \{R_k, B_k\}$, $k = 1, 2$. Typical participants are indifferent between betting on R_1 or B_1; $R_1 \sim B_1$.

[9]The continuity of $\succeq$ and $\succeq^*$, the compactness of each D_l, and the continuity of φ guarantees that these two sets are nonempty.

[10]For the case $L = 2$, we write $\sum_{l=1}^{2} \alpha_l \mathcal{P}_l$ also as $\alpha_1 \mathcal{P}_1 + (1-\alpha_1)\mathcal{P}_2$.

Under Condition 1, in this case, $\frac{1}{2}R_1 + \frac{1}{2}R_2 \sim^* \frac{1}{2}B_1 + \frac{1}{2}R_2$ would hold. However, this prediction is not convincing if the participant believes that ball-draws from two urns correlate. Suppose she believes that R_2 is more likely than B_2 conditional on R_1, and B_2 is more likely than R_2 conditional on B_1. Then, both components of $\frac{1}{2}R_1 + \frac{1}{2}R_2$ are good options conditional on R_1, but they are bad options conditional on B_1. However, two components of $\frac{1}{2}B_1 + \frac{1}{2}R_2$ are good options conditional on B_1, and in R_1, respectively. So the participant may view $\frac{1}{2}R_1 + \frac{1}{2}R_2$ as suffering more ambiguity than $\frac{1}{2}B_1 + \frac{1}{2}R_2$ does. Then, depending on her ambiguity attitude, the indifference $\frac{1}{2}R_1 + \frac{1}{2}R_1 \sim^* \frac{1}{2}B_1 + \frac{1}{2}R_2$ may well be violated. Condition 1 excludes such behavior coming from perceptions of correlation. However, if the DM is confident that the ambiguity sources are independent, it is natural that she does not hedge ambiguity by mixing bets on different ambiguity sources.

Condition 1 contains two preference relations, $\succeq$ and $\succeq^*$. As noted above, whereas $\succeq^*$ dictates the observed data, $\succeq$ is not directly observed. Thus, this condition is what to assume, rather than to test. It guarantees the incentive compatibility of RIS with independent choice situations.

Proposition 1. Any RIS is incentive compatible if $\mathcal{D}$ is independent and $(\succeq, \succeq^*)$ satisfies Condition 1.

Proof. En route to a contradiction, suppose $\varphi(P_1, \ldots, P_L) \in \arg\max_{\succeq^*} \varphi(M)$, and $Q_l \succ P_l$ for some l and $Q_l \in D_l$. Then, by Condition 1,

$$\begin{aligned}
\varphi(P_1, \ldots, P_L) &= \sum_{l'=1}^{L} \lambda(D_{l'}) P_{l'} \\
&= (1 - \lambda(D_l)) \sum_{l' \neq l} \frac{\lambda(D_{l'})}{1 - \lambda(D_l)} P_{l'} + \lambda(D_l) P_l \\
&\prec^* (1 - \lambda(D_l)) \sum_{l' \neq l} \frac{\lambda(D_{l'})}{1 - \lambda(D_l)} P_{l'} + \lambda(D_l) Q_l \\
&= \varphi(P_1, \ldots, P_{l-1}, Q_l, P_{l+1}, \ldots, P_L).
\end{aligned}$$

The strict preference follows from $I_l \cap \bigcup_{l' \neq l} I_{l'} = \emptyset$ and Condition 1. A contradiction. $\square$

In our experiment, participants are instructed that outcomes of acts or random acts are determined by the sampling of balls with replacement from a fixed ambiguous urn, which guarantees the independence of choice situations. In addition, we assume Condition 1 for the incentive compatibility of our incentive scheme in Part 1. To distinguish RIS with independent choice situations from the usual RIS in which acts depend on a common state-space, we call the former as *independent RIS (I-RIS)*.

3.4 Example

Maximin expected utility with independent multiple priors is an example of models that satisfy Condition 1 and have a nonneutral ambiguity attitude.[11] Consider the case of $K = 2$. Let $C_k \subset \Delta S_k$ $(k = 1, 2)$ be closed convex sets. Gilboa and Schmeidler (1989) define the product of C_1 and C_2 as $C_1 \otimes C_2 = \overline{\text{co}}\{p_1 \otimes p_2 | \, p_k \in C_k, \; k = 1, 2\}$, where $p_1 \otimes p_2$ is the product measure of p_1 and p_2 over $\Omega = S_1 \times S_2$.[12,13]

Let $\succeq$ over $\mathcal{F}$ be defined by

$$V(f) = \min_{\pi \in C_1 \otimes C_2} \int_{S_1 \times S_2} u(f) d\pi. \tag{1}$$

Assume that the DM ignores the order of uncertainty resolutions, and reduces multistage objective uncertainty as the corresponding one-shot uncertainty.[14] Then, $\succeq$ and $\succeq^*$ satisfy Condition 1. Because the DM identifies any second-order random acts as some act that

[11]Maximin expected utility itself represents preferences for acts. See footnote 14 for how we extend this model to represent $\succeq^*$.

[12]The symbol $\overline{\text{co}}(\cdot)$ denotes for closed convex hull.

[13]These multiple priors are what Oechssler and Roomets (2014) regard as superstitious.

[14]Formally, define $\Phi : \Delta(\Delta\mathcal{F})) \to \mathcal{F}$ by $\Phi(\mathcal{P})(\omega) = \int_{\Delta\mathcal{F}} \left(\int_{\mathcal{F}} f(\omega) dP(f) \right) d\mathcal{P}(P)$ and assume $\mathcal{P} \succeq^* \mathcal{Q} \Leftrightarrow \Phi(\mathcal{P}) \succeq \Phi(\mathcal{Q})$.

depends on the same state-space as the former, it is sufficient to see

$$f \succeq g \Leftrightarrow \alpha f \oplus (1-\alpha)h \succeq \alpha g \oplus (1-\alpha)h \tag{2}$$

for any $f, g \in \mathcal{F}_1$, $h \in \mathcal{F}_2$, and $\alpha \in (0,1]$. Because

$$\begin{aligned} V(\alpha f \oplus (1-\alpha)h) &= \min_{\pi_1 \in C_1, \pi_2 \in C_2} \int_{S_1 \times S_2} \alpha u(f) + (1-\alpha) u(h) \, \mathrm{d}\pi_1 \otimes \pi_2 \\ &= \alpha \min_{\pi_1 \in C_1} \int_{S_1} u(f) \mathrm{d}\pi_1 + (1-\alpha) \min_{\pi_2 \in C_2} \int_{S_2} u(h) \mathrm{d}\pi_2 \\ &= \alpha V(f) + (1-\alpha) V(h) \end{aligned}$$

and similarly $V(\alpha g \oplus (1-\alpha)h) = \alpha V(g) + (1-\alpha)V(h)$, (2) holds.[15]

To be specific, again, consider a Ellsberg-type experiment; Let $S_k = \{R_k, B_k\}$, $k = 1, 2$. Consider choice situations $\mathcal{D} = \{D_1, D_2\}$, where $D_1 = \{R_1, H\}$ and $D_2 = \{B_2, T\}$, and R_i (resp. B_i) is the bet that wins if a red (resp. black) ball is drawn from the ith urn. Furthermore, H (resp. T) is the bet that wins when a flipped fair coin lands with on heads (resp. tails). Then, $\mathcal{D}$ is a list of independent choice situations. Therefore, RIS elicits the true preferences of a participant who admits representation (1).

As an example of choice situations that violate the independence condition, consider $\mathcal{D}' = \{D_1', D_2'\}$, where $D_1' = \{R_1, H\}$ and $D_2' = \{B_1, T\}$. The difference between $\mathcal{D}'$ and $\mathcal{D}$ is that, in the second choice situation, the ambiguous bet wins if a black ball is drawn from the first urn, not from the second. If the RIS assigns a probability of 1/2 to each choice situation, the participant has no reluctance to choose ambiguous bets in both situations.

[15] In the second line, we identify f and h as their obvious counterparts defined on S_1 and S_2, respectively.

4 Experiment

Our experiment is intended to test the validity of RIS in indirect and direct manners. First, we measure participants' attitudes toward ambiguity, randomization, and reversal of uncertainty resolution order. Second, we compare the performance of the standard RIS and I-RIS. Specifically, we ask the following:

- Are more randomization seeking participants more likely to misreport their preferences under the standard RIS?
- Does the use of I-RIS improve incentive compatibility compared with the standard RIS?
- Does the improvement by I-RIS, if any, depend on randomization attitude?

We recruited a total of 195 participants from the subject pool of ISER, Osaka University, managed by ORSEE (Greiner, 2015). Among them, 192 (95 in IND, and 97 in COR) completed both parts of the experiment, which were run two weeks apart. We used Qualtrics (`www.qualtrics.com`) to conduct our online experiment. Registered participants were asked to individually complete the task by clicking the link they received via e-mail within the same day. The link for the experiment site was sent to all the registered participants around 10:00 am on the date of the experiment. The median of times spent by participants in completing the first and second parts of the experiment are 20 and three minutes, respectively.[16] They earned, on average, 979 JPY and 533 JPY in the first and second parts of the experiment including 500 and 300 JPY as participation fees, respectively. Participants received their reward in the form of an Amazon gift card, e-mail version.

[16]In the text, we report the median times in the experiment because there are outliers. The mean times are 29 and 7 minutes for the first and second parts, respectively.

4.1 Part one – preference elicitation

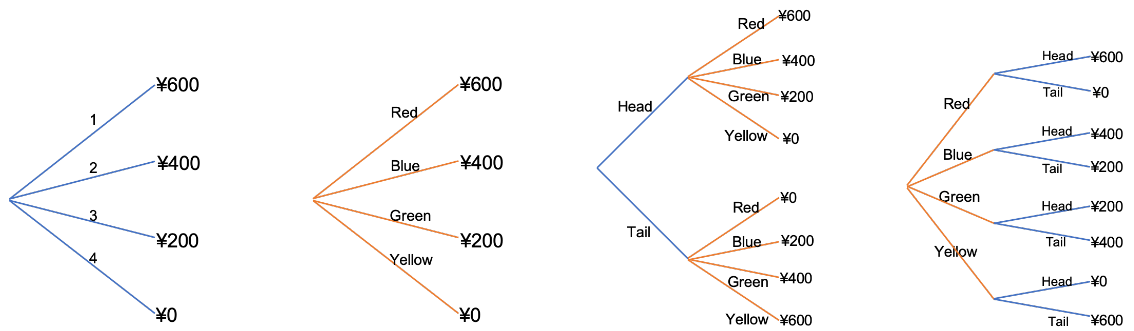
4.1.1 Task and incentive

In this part, participants face a series of choice situations where they are asked to report their WTP for a lottery, which pays an uncertain amount of money. The lotteries are classified into the following four classes in terms of the sources of uncertainty.

- *Risky lotteries* that pay monetary rewards contingent on a roll of a four-sided fair die.
- *Ambiguous lotteries* that are obtained from risky lotteries by changing the source of uncertainty, from a die to a four-color Ellsberg urn, while keeping possible monetary outcomes the same.
- *Coin–ball lotteries* that resolve in two steps: first a fair coin is tossed and then a ball is drawn from the Ellsberg urn. From an ambiguous lottery, we constructed a corresponding coin–ball lottery in the following way. Suppose the ambiguous lottery f that gives f_1, f_2, f_3, and f_4 JPY when the drawn ball is red, blue, green, and yellow, respectively. Now, construct a corresponding symmetric lottery f' that gives f_4, f_3, f_2, and f_1 JPY when the ball is red, blue, green, and yellow, respectively. The coin–ball lottery corresponding to f reduces to f when the coin lands with heads up, but it reduces to f' when the coin lands with tails up.
- *ball–coin lotteries* that are obtained from coin–ball lotteries by reversing the order of a coin toss and a ball draw.

An example from each class is shown in Figure 1. The list of lotteries can be found in Table 2 in the Appendix. An English translation of the instruction is provided in the online supplementary material.

Each class consists of 10 lotteries. For each lottery, we employ the BDM method to elicit their WTPs. Here, we employ I-RIS to enhance the credibility of the elicited preference indices.



(a) Risky lottery **(b)** Ambiguous lottery **(c)** Coin–ball lottery **(d)** Ball–coin lottery

Figure 1: Example of each class of lottery

4.1.2 Preference indices

From WTPs that we have elicited, we construct three indices, *the ambiguity attitude index* (I_A), *the preference for randomization index* (I_{PR}), and *the reversal-of-order index* (I_{RO}), to summarize the preference characteristics of each participant. Suppose the participant's reported WTPs of risky and ambiguous lotteries are $V^R = (v_1^R, \ldots, v_{10}^R)$ and $V^A = (v_1^A, \ldots, v_{10}^A)$, where v_i^R is the WTP of the ith risky lottery and similarly for ambiguous lotteries. Then, the I_A of the participant is defined by

$$I_A = |\{i|v_i^R > v_i^A\}| - |\{i|v_i^R < v_i^A\}|$$

as a measure of his/her degree of ambiguity aversion. I_A ranges from -10 to 10. In the analyses below, we label participants as ambiguity averse or seeking when $I_A \geq 4$ or $I_A \leq -4$, respectively, and as ambiguity neutral when neither is the case.

Similarly, suppose the participant's WTP in coin–ball lotteries and ball–coin lotteries are

V^{CB} and V^{BC}. Then, we define I_{PR} and I_{RO} as

$$I_{PR} = |\{i|v_i^{CB} > v_i^A\}| - |\{i|v_i^{CB} < v_i^A\}|,$$
$$I_{RO} = |\{i|v_i^{BC} > v_i^{CB}\}| - |\{i|v_i^{BC} < v_i^{CB}\}|.$$

To interpret I_{PR}, observe that the ith coin–ball lottery is a fair lottery over two ambiguous lotteries such that one of them is obtained from the other by interchanging ball colors. Moreover, one of such lotteries is the ith ambiguous lottery. Thus, assuming symmetric beliefs over the likelihood of ball colors, comparing corresponding ambiguous/coin–ball lotteries gives a degree of preference for randomization.

I_{RO} is calculated by comparing the valuations of ball–coin lotteries and coin–ball lotteries. We are interested in this index because it reflects participants' conformity to the reversal-of-order axiom.

As discussed in Section 2.2, if a participant is not ambiguity neutral, the reversal-of-order axiom implies his/her nonneutrality to randomization. Thus, we are interested in their attitude toward reversal-of-order.

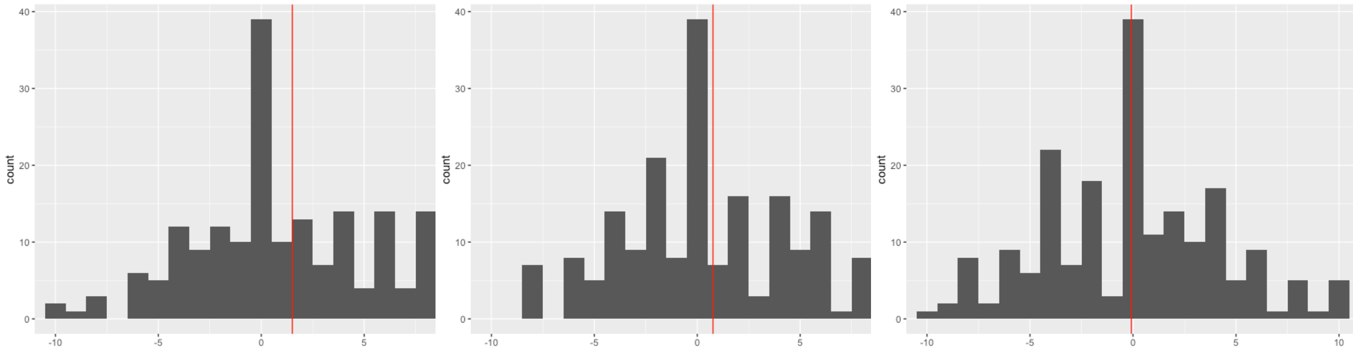
Hypothesis 1. The participants' preferences satisfy the reversal-of-order axiom.

If a participant's preferences satisfy the axiom, his/her I_{RO} is zero because s/he is indifferent between the corresponding coin–ball lottery and ball–coin lottery, which are the same except the timing of uncertainty resolution: $v_i^{BC} - v_i^{CB} = 0$, $i = 1, \ldots, 10$. Thus Hypothesis 1 is rejected if these numbers are significantly different from zero.

4.1.3 Descriptive statistics

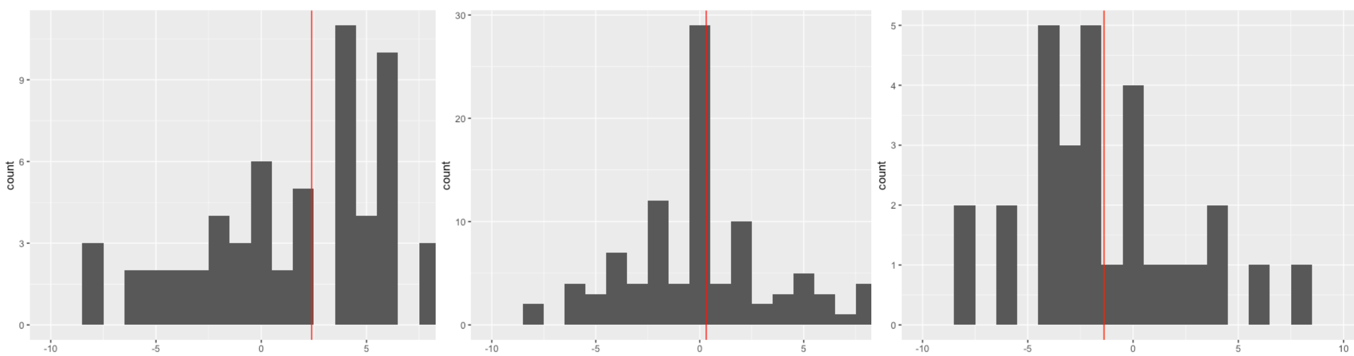
Before examining the joint analysis of the data from parts 1 and 2 of the experiment, let us first describe the elicited preferences.

Figure 2 shows the histograms of I_{AM} (left), I_{PR} (middle), and I_{RO} (right) of the full



(a) Histogram of I_{AM} **(b)** Histogram of I_{PR} **(c)** Histogram of I_{RO}

Figure 2: Histograms of I_{AM}, I_{PR}, and I_{RO} in the whole sample. Red vertical lines in each histogram represent the mean of that index.

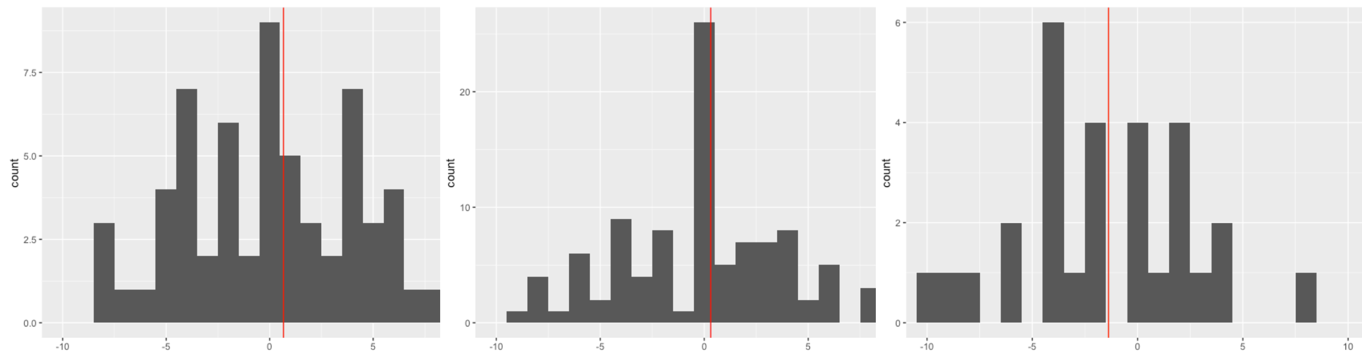


(a) Ambiguity averse participants **(b)** Ambiguity neutral participants **(c)** Ambiguity seeking participants

Figure 3: Histogram of I_{PR} for each ambiguity attitude. The red vertical line in each histogram represents the mean of the subpopulation.

sample (192 observations each). Each of the three panels shows that whereas there is a substantial fraction of participants with an index value of indices equal to zero, there exists substantial heterogeneity in the value of each of the three indices. We classify participants based on their I_{AM}, and then examine the distribution of I_{PR} and I_{RO}.

Figure 3 shows the histograms of I_{PR} for ambiguity averse (left), neutral (center), and seeking (right) participants. These three panels of Figure 3 demonstrate a heterogeneity of preferences for randomization among participants within each ambiguity class. Whereas the mean I_{PR} of ambiguity averse participants is significantly different from zero ($p < 0.001$,



(a) Ambiguity averse participants **(b)** Amguity neutral participants **(c)** Ambiguity seeking participants

Figure 4: I_{RO} for each ambiguity attitude. The red vertical lines represent its mean of the subpopulation.

Wilcoxon signed-rank test), that of ambiguity seeking and neutral participants is not ($p =$ 0.068 and $p = 0.619$, respectively). It is noteworthy that a nonnegligible number of ambiguity averse (seeking) participants have negative (positive) preference for randomization. This result suggests that preferences for randomization are not determined solely by ambiguity attitude. The I_{PR}s are significantly different across the three ambiguity classes ($p < 0.001$, Kruskal–Wallis test).

Figure 4 shows the histograms of I_{RO} for ambiguity averse (left), seeking (center), and neural (left) participants. Whereas the mean of I_{RO} for the ambiguity seeking participants is significantly different from zero ($p = 0.042$, Wilcoxon signed-rank test), that of the ambiguity seeking and neutral participants is not ($p = 0.333$ and $p = 0.681$, respectively). The I_{RO}s are not significantly different across the three ambiguity classes ($p = 0.116$, Kruskal–Wallis test).

We now consider a test of the reversal-of-order axiom at the individual level. For each participant, we tested the hypothesis that his/her mean of $v_i^{BC} - v_i^{CB} (i = 1, \ldots, 10)$ is zero using a nonparametric bootstrap test. As a result, for 52 of the 195 participants, the hypothesis is rejected.[17] Because a nonnegligible number of participants violated the reversal-of-order axiom, Hypothesis 1 is rejected. However, this result does not guarantee the incentive

[17] Among the participants whose null hypothesis is rejected, 20 tend to prefer coin–ball lotteries and 32 tend to prefer ball–coin lotteries.

Figure 5: Choice alternatives in Part 2.

compatibility of RIS. Indeed, the among ambiguity averse (resp. seeking) participants, 20 out of 29 (resp. 41 out of 66) are consistent with reversal-of-order. Thus, if such participants view an experiment as a single decision choice problem, RIS would not be incentive compatible. However, once we pooled all the participants and applied the same test, the hypothesis that the mean is zero is not rejected. This suggests that the aggregate behavior of the participants does not contradict the reversal-of-order axiom, which is consistent with Oechssler et al. (2019).

Result 1. A nonneglible number of participants violated the reversal-of-order axiom. The aggregate behavior of participants is consistent with the reversal-of-order axiom.

4.2 Part two – Comparison of RIS and I-RIS

4.2.1 Task and incentive

In Part 2, participants are informed that they will face two *identical* two-alternative choices. The two lotteries involved in these choices are ambiguous lotteries and are shown in Figure 5. An English translation of the instructions is provided in the online supplementary material.

One of the lotteries pays 510 JPY if the drawn ball is red or blue and 10 JPY if the drawn ball is green or yellow, whereas the other lottery pays 0 JPY if the drawn ball is red or blue and 500 JPY if the drawn ball is green or yellow. Because participants are instructed about the repetition of the choice situation, if an incentive scheme employed here is incentive compatible and a participant is not indifferent between these two lotteries, s/he should choose the same lottery twice.

There are two treatments, *Independent* (IND) and *Correlated* (COR), in which we used different incentive schemes. Whereas the standard RIS is used in COR, I-RIS is used in IND. In both treatments, one of two choice situations is randomly picked to use for compensation at the beginning of the experiment. The difference between the treatments is in the final stage of the experiment where the uncertainties of lotteries are resolved. Whereas only one ball is drawn in COR, four balls are independently drawn with replacement in IND; they are used to evaluate four lotteries that were presented to the participants. Thus, the two choice situations in COR do not satisfy the independence condition, but those of IND do.

The two lotteries in this part pay positive, and almost the same, amounts of money in different states. Thus if a participant is ambiguity averse, s/he may prefer their state-wise mixture of to themselves. In COR, if s/he believes ex ante randomization of RIS hedges ambiguity likewise, she may intentionally choose different alternatives in the two repetitions. However, a participant has no incentive to choose different alternatives in IND if s/he satisfies Condition 1, which is what Proposition 1 states.

We now test our hypotheses using the data from Part 2. We say a participant is *inconsistent* if s/he chooses different lotteries during the repetitions. If the use of I-RIS improves incentive compatibility, we expect that the proportion of inconsistent participants is smaller in IND than in COR.

Hypothesis 2. The proportion of participants making inconsistent choices is smaller in IND than in COR.

Because the two lotteries in each choice situation pay more in different states, behaving inconsistently may hedge ambiguity. Therefore, it is expected that the more randomization seeking (averse) a participant is, the more (less) s/he tends to be inconsistent. Thus, we expect the following:

Hypothesis 3. In COR, randomization seeking participants are more likely to make an inconsistent choice than randomization averse participants.

Finally, we consider the treatment effect conditional on randomization attitude. In Section 3, it is shown that I-RIS is incentive compatible under Condition 1. If I-RIS improves the standard RIS, the proportion of randomization seeking participant who behave consistently would increase in IND, compared with COR. However, randomization averse participants would have a weaker incentive to behave inconsistently in IND than in COR.

Hypothesis 4. Randomization seeking (resp. averse) participants are more (resp. less) likely to make inconsistent choices in COR than in IND.

4.2.2 Results

In IND, 13 out of 95 participants' choices were inconsistent, whereas 17 out of 97 were inconsistent in COR. The fractions of participants making inconsistent choices are not significantly different between the two treatments ($p = 0.5523$, Fisher's exact test). Thus, we reject Hypothesis 2, which states that a smaller fraction of participants making inconsistent choices in IND than in COR.

Result 2. There is not a significant difference between IND and COR in the proportion of participants behaving inconsistently.

To test Hypotheses 3 and 4, we focus on the participants with nonneutral randomization attitudes and used logistic regressions to investigate the relationship between the elicited preference indices and inconsistent choices.[18] The dependent variable is a dummy variable that equals 1 if a participant is making inconsistent choices, and 0 otherwise. The set of independent variables includes a dummy variable that equals 1 for COR, and 0 otherwise, a

[18]Including randomization neutral participants does not change the following results.

	Dependent variable:
	inconsistent
correlated	2.163*
	p = 0.054
R_seeking	2.115*
	p = 0.070
correlated:R_seeking	−2.856*
	p = 0.052
Constant	−3.367***
	p = 0.001
Observations	90
Log Likelihood	−33.993
Akaike Inf. Crit.	75.985
Note:	*p<0.1; **p<0.05; ***p<0.01

Table 1: Logistic regressions with ambiguity-neutral participants omitted.

dummy variable that equals 1 if a participant is randomization seeking, and 0 otherwise, as well as interactions between the randomization dummies and COR. Table 1 shows the results of the specification we considered.

We used the Wald test to understand the relation of randomization attitudes and inconsistency of choices in COR. We found no significant effect of randomization attitudes to inconsistency ($p = 0.4$). Thus Hypothesis 3 is rejected.

Result 3. In COR, there is no significant difference in the proportion of participants behaving inconsistently between randomization seeking and randomization averse participants.

We, again, used the Wald test to understand the treatment effect among the subpopulation of randomization seeking participants, and found that the treatment effect is insignificant ($p = 0.46$). The null hypothesis that the coefficient of the COR dummy is zero is not rejected ($p = 0.054$), which shows that the treatment effect for randomization averse participants is also insignificant. Thus, Hypothesis 4 is rejected.[19]

[19] We also estimated a similar model in which the dummy for randomization attitudes is replaced with dummies

Result 4. There is no significant difference between COR and IND in the proportion of inconsistent participants among randomization seeking or averse participants.

5 Discussion

In this section, we discuss the results of our experiment. As explained in Section 2, some theoretical studies find that RIS is not incentive compatible when an experiment involves ambiguity. They conjecture that participants may hedge ambiguity by exploiting the randomness of RIS, assuming they are (at least partially) indifferent about the order of the uncertainties. The rejection of Hypothesis 1 means that their concern do not apply to all participants. However, this result does not guarantee the incentive compatibility of RIS because the majority of participants with nonneutral ambiguity attitudes is consistent with reversal-of-order.

Using data collected in Part 2, we tested three hypotheses. Hypothesis 3 states that in COR, randomization seeking participants are more likely to make an inconsistent choice than randomization averse participants. Its rejection suggests that inconsistent choices when RIS is used cannot be explained by preferences for randomization that have roots in ambiguity attitudes.

Hypothesis 2 and Hypothesis 4 were about the treatment effect. Hypothesis 2 states that the proportion of participants making inconsistent choices are smaller in IND than in COR. Hypothesis 4 states that randomization seeking (resp. averse) participants are more (resp. less) likely to make inconsistent choices in COR than in IND. We rejected that both of these hypotheses. That is, no significant improvement is obtained by the use of I-RIS. This may be because the observed inconsistent behavior in Part 2 might not be caused by nonneutral randomization attitudes. This is the case if participants viewed the choice situations in

for ambiguity attitudes. Conducting similar analyses, we obtained results that are consistent with those presented in this and the previous paragraph.

isolation and inconsistent choices are just errors without deliberation. Overall, the results above suggest that misreporting under RIS, if any, is not motivated by the desire to hedge ambiguity.

6 Conclusion

We proposed a modification of RIS, named I-RIS, in which participants face ambiguity from different sources in different choice situations. Then, we posed a preference condition that guarantees the incentive compatibility of I-RIS.

We conducted an experiment to test the performance of RIS directly and indirectly and obtained the following results. First, whereas nonneglibile fraction of participants violate the reversal-of-order axiom, the majority of participants with nonneutral ambiguity attitudes may be consistent with it. This implies that RIS is not incentive compatible if they regard an experiment as a single decision choice problem. Second, we found no significant difference in the performances of RIS and I-RIS. Third, randomization attitudes do not explain inconsistent behaviors under RIS. Fourth, there is no significant difference in performance between RIS and I-RIS among randomization seeking or averse participants. These results suggest that preferences for randomization, which are motivated by the hedging of ambiguity, do not reduce the reliability of RIS.

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A List of lotteries

#	1	2	3	4
1	600	600	0	0
2	600	400	200	0
3	600	300	300	0
4	800	800	0	0
5	800	600	200	0
6	800	400	400	0
7	1000	1000	0	0
8	1000	800	200	0
9	1000	500	500	0
10	1200	1200	0	0

(a) Risky lotteries

#	red	blue	green	yellow
1	600	600	0	0
2	600	400	200	0
3	600	300	300	0
4	800	800	0	0
5	800	600	200	0
6	800	400	400	0
7	1000	1000	0	0
8	1000	800	200	0
9	1000	500	500	0
10	1200	1200	0	0

(b) Ambiguous lotteries

#	Head				Tail			
	red	blue	green	yellow	red	blue	green	yellow
1	600	600	0	0	0	0	600	600
2	600	400	200	0	0	200	400	600
3	600	300	300	0	0	300	300	600
4	800	800	0	0	0	0	800	800
5	800	600	200	0	0	200	600	800
6	800	400	400	0	0	400	400	800
7	1000	1000	0	0	0	0	1000	1000
8	1000	800	200	0	0	200	800	1000
9	1000	500	500	0	0	500	500	1000
10	1200	1200	0	0	0	0	1200	1200

(c) Coin–ball lotteries

#	red		blue		green		yellow	
	head	tail	head	tail	head	tail	head	tail
1	600	0	600	0	0	600	0	600
2	600	0	400	200	200	400	0	600
3	600	0	300	300	300	300	0	600
4	800	0	800	0	0	800	0	800
5	800	0	600	200	200	600	0	800
6	800	0	400	400	400	400	0	800
7	1000	0	1000	0	0	1000	0	1000
8	1000	0	800	200	200	800	0	1000
9	1000	0	500	500	500	500	0	1000
10	1200	0	1200	0	0	1200	0	1200

(d) Ball–coin lotteries

Table 2: List of lotteries used in Part one.

B Instructions

B.1 Instruction for Part 1

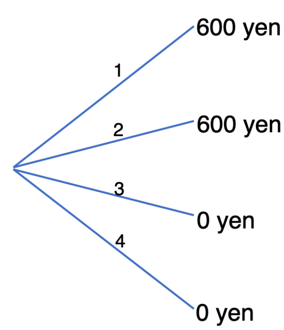
In Part 1, we randomized the order of the presentation of its subparts 3 and 4 in which coin–ball lotteries and ball–coin lotteries are evaluated, respectively. The following are the instructions for the case where subpart 3 is presented before subpart 4. The only difference between this and the other case is the order of explanations of these subparts.

Contents of the Experiment

In this experiment, you will be asked to answer questions about lotteries that allow you to receive an uncertain amount of money. At the end of the experiment, you will receive a reward. The reward is a sum of money that depends on the outcome of the experiment and the participation fee of 500 yen.

Decisions are made by you alone, and the actions of other participants do not affect your decisions or rewards. The experiment consists of four parts. Please answer 10 questions in each part.

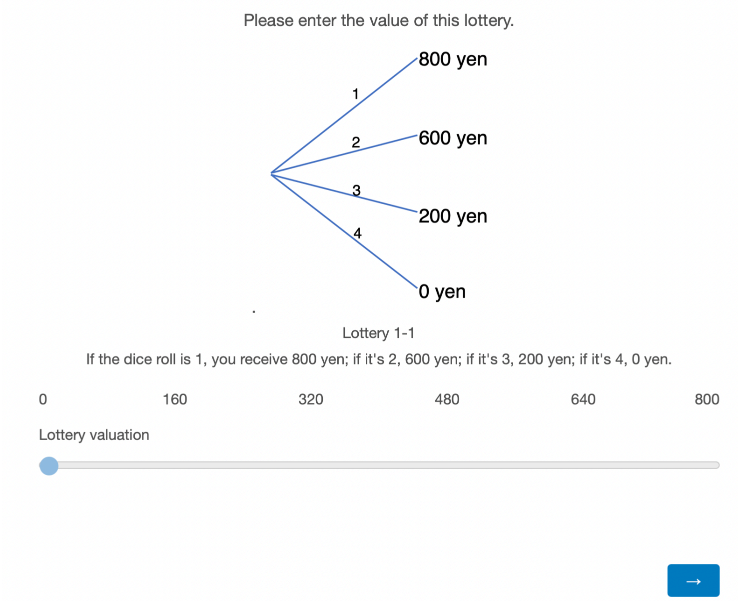
The lotteries are designed to provide monetary rewards for uncertain events. One example is the lottery illustrated below, where a four-sided die is thrown and you receive 600 yen if the die rolls a 1 or 2, and 0 yen if the die rolls a 3 or 4.



In this experiment, you will be asked to evaluate the value of various lotteries, where the value is a certain amount of money that is worth as much to you as receiving the lottery ticket. There is no right answer.

The value of a lottery ticket should range from the lowest possible value to the highest possible value that you could receive from that lottery ticket. For the lottery shown above, the range is from 0 yen to 600 yen.

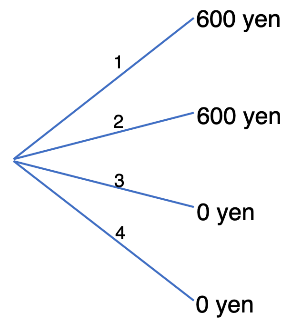
The figure below is an example of the input screen. Below the lottery diagram, you can see a text description of the lottery. Use the slider to enter the value of the lottery. When you have finished, click the "→" button to go to the next page.



Answer the same questions for a total of 40 different lotteries. Starting from the next page, we will explain the types of lotteries that are presented in each part.

Description of Part 1

The realizations of the lotteries in Part 1 are determined by throwing a four-sided die. Each side has a probability of 1/4 of appearing. The figure below shows an example of this type of lottery.



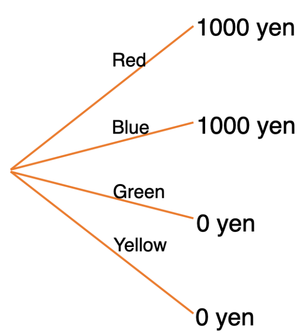
This is a lottery where you get 600 yen if the die roll is 1 or 2, and 0 yen if the die roll is 3 or 4. Here are some questions about the 10 different types of lotteries.

Explanation of Part 2 to Part 4

The other day, a student at Osaka University filled an urn with 100 balls of four different colors: red, blue, green, and yellow. It is not necessary to have the same number of balls of each color. A computer simulation of this urn is used in parts 2, 3, and 4. The realized value of the lottery in these parts depends on the color of the balls randomly taken from the urn.

Description of Part 2

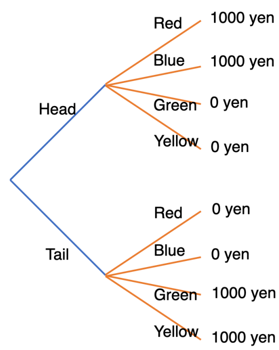
The realizations of the lotteries in Part 2 are determined solely by the color of the ball that is drawn from the urn. The figure below shows an example of this type of lottery.



This is a lottery where a ball is drawn and if it is red or blue you get 1000 yen, and if it is green or yellow you get 0 yen. There are some questions about the 10 different types of lotteries.

Description of Part 3

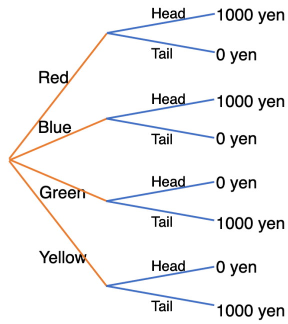
The realizations of the lottery presented in Part 3 are determined by first tossing a coin and then drawing a ball from the urn. The probability of tossing a coin and having it lands on heads or tails is 1/2. The figure below presents an example of this type of lottery.



In this lottery, a coin is tossed and if it lands heads up and the drawn ball is red or blue, you get 1000 yen. Furthermore, if the coin lands tails up and the drawn ball is green or yellow, you get 1000 yen. Otherwise, you get nothing. The questions are about 10 different lotteries

Description of Part 4

The realizations of lotteries that are presented in Part 4 are determined by first drawing a ball from the urn and then tossing a coin. The probability of the coin landing on heads or tails is 1/2. The figure below shows an example of this type of lottery.



In this lottery, if the ball is red or blue and the coin lands heads up, you get 1000 yen. If the ball is green or yellow and the coin lands tails up, you get 1000 yen. Otherwise, you get 0 yen. We ask you about these 10 different kinds of lotteries.

Reward Description

Compensation for the experiment is determined as follows.

1. Immediately after the explanation of the experiment, the computer
   - selects one lottery ticket from among all the lotteries, and
   - randomly chooses a value p in the range from the lowest to the highest amount that you might receive from the lottery.
2. After you have evaluated all the lotteries, you will get whichever you prefer between the lottery that was chosen in step 1 and p yen with certainty.
   - If the valuation of the chosen lottery is greater than or equal to p yen, then the lottery must be better, so we simulate the lottery and pay the realized value.
   - If the value of the lottery is less than p yen, then p yen should be preferred, so we pay p yen.

In step 1 of the above procedure, every lottery ticket is chosen with the same probability, and every possible value of p is chosen with the same probability. However, the lottery and the value of p are not be known until the stage where the reward is paid.

Under this procedure, it is optimal for you to provide your true valuation. We will explain why it is optimal for you to answer the true valuation. For example, if your true value of a lottery ticket is 200 yen, but you answer that it is worth 300 yen, you will lose money when the value of p lies between 200 and 300. As an example, consider the case where the value of p is 250. In this case, you would have been rewarded with your preferred option out of the guaranteed 250 yen and the lottery. If you had answered 200 yen, you would have preferred the 250 yen with certainty to the lottery, so you would have been paid 250 yen. However, if you had answered 300 yen, it would be determined that you prefer the lottery to the 250 yen with certainty, and you would be paid the lottery. Because your true valuation is 200 yen, you would prefer 250 yen to the lottery. Therefore, if you had provided your true valuation, you would have obtained a better result. This example illustrates the case where the valuation is overreported, but underreporting will still result in a loss.

Each lottery realization is determined independently of each other by the following procedure, after you have answered all the questions.

Lotteries for Part 1 For each lottery on the computer, toss a coin to determine the realized value.

Lotteries for Part 2 For each lottery, a ball is randomly drawn from the urn to determine the realized value. Each time, the ball is returned to the urn.

Lotteries for Part 3 For each lottery, a coin is tossed and a ball is randomly drawn to determine the realization. Each time, the ball is returned to the urn.

Lotteries for Part 4 For each lottery, a ball is drawn at random and then a coin is tossed to determine the realization. Each time, the ball is returned to the urn.

In summary, the experiment will proceed along the following lines.

1. A lottery and a random number p will be chosen as rewards.
2. All lotteries will be evaluated by you.

3. According to the lottery value and the value of p chosen in step 1, you receive the lottery ticket or p yen with certainty.
4. The realized values of all lotteries are determined independently.
5. If a lottery is received, the realized value is taken as the reward.

This concludes the explanation of the experiment.

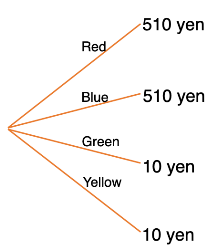
B.2 Instruction for COR treatment in Part 2

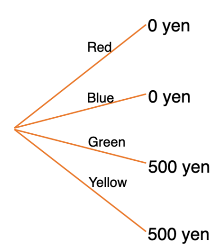
Contents of the Experiment

In this experiment, you will be asked to answer questions about lotteries that pay an uncertain amount of money. At the end of the experiment, you will receive a reward. Decisions are made by you alone, and the actions of other participants do not affect your decisions or rewards.

The other day, a student at Osaka University filled an urn with 100 red, blue, green, and yellow balls. It is possible that not all balls have the same number In this experiment, we will use a computer simulation of this urn.

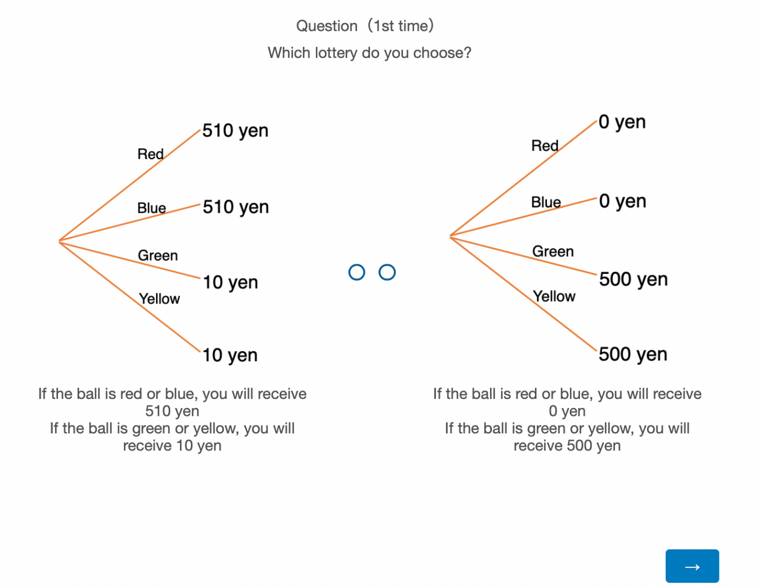
This experiment uses with the two lotteries shown below.





On the left is a lottery where you receive 510 yen if the ball is red or blue, and 10 yen if it is green or yellow. On the right is a lottery where you receive 0 yen if the ball is red or blue, and 500 yen if it is green or yellow.

In this experiment, the participants were asked twice which of the two lotteries they would choose. The figure below shows the response screen.



Check one of the options on the left or right side of the screen, and click the "→" button. Then, the lottery shown on the next page will be the same pair of lotteries again. When you answer the second question, the experiment is over.

Reward Description

At the beginning of the experiment, the computer chooses one question to be rewarded, either the first or the second. Both questions have the same probability of being chosen. After you have answered both questions, the question chosen by the computer will be revealed. The lottery you had chosen for that question will be the reward.

At the end of the experiment, a ball is drawn from the urn on the computer. The color of the ball determines the realized value of the rewarded lottery. Your reward for this experiment will be the realized value of the lottery plus 300 yen.

In summary, the experiment proceeds in the following way.

1. The computer randomly decides which question will be the target of the reward.

2. You answer the same question twice, which relates to which of the two lotteries you would prefer.
3. You receive the lottery for the reward question the computer chose in step 1.
4. A ball is drawn at random from the urn to determine the realized value of the lottery, and you receive the realized value of your lottery plus the participation fee.

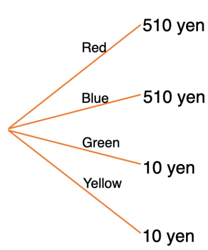
B.3 Instruction for IND treatment in Part 2

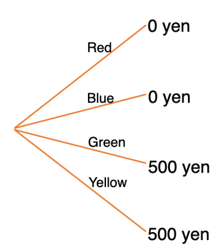
Contents of the Experiment

In this experiment, you will be asked to answer questions about lotteries that allow you to receive an uncertain amount of money. At the end of the experiment, you will receive a reward. Decisions are made by you alone, and the actions of other participants do not affect your decisions or rewards.

The other day, a student at Osaka University filled an urn with 100 red, blue, green, and yellow balls. It is possible that not all balls have the same number. In this experiment, we will use a computer simulation of this urn.

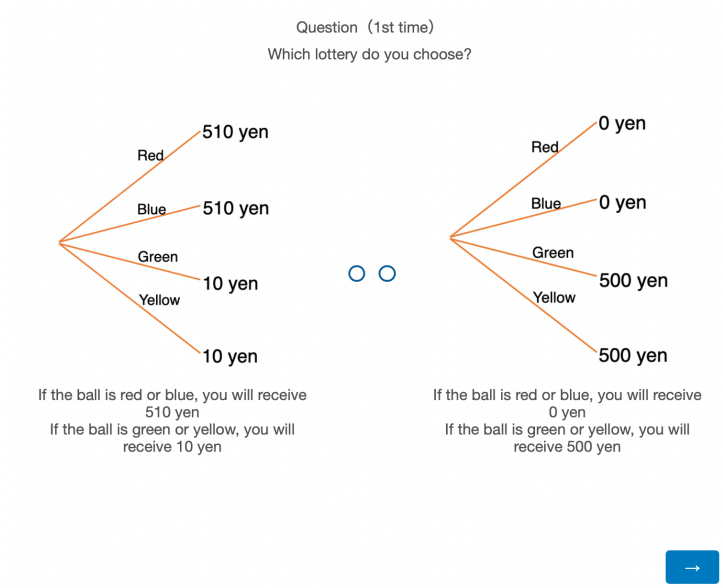
This experiment uses with the two lotteries shown below.





On the left is a lottery where you receive 510 yen if the ball is red or blue, and 10 yen if it is green or yellow. On the right is a lottery where you receive 0 yen if the ball is red or blue, and 500 yen if it is green or yellow.

In this experiment, the participants were asked twice which of the two lotteries they would choose. The figure below shows the response screen.



Check one of the options on the left or right side of the screen, and click the ”→” button. Then, the lottery shown on the next page will be the same pair of lotteries again. When you answer the second question, the experiment is over.

Reward Description

At the beginning of the experiment, the computer chooses one question to be rewarded, either the first or the second question. Both questions have the same probability of being chosen. After you have answered both questions, the question chosen by the computer will be revealed. The lottery you had chosen for that question will be the reward.

At the end of the experiment, the realizations of all the lotteries are determined. Two lotteries are shown for the first and second questions, so there are four lotteries in total. The realized value of each lottery is determined by drawing a ball from the urn independently. In other words, the procedure of drawing one ball from the urn and putting it back is repeated four times. Your reward for this experiment is the realized value of the lottery plus the participation fee of 300 yen.

In summary, the experiment proceeds in the following way.

1. The computer randomly decides which question will be the target of the reward.
2. You answer the same question twice, which relates to which of the two lotteries you would prefer.
3. You receive the lottery for the reward question the computer chose in step 1.
4. Four balls are drawn at random and independently to determine the realized values of the lotteries, and you receive the realized value of your lottery plus the participation fee.