Probabilistic Social Preference:

How Machina's Mom Randomizes Her Choice

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This study investigates social preference under risk in an experimental setting, in which decision makers choose probabilistically two allocations between oneself and an anonymous recipient. We observe that substantial proportions of subjects choose interior probability to randomize in various pairs of allocations, including the pairs with one allocation permitting advantageous inequality and the other one with disadvantageous inequality, as well as the pairs with one allocation permitting disadvantageous inequality and the other one proportionally shrinking the pie. The observed patterns have rich implications for various assumptions in social preference models, including stochastic dominance, proportional monotonicity, and convexity, and shed light on recent studies combining ex-ante and ex-post preferences.

KEYWORDS: social preference, risk, experiment

JEL: D63, D64, C91

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1. Introduction

Social preference has been extensively studied both theoretically and experimentally, and many models have been proposed to capture various aspects of social preference for better descriptive purposes, including inequality concern (Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000) and equality-efficiency trade-off (Andreoni and Miller, 2002; Charness and Rabin, 2002). When the environment involves risks, it is natural to extend the existing models using either expected or non-expected utility approach, i.e., one first evaluates each alternative allocation and then aggregates the utility of the risky allocation with expected or non-expected utility. The resulting representation exhibits preference for ex-post fairness. Such utility cannot account for preference for ex-ante fairness (Diamond, 1967), which is best illustrated in the classical thought example of Machina (1989) as follows. Consider a mother to allocate an indivisible good to two children that she equally likes, and she strictly prefers randomizing her choice through a coin flip rather than giving the good to either child. Ex-post social preference cannot explain the behavior of Machina's Mom since it implies any probabilistic combination of allocating the good to either child has the same valuation. Meanwhile, ex-ante fairness preference, evaluating the expected allocation of the distribution, can be compatible with preference for randomization.[1]

The intuition of Machina's example remains valid when extended from the perspective of a social planner to the situations where the material payoffs of the decision maker are involved. Consider a decision maker facing three options regarding how to allocate one indivisible token between herself and an anonymous recipient: keeping the token to herself; giving the token to the recipient; or keeping the token to herself if a coin toss is head and giving the token to the recipient otherwise. A choice of randomization similarly manifests preference for ex-ante fairness in the context of social preference. A number of recent studies investigate the implications of ex-ante and ex-post social preferences. Fudenberg and Levine (2012) show that preference for ex-ante fairness is incompatible with the independence axiom, and further suggest the need to combine both ex-ante and ex-post preferences. Saito (2013) provides an axiomatic foundation for a combinational preference with the built-in specification of Fehr and Schmidt (1999). At the meantime, Brock,

[1]Please refer to Section 3 for the formal definitions of ex-post and ex-ante preferences.

Andreas, and Ozbay (2013) provide experimental evidence in support of preference with a combination of both ex-ante and ex-post concerns.

In this study, we generalize the example of Machina to a setting in which the decision maker chooses whether and how to randomize between various pairs of allocations between oneself and the other. Specifically, we introduce a probabilistic convex dictator game in which the dictator chooses probabilities to implement two possible allocations, namely, (x_1, x_2) and (y_1, y_2), between herself and an anonymous recipient.[2] A chosen probability $p \in [0,1]$ delivers the allocation (x_1, x_2) with probability p and (y_1, y_2) with probability $1 - p$.

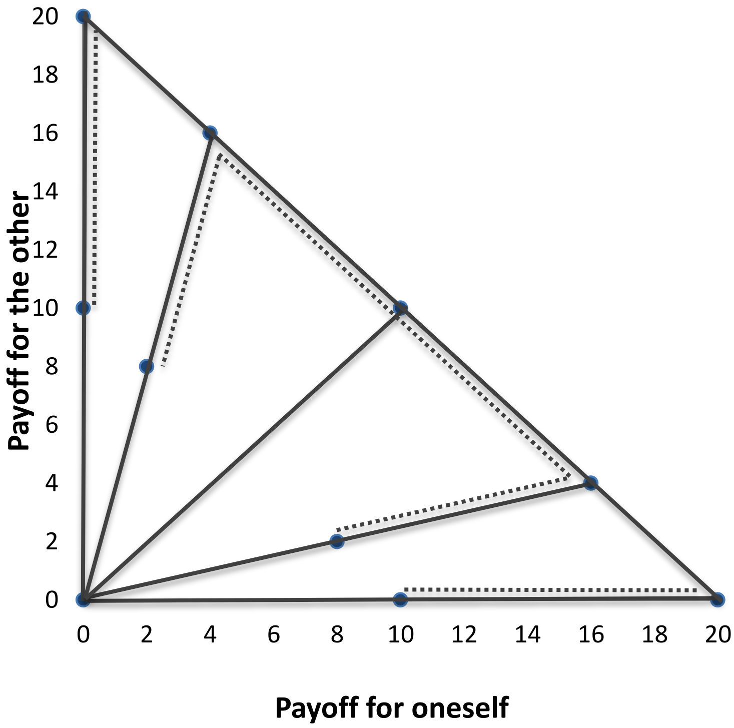

Figure 1. Experimental Conditions. In the triangle, one dot represents a deterministic allocation with x-axis representing the payoff for the dictator, and y-axis representing the payoff for the recipient. A link connecting two dots represents one condition. For instance, the line connecting (0,0) and (4,16) represents condition $(4,16; 0,0)$.

Our study consists of 11 pairs of allocations $(x_1, x_2; y_1, y_2)$ as illustrated by the allocation triangle in Figure 1. Conditions $(20,0; 0,20)$ and $(16,4; 4,16)$ as shown in the hypotenuse of Figure 1 are similar to that considered in Machina (1989), i.e., two alternative allocations have symmetric inequality and the total pie is fixed at 20. In conditions $(0,20; 0,0)$ and $(4,16; 0,0)$ as shown in the upper triangle of Figure 1, one

[2]The subscript 1 represents oneself, and 2 represents the recipient. That is, x_1 represents payoff for the dictator and x_2 represents payoff for the recipients. The representations are the same for (y_1, y_2).

allocation has disadvantageous inequality for the dictator, whereas the other allocation shrinks the pie to zero for both players. We have another two conditions in the upper triangle, in which one allocation has disadvantageous inequality for the dictator, and the other allocation shrinks the pie by 50% for both players, that is, $(0,20; 0,10)$ and $(4,16; 2,8)$. Correspondingly, we have four conditions with advantageous inequality for the dictator as shown in the lower triangle including $(20,0; 0,0)$, $(16,4; 0,0)$, $(20,0; 10,0)$, and $(16,4; 8,2)$. The last condition is $(10,10; 0,0)$.

Our design links to a number of earlier experimental studies related to ex-ante and ex-post social preferences. Sandroni, Ludwig, and Kircher (2013) provide a test for Machina's example in which subjects choose among three options, namely, advantageous inequality, disadvantageous inequality, and flipping a coin between the first two alternatives. They report that 30% of the subjects choose the randomization option, in support of preference for ex-ante fairness. In Bolton and Ockenfels (2010), subjects decide on a number of binary choices between a safe and a risky allocation. They find that subjects are more risk taking when the safe option yields unequal payoffs and that risk taking does not depend on whether the risky option yields unequal payoffs. They suggest that subjects are less uncomfortable with ex-post inequality when risky options yield ex-ante equality. In Cappelen et al. (2013), subjects initially make risky decisions, and are subsequently asked to make redistribution decisions after the first-stage choices and outcomes are revealed. They find support for ex-ante fairness preference, but the evidence is mixed because ex-post redistribution also takes place. Krawczyk and Le Lec (2010) propose an experiment in which subjects share the chances to win a fixed prize with either independent or dependent draws. They observe that subjects do share the chances of winning in the dependent draws, and the shared chance is smaller relative to that in the independent draws. Overall, they suggest a mix of distributive and procedural fairness preferences. Brock, Andreas, and Ozbay (2013) further vary the dictator's own risk exposure and the ability to achieve ex-post fairness by allowing the dictator to allocate tokens that could be transformed into lotteries. They argue that neither ex-ante preference nor ex-post preference alone could account for the observations, and suggest preferences combining both motives.

Compared with our design, most of these aforementioned studies stay along the hypotenuse in the allocation triangle since the ex-ante allocation adds up to a constant sum.[3] In this study, we essentially probe probabilistic social preference inside the allocation triangle. When entering the interior of the triangle, our design incorporates the efficiency motive that is often missing in these recent studies since the total pie is fixed along the hypotenuse. Moreover, our design enables a systematic examination of the differences between advantageous inequality and disadvantageous inequality under risk, that is, the lower and upper triangle in Figure 1, which is difficult in usual dictator games because the subjects in general choose an allocation in the lower triangle.

Overall, we find that a substantial proportion of subjects choose interior probabilities in various conditions. We also observe different patterns in choosing corner probabilities (either 0 or 1) between the conditions that have common intersections (represented by dotted links and solid links). The observed patterns have rich implications on the theoretical social preference literature. Firstly, it is straightforward that an interior choice is incompatible with ex-post preference if it respects stochastic dominance since dominance implies choosing corner probabilities in all conditions. Interior choice likewise suggests that ex-ante preference on expected allocations cannot be monotonic along the interval covered by the condition. In particular, in the conditions other than those along the hypotenuse, interior choice is inconsistent with monotonicity along the lines passing 0, which we term as *proportional monotonicity*. Moreover, the different choice patterns in the conditions with overlaps suggest that ex-ante preference cannot be strictly convex since otherwise the chosen probabilities should generate identical ex-ante allocations.

Lastly, when considering a combinational preference that incorporates both ex-ante and ex-post concerns, we demonstrate that an interior choice implies that the combinational preference cannot simultaneously permit stochastic dominance in ex-post preference, proportional monotonicity in ex-ante preference, and monotonicity in the combination function, which suggests against the specification as stated in Fudenberg and Levine (2012) and Saito (2013). We further discuss alternative means of combining ex-ante and ex-post preferences by relaxing proportional monotonicity.

[3] In the deterministic setup, traditional dictator/ultimatum games examine deterministic social preference along the hypotenuse (see Camerer 2003 for a review) as the subjects choose to allocate a fixed pie. Andreoni, Castillo, and Petrie (2003) extend the analysis to inside the triangle with a convex ultimatum game, in which the responder can choose to shrink the pie rather than the take-it-or-leave-it option in the standard ultimatum game.

The rest of this paper is organized as follows. We detail our experimental design in Section 2, and discuss their implications on probabilistic social preference theories in Section 3. We initially analyze the aggregate patterns and subsequently perform an individual-level analysis in section 4. Section 5 concludes.

2. Experimental Design

2.1 Experiment I

Subjects are presented with two allocations—Allocation 1 and Allocation 2—between oneself and the other anonymous participant, randomly selected in the experimental venue (see Appendix D for the experimental instructions). The decision that subjects have to make is to choose probability p including 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, and 1 to implement Allocation 1, and the complementary probability $1-p$ to implement Allocation 2 as in Table 1 below. Note that probabilities p and $1-p$ are dependent. The chosen probability will be implemented by drawing one card from a set of 10 cards numbered from 1 to 10. If p is 0, Allocation 1 will not be implemented and Allocation 2 will be implemented regardless of the card drawn. If p is 0.1, Allocation 1 will be implemented if the card drawn has number 1, otherwise Allocation 2 will be implemented. If p is 0.2, Allocation 1 will be implemented if the card drawn is either 1 or 2, otherwise Allocation 2 will be implemented, and so on.

Allocation 1		*Allocation 2*	
You	*Other*	*You*	*Other*
x_1	x_2	y_1	y_2
P:		***1-P:***	

Table 1. Decision Table for the Subjects. Given two possible allocations (x_1, x_2) and (y_1, y_2), subjects choose the probability p to implement the first allocation and $1-p$ to implement the second allocation.

We include 11 pairs of allocations that vary in inequality and efficiency in the allocation triangle as illustrated in Figure 1 and explained in the introduction. In conditions $(20{,}0; 0{,}20)$ and $(16{,}4; 4{,}16)$, the total pie is fixed and inequality reverses between the two allocations. $(20{,}0; 0{,}20)$ essentially follows the idea in Machina (1989), and is tested in Sandroni, Ludwig, and Kircher (2013). Intuitively, subjects may choose $(20{,}0)$ over $(0{,}20)$ in a deterministic situation by selfishness motive, whereas ex-ante fairness concern drives the subjects to randomize between the two allocations. With $(16{,}4; 4{,}16)$, we can test whether subjects are more or less willing to randomize when the inequality is less extreme.

In conditions $(0{,}20; 0{,}0)$ and $(4{,}16; 0{,}0)$, one allocation has disadvantageous inequality for the dictator with the other allocation shrinking the pie to zero for both players. In two other conditions $(0{,}20; 0{,}10)$ and $(4{,}16; 2{,}8)$, one allocation has disadvantageous inequality for the dictator, whereas the other allocation shrinks the pie by 50% for both players. Intuitively, inequality aversion predicts preference for $(0{,}0)$ over $(0{,}20)$, whereas efficiency concern predicts the opposite. Should a decision maker randomize between the two allocations, such decisions would reflect a mixture of both equality and efficiency motives. This view echoes the intuition in the convex ultimatum game in Andreoni, Castillo, and Petrie (2003), in which the responders can choose to shrink the pie instead of accepting or rejecting the offer.

We introduce four more conditions, $(20{,}0; 0{,}0)$, $(16{,}4; 0{,}0)$, $(20{,}0; 10{,}0)$, and $(16{,}4; 8{,}2)$, which inherit similar intuitions discussed above except that we switch the payoffs between the dictator and the recipient to impose advantageous inequality for the dictator. This enables us to compare between disadvantageous and advantageous inequality. The final condition is $(10{,}10; 0{,}0)$, in which the subjects are in equal situation and the alternative is to obtain 0 for both. This condition is included as a control because any mixture of selfishness, inequality, or efficiency concern would not predict randomization.

We recruited 157 students using advertisement posted in Integrated Virtual Learning Environment at the National University of Singapore (NUS).[4] The experiment consisted of six sessions with 20 to 30 subjects in each session. After arriving at the experimental venue, subjects were given the consent form approved by NUS institutional review board. Subsequently, general instructions were read aloud to the subjects followed by demonstrations of several examples. We subsequently gave several exercises for the subjects to practice and to ensure their understanding of the tasks. After ensuring that the subjects fully understand the task, subjects began with their decisions-making tasks. The 11 conditions were randomly presented to each subject. Most of the subjects completed the tasks within 10 minutes. Each subject received S$10 (approximately US$7) as participation fee at the end of the session. We

[4]One participant did not complete some of the tasks. We did not count this subject in the 157 subjects.

randomly selected one participant in each session to implement one of her 11 choices, and matched her choice with one randomly selected subject in the session.

2.2 Experiment II

In Experiment 1, we incentivize subjects by randomly selecting one participant in each session to implement one of her 11 choices. Although this so-called random lottery mechanism has been widely used and has a number of advantages in data collections, validity could be of concern (see, Wakker 2007 for discussions), especially given our interest in ex-ante preference. To address this concern and to check the robustness of the results in Experiment 1, we conduct Experiment 2 in which the subjects play the role of either dictator or recipient. In addition, each dictator makes one single choice in the experiment, which is implemented for sure with real incentive. For the other group of subjects as recipients, each subject is matched with one dictator and makes no choice in the experiment. We include two conditions from Experiment 1, namely, $(0,20; 0,0)$ and $(0,20; 0,10)$. Other aspects of the experiment are the same as Experiment 1.

We recruited 188 subjects for this experiment. 94 subjects played the role of dictators, including 45 subjects for condition $(0,20; 0,0)$ and 49 subjects for condition $(0,20; 0,10)$. The rest of 94 subjects as recipients were matched to the 94 dictators. We had 7 sessions and mixed the two conditions in each session to control the possible session effect. Each subject received a $5 show up fee, in addition to the payment based on the choice of the dictators.

3. Theoretical Implications

In this section, we briefly analyze the implications of some existing models, including ex-post preference, ex-ante preference and combinational preference, on the choice patterns in different conditions.

In the following, let $U(x_1, x_2)$ be the utility function on deterministic allocation (x_1, x_2), where x_1 is the payoff to the dictator and x_2 is the payoff to the recipient. A general social utility function $\Phi\big((x_1, x_2), p; (y_1, y_2), 1-p\big)$ is defined on a contingent allocation $\big((x_1, x_2), p; (y_1, y_2), 1-p\big)$, which yields the allocation (x_1, x_2) with probability p and (y_1, y_2) with probability $1-p$.

Denote ex-post preference by $\Phi_{ex-post} = \Theta(U(x_1, x_2), p; U(y_1, y_2), 1-p)$ in which Θ is a risk aggregator function. Similarly denote ex-ante preference by $\Phi_{ex-ante} = U\big(p(x_1, x_2) + (1-p)(y_1, y_2)\big)$ in which $p(x_1, x_2) + (1-p)(y_1, y_2)$ refers to the outcome mixture that produces the deterministic allocation $(px_1 + (1-p)y_1, px_2 + (1-p)y_2)$. Lastly, a combinational preference is denoted by $\Phi\big(\Phi_{ex-ante}, \Phi_{ex-post}\big)$, where Φ is an aggregator function on both ex-post and ex-ante utilities.

In the sequel, we discuss several implications of these preferences under certain assumptions.

Implication 1. *Ex-post preference predicts corner choices in all conditions if the aggregator function Θ respects stochastic dominance.*

This implication is due to the fact that stochastic dominance implies $\Theta\big(U(x_1, x_2)\big) > \Theta(U(x_1, x_2), p; U(y_1, y_2), 1-p) > \Theta\big(U(y_1, y_2)\big)$ for $p \in (0,1)$ if $U(x_1, x_2) > U(y_1, y_2)$ and vice versa.[5] Note that stochastic dominance is permitted by most commonly used models, including expected utility, rank-dependent utility (Quiggin, 1982) and those adopting the betweenness approach (Chew 1983; Dekel 1986).

Implication 2a. *Ex-ante preference predicts corner choices for conditions $(x_1, x_2; px_1, px_2)$ if U is proportionally monotonic, i.e., $U(px_1, px_2)$ is monotonically increasing or decreasing in p for $p \geq 0$.*

Given that U is proportionally monotonic, i.e., monotonic along the line passing (0,0), it is straightforward that ex-ante preference implies corner choices in all conditions including $(0{,}20; 0{,}0)$, $(4{,}16; 0{,}0)$, $(0{,}20; 0{,}10)$, $(4{,}16; 2{,}8)$, $(20{,}0; 0{,}0)$, $(16{,}4; 0{,}0)$, $(20{,}0; 10{,}0)$, and $(16{,}4; 8{,}2)$ except for those along the hypotenuse. Notably, proportional monotonicity is widely admitted in various utility models including Fehr and Schmidt (1999), Bolton and Ockenfels (2000), Charness and Rabin (2002), Andreoni and Miller (2002), and Cox and Sadirij (2004).[6] The other common property

[5]This implication is in line with the independence property imposed on half/half risky allocation in Fudenberg and Levine (2012).

[6]Fehr and Schmidt (1999) take the form $x_1 - \alpha \max\{x_1 - x_2, 0\} - \beta \max\{x_2 - x_1, 0\}$. Bolton and Ockenfels (2000) take the form $x_1 - \alpha \max\{(x_1 - x_2)/(x_1 + x_2), 0\} - \beta \max\{(x_2 - x_1)/(x_1 + x_2), 0\}$. Charness and Rabin (2002) take the form $(1-\gamma)x_1 + \gamma\big(\delta \min\{x_1, x_2\} + (1-\delta)(x_1 + x_2)\big)$. Andreoni and Miller (2002) take the form $(\delta x_1^{\alpha} + (1-\delta)x_2^{\alpha})^{1/\alpha}$. Cox and Sadirij (2004) take the form $(1-\theta)x_1^{\alpha} + \theta x_2^{\alpha}$, In all of these models, varying p in (px_1, px_2) does not change the relative rank

of U besides proportional monotonicity is convexity, and next implication states the implication of strict convexity in our design.

Implication 2b. *Ex-ante preference predicts more corner choices of* $p = 0$ *when the coverage shrinks if* U *is strictly convex.*

This implication is due to the fact that a strictly convex U admits a unique optimal allocation along any straight line.[7] Consider the two conditions $(x_1, x_2; 0,0)$ and $(x_1, x_2; 0.5x_1, 0.5x_2)$, a chosen probability $p \leq 0.5$ in condition $(x_1, x_2; 0,0)$ generates an ex-ante allocation, (px_1, px_2), which is not covered by $(x_1, x_2; 0.5x_1, 0.5x_2)$. Given this, the optimal chosen probability p' in condition $(x_1, x_2; 0.5x_1, 0.5x_2)$ must be 0 since otherwise there would exist a continuum of optimal allocations between the ex-ante allocations (px_1, px_2) and $(p'x_1 + 0.5(1-p')x_1, p'x_2 + 0.5(1-p')x_2)$, which contradicts strict convexity. Therefore, a strict convex U implies that the proportion of choosing $p \leq 0.5$ in condition $(x_1, x_2; 0,0)$ is the same as the proportion of choosing $p = 0$ in condition $(x_1, x_2; 0.5x_1, 0.5x_2)$. That is, there are (weakly) more corner choices of $p = 0$ when the coverage shrinks.[8] Note that strict convexity is permitted in several social preference specifications admitting the CES form, such as Andreoni and Miller (2002) and Cox and Sadirij (2004).

Krawczyk and Le Lec (2014) recently suggest that several observations on ex-ante preferences in Brock, Andreas, and Ozbay (2013) can be rationalized by risk aversion. They consider the following general ex-ante preference specification $U\big(\mathrm{CE}(x_1, p; y_1, 1-p), \mathrm{CE}(x_2, p; y_2, 1-p)\big)$, where CE is a certainty equivalent aggregator that is affected by risk attitude and we have $\mathrm{CE}(x_1, p; y_1, 1-p) = px_1 +$

between px_1 and px_2, and thus would not change the parameters in these models when evaluating (x_1, x_2) and (px_1, px_2). Given the linearity in the first three functional forms and the CES form in the latter two, all of these models exhibit proportional monotonicity. Non-monotonic preferences could be potentially problematic in the theoretical setup. Suppose a decision maker always chooses an interior probability in condition $(0, x; 0,0.5x)$ for any x, this would imply that the preference is non-monotonic between $(0, x)$ and $(0,0.5x)$, which is implausible.

[7]Levati, Nicholas, and Rai (2014) test the single-peakedness property of social preference, which is implied by convexity.

[8]The same argument could be applied to for conditions $(20,0; 0,20)$ and $(16,4; 4,16)$. The proportion of choosing $p \leq 0.2$ in condition $(20,0; 0,20)$ is the same as that of choosing $p = 0$ in condition $(16,4; 4,16)$, and the proportion of choosing $p \geq 0.8$ in $(20,0; 0,20)$ is the same as that of choosing $p = 1$ in $(16,4; 4,16)$. A further implication of strict convexity is that an interior choice p in $(16,4; 4,16)$ implies choosing the probability $\big(16p + 4(1-p)\big)/20$ in $(20,0; 0,20)$ to generate exactly the same ex-ante allocation.

$(1-p)y_1$ under risk neutrality. Given this general ex-ante preference, it is not clear how the dictator would behave in most of the conditions when the coverage shrinks except on the vertical line of the allocation triangle where risk attitude does not affect the certainty equivalent received by the dictator. With either strict convexity or proportional monotonicity, a dictator choosing either $p = 0$ or $p = 1$ in condition $(0{,}20; 0{,}0)$ must also choose the same corner probabilities in condition $(0{,}20; 0{,}10)$, because the ex-ante allocations considering the effect of risk attitude always lie on the vertical line of the triangle in both conditions.[9]

Implication 3. *Combinational preference* $\Phi(\Phi_{ex-ante}, \Phi_{ex-post})$ *predicts corner choices if the following hold. 1)* $\Phi_{ex-ante}$ *respects stochastic dominance, 2)* $\Phi_{ex-post}$ *admits proportional monotonicity, and 3)* Φ *is monotonic in both arguments.*

The reason for this implication is as follows: suppose $\Phi_{ex-post}$ is monotonic (respects dominance) in p, and $\Phi_{ex-ante}$ is proportionally monotonic, the optimal choice of p will be in the corner due to the monotonicity of Φ. A combinational model satisfying all these conditions, with U admitting the Fehr-Schmidt (1999) specification and Φ an weighted average of ex-post and ex-ante utilities, is recently discussed in Fudenberg and Levine (2012) and axiomatized in Saito (2013). Appendix B shows that the incompatibility between interior choice and Saito (2013) is due to the axioms of Quasi-comonotonic Independence and Probability Certainty Independence.

4. Results and Analyses

4.1 Basic Patterns

In this subsection, we summarize the basic choice patterns in Experiment 1 with respect to the theoretical implications discussed and check whether the patterns are robust in Experiment 2. Figure 2 below summarizes the percentage of subjects choosing $p = 0$, $p = 1$ and interior probabilities for each of the 11 conditions for Experiment 1 (see also Table A1 of Appendix A). We observe one basic pattern as follows.

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[9]The payoff for the dictator is always 0 and thus is not affected by risk attitude. For the recipient, given the ex-ante payoff: p chance of receiving 20 and $1-p$ chance of receiving 0/10, the certainty equivalent that considers the risk attitude still lies between 0/10 and 20. Similar implication can be made for the conditions along the bottom line of the allocation triangle.

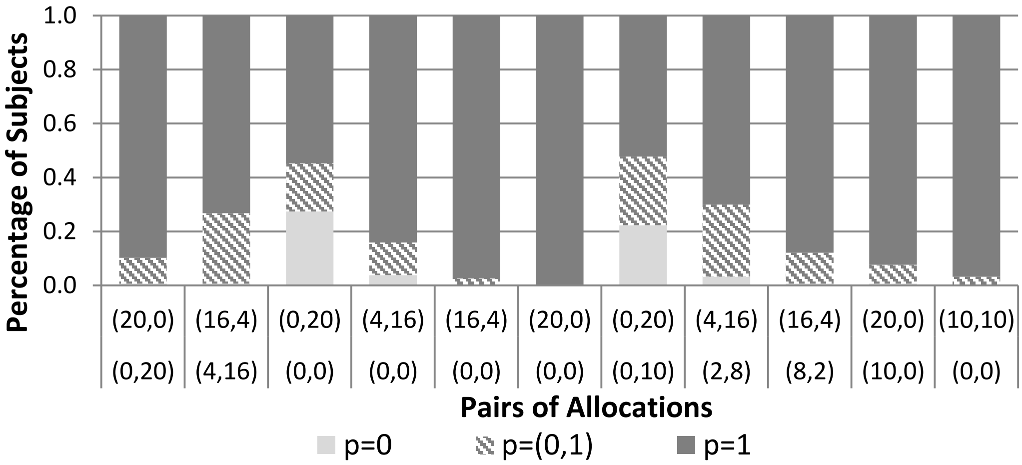

Figure 2. Percentage of choosing different types of probability for each pair.

Observation 1. *Substantial proportions of subjects choose interior probability across conditions.*

On average, 12.9% of the choices are interior probability, which is significantly different from zero using a one-sample proportion test ($p < 0.001$). The proportion of interior choices varies across different conditions from 0% to 26.8%. For instance, no subject chooses interior p in $(20{,}0; 0{,}0)$, whereas 26.8% of the subjects choose interior p in $(4{,}16; 2{,}8)$. In the control condition $(10{,}10; 0{,}0)$, 96.8% of the subjects choose $p = 1$, no subject chooses $p = 0$, and 5 out of 157 subjects (3.2%) choose interior p, which is significantly smaller than the average interior probability choices of 12.9%. This finding suggests that the interior probability choices are unlikely due to choice errors.

For the two conditions along the hypotenuse $(20{,}0; 0{,}20)$ and $(16{,}4; 4{,}16)$, the majority of the subjects choose $p = 1$, one subject chooses $p = 0$ in $(20{,}0; 0{,}20)$, and another chooses $p = 0$ in $(16{,}4; 4{,}16)$.[10] The levels of interior probability choices are 9.6% and 26.1%, respectively, which are significantly more than 0 in the proportion test ($p < 0.001$, two-tailed). This observation is similar to that in Sandroni, Ludwig, and Kircher (2013) and supports the intuition in Machina's thought experiment in the context of social preference. The average probabilities for these interior choices are 0.673 and 0.741, both of which are significantly larger than 0.5 ($p < 0.001$). This

[10]These two incidences of choosing $p = 0$ are similar to those giving more than 50% in the standard dictator game (e.g., Camerer, 2003). Our results are robust to the exclusion of these two subjects. If we consider the five subjects choosing interior p for $(10{,}10; 0{,}0)$ as noises, our results are also robust to the exclusion of these five subjects.

result suggests that although the dictator prefers to share the chance with the recipient, she would prefer to give herself a better chance.

For disadvantageous inequity, the percentage of interior choices is 17.8% in $(0,20;0,0)$ and 25.5% in $(0,20;0,10)$, with the corresponding mean interior probabilities from 0.414 to 0.493. Similarly, the percentage of interior choices is 12.1% in $(4,16;0,0)$ and 26.8% in $(4,16;2,8)$, with mean interior probabilities of 0.515 and 0.595, respectively. When subjects face advantageous inequity, the percentage of interior choices is 0% in $(20,0;0,0)$ and 7% in $(20,0;10,0)$, as well as 2.5% in $(16,4;0,0)$ and 11.5% in $(16,4;8,2)$. Comparing disadvantageous inequity and advantageous inequity, the proportion test shows the presence of significant differences for all of the comparisons (Table A2 of Appendix A). The mean interior probability is 0.501 for four conditions with disadvantageous inequality, and 0.716 for four conditions with advantageous inequality. These results suggest that although some subjects choose randomization under advantageous inequality, the chosen probabilities are higher than that in the conditions with disadvantageous inequality.

In sum, the prevalence for interior choices indicates that pure ex-post preference respecting stochastic dominance could not account for subjects' preference for randomization as in Implication 1. Moreover, it suggests that a substantial proportion of subjects violate proportional monotonicity as in Implication 2a. Lastly, it is also incompatible with a combinational preference concurrently permitting dominance, proportional monotonicity, and monotonicity as in Implication 3.

We further check the robustness of the results in Experiment 2. In Experiment 2, the percentage of interior choices is 37.8% in $(0,20;0,0)$ and 26.5% in $(0,20;0,10)$. Adopting a two-sample proportion test, we find that the proportions are not significantly different between the two experiments for $(0,20;0,0)$ ($p > 0.183$), as well as for $(0,20;0,10)$ ($p > 0.208$).[11] This suggests that the observed preference for randomization is robust across different elicitation mechanisms.

To examine Implication 2b, we test whether more subjects choose $p = 0$ when the coverage shrinks from $(x_1, x_2; 0,0)$ to $(x_1, x_2; 0.5x_1, 0.5x_2)$. We obtain the following observation.

Observation 2. *There is significantly less subjects choosing $p = 0$ when the coverage shrinks from $(x_1, x_2; 0,0)$ to $(x_1, x_2; 0.5x_1, 0.5x_2)$.*

[11] Alternatively, we use Chi-square test, which yields similar statistics.

As explained in the theory section, if the preference is strictly convex, the proportion of choosing $p \le 0.5$ in $(x_1, x_2; 0{,}0)$ will be the same as that of choosing $p = 0$ in $(x_1, x_2; 0.5x_1, 0.5x_2)$. In Experiment 1, the proportion choosing $p = 0$ in $(0{,}20; 0{,}10)$ is 22.3%, which is significantly less than 42.7%, the corresponding proportion of choosing $p \le 0.5$ in $(0{,}20; 0{,}0)$ (p < 0.001). Similarly, the proportion choosing $p = 0$ in $(4{,}16; 2{,}8)$ is 2.3%, which is significantly less than 10.2%, the corresponding proportion of choosing $p \le 0.5$ in $(4{,}16; 0{,}0)$ (p < 0.013). This contradicts the implication of a convex ex-ante preference as in Implication 2b.

For Experiment 2, the proportion choosing $p = 0$ is 18.4% for $(0{,}20; 0{,}10)$, which is significantly less than 48.9%, the proportion choosing $p \le 0.5$ in $(0{,}20; 0{,}0)$ (p < 0.002). This replicates the observation in Experiment 1, and similarly suggests the violation of strictly convex ex-ante preferences.

4.2 Individual Analysis

We proceed to conduct an individual-level analysis by characterizing the subjects into different types according to the implications of different theories. As Experiment 1 is conducted using a within-subject design and Experiment 2 is conducted using a between-subject design, the individual analysis is only feasible for Experiment 1. We impose stochastic dominance in ex-post preference and strict convexity in ex-ante preference for the analysis, because otherwise, either theory could be compatible with any type of behavior.

The ex-post preference type chooses corner probabilities for all of the conditions. 75 subjects (47.8%) belong to this type.[12] The ex-ante preference type makes consistent choices in conditions $(x_1, x_2; 0{,}0)$ and $(x_1, x_2; 0.5x_1, 0.5x_2)$, as well as in $(20{,}0; 0{,}20)$ and $(16{,}4; 4{,}16)$. That is, if the chosen probability in $(x_1, x_2; 0{,}0)$ generates an ex-ante allocation that lies in between (x_1, x_2) and $(0.5x_1, 0.5x_2)$, then the chosen probability in $(x_1, x_2; 0.5x_1, 0.5x_2)$ should generate the same ex-ante allocation.[13] With a certain level of choice error,[14] the ex-ante preference type comprises 69 subjects (44.0%). There are intersections of these two types, and the

[12]We also check whether the chosen probabilities result in violations of transitivity. For instance, $p = 1$ in $(20{,}0; 0{,}0)$, $p = 0$ in $(0{,}20; 0{,}0)$, and $p = 0$ in $(20{,}0; 0{,}20)$ violates transitivity. No subject violated transitivity.

[13]If the generated ex-ante allocation does not lie in between (x_1, x_2) and $(0.5x_1, 0.5x_2)$, then the chosen probability must be 0 in condition $(x_1, x_2; 0.5x_1, 0.5x_2)$ to be consistent with strict convexity.

[14]With only 11 available probabilities in each condition, sometimes the chosen probabilities cannot generate exactly the same ex-ante allocation. We allow for a difference of 0.05 in the probabilities when counting for ex-ante type.

behavioral pattern of 63 subjects (40.1%) can be explained by both theories. These subjects always choose corner probabilities and, in particular, they choose the same corner probabilities in conditions with common intersections as implied by convexity.

The combinational preference type with Fehr-Schmidt specification by Saito (2013) predicts corner choices in all of the conditions except for $(20,0; 0,20)$ and $(16,4; 4,16)$ due to proportional monotonicity. The 63 subjects in both ex-post and ex-ante groups also belong to this type, and another 16 subjects belong to this group because it does not impose corner choices along the hypotenuse. In sum, 79 subjects (50.3%) comprise this type.

Overall, the behavior patterns of 91 subjects (58.0%) could be accounted for by various theories mentioned above, whereas the remaining 66 the subjects (42.0%) do not belong to any type. These patterns suggest that the incompatibility between theoretical assumptions and observed patterns persists at the individual level.

We likewise check several primitive behavioral patterns consistent with pure selfishness, efficiency, and inequality aversion motives. The selfish type chooses 1 in all of the conditions except for $(0,20; 0,0)$ and $(0,20; 0,10)$, and 86 subjects (54.8%) belong to this group. The efficiency type chooses 1 in all of the conditions to maximize efficiency except for $(20,0; 0,20)$ and $(16,4; 4,16)$, and comprises 67 subjects (42.7%). In contrast, no subject belongs to the inequality aversion type, who is supposed to minimize the inequality.[15]

4.3 Further Discussions

Overall, the observe choice patterns are against both ex-ante and ex-post preferences under weak assumptions. In addition, interior choices are also incompatible with certain assumptions in combinational preference $\Phi(\Phi_{ex-ante}, \Phi_{ex-post})$. Generally speaking, it is relatively easier to give up proportional monotonicity in ex-ante preference while maintaining stochastic dominance in ex-post preference and monotonicity in combination function. For instance, Andreoni, Castillo, and Petrie (2003) observe evidence against proportional monotonicity in the responder

[15] The implications of selfishness type are independent of ex-ante and ex-post concerns, that is, maximizing either the ex-ante or ex-post selfishness utility results in the same predictions. Similarly, ex-ante and ex-post efficiency concerns predict the same choice patterns. The implication for inequality aversion is slightly different, as ex-post and ex-ante inequality-averse subjects may behave differently in conditions $(20,0; 0,20)$ and $(16,4; 4,16)$. For instance, a quadratic ex-ante inequality-averse agent chooses 0.5, whereas a quadratic ex-post inequality-averse subject is indifferent among all of the probabilities.

preferences in a convex deterministic ultimatum game, and suggest that the intention model in Rabin (1993) can display such non-monotonicity. As the disadvantageous inequity is not caused by the intention of the recipient in our setup, Rabin's model does not seem natural to account for the observed violation of proportional monotonicity.

One can have non-monotonicity in our setup using a non-linear tradeoff between selfishness and inequality aversion as mentioned in Fehr and Schmidt (1999), for example, $x_1 - \alpha(\max\{x_1 - x_2, 0\})^2 - \beta(\max\{x_2 - x_1, 0\})^2$. The ex-ante form of this model can accommodate the interior choices as in Observation 1 because of the convexity in inequality aversion. With $\alpha < \beta$, the inequality aversion incentive becomes stronger when switching from the lower to the upper triangle, which could induce more interior choices in the upper triangle. Nevertheless, this is incompatible with the interior choices in conditions $(0{,}20; 0{,}0)$ and $(0{,}20; 0{,}10)$ because no selfishness incentive is involved. Choosing $p > 0$ in these two conditions indicates the potential existence of efficiency concern, which could be captured by some additional term $\gamma(x_1 + x_2)$ to obtain $x_1 + \gamma(x_1 + x_2) - \alpha(\max\{x_1 - x_2, 0\})^2$ $-\beta(\max\{x_2 - x_1, 0\})^2$.[16] This utility function is globally concave, and hence ex-ante preference with this utility is still incompatible with Observation 2. A combinational preference could account for the choice patterns in Observation 2 through the additional concern from the ex-post preference. Intuitively, ex-post preference respecting stochastic dominance predicts corner choices, which drives subjects away from choosing interior probabilities. When the coverage shrinks from $(x_1, x_2; 0{,}0)$ to $(x_1, x_2; 0.5x_1, 0.5x_2)$, the incentive of choosing corner probabilities from ex-post preference may decline. Therefore, it is possible to have less choices of $p = 0$ in condition $(x_1, x_2; 0.5x_1, 0.5x_2)$ as in Observation 2. We provide detailed analyses of the proposed behavioral model in Appendix C.

In sum, the overall data are incompatible with certain assumptions in various models, such as stochastic dominance, convexity, and proportional monotonicity. We recognize the possibility of giving up (one of) these assumptions and obtaining a

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[16]Efficiency and inequality aversion alone cannot account for the overall behavior because efficiency constantly predicts the choice of $p = 1$ in all conditions except for $(20{,}0; 0{,}20)$ and $(16{,}4; 4{,}16)$, whereas inequality is minimized along the 45° line. The presence of only efficiency and inequality aversion motives would imply that we should observe more corner choices as we approach the 45° line, which is incompatible with the overall data.

distributional social preference utility function that is compatible with the overall behavior.

5. Conclusion

Building on recent theoretical and experimental works on ex-ante and ex-post social preferences, we provide an experimental setup that enables the systematic exploration of probabilistic social preferences inside the allocation triangle. We reveal evidence against a number of weak assumptions, including stochastic dominance, proportional monotonicity, and convexity. We further propose a combinational preference with a modified Fehr-Schmidt (1999) specification that can capture most of the observed patterns. More generally, our study sheds light on future investigations on probabilistic social preferences, especially on those combining both ex-ante and ex-post concerns.

Appendix A: Supplementary Tables

	Allocation 1		Allocation 2		# p=1	% p=1	# p=0	% p=0	# p=(0,1)	% p=(0,1)	Mean p1	Mean p2
Condition	Self1	Other1	Self2	Other2								
1	20	0	0	20	141	0.90	1	0.01	15	0.10	0.96	0.67
2	16	4	4	16	115	0.73	1	0.01	41	0.26	0.93	0.74
3	0	20	0	0	86	0.55	43	0.27	28	0.18	0.62	0.41
4	4	16	0	0	132	0.84	6	0.04	19	0.12	0.90	0.52
5	16	4	0	0	153	0.97	0	0.00	4	0.03	0.99	0.55
6	20	0	0	0	157	1.00	0	0.00	0	0.00	1.00	0.00
7	0	20	0	10	82	0.52	35	0.22	40	0.25	0.65	0.49
8	4	16	2	8	110	0.70	5	0.03	42	0.27	0.85	0.56
9	16	4	8	2	138	0.88	1	0.01	18	0.11	0.97	0.76
10	20	0	10	0	145	0.92	1	0.01	11	0.07	0.98	0.74
11	10	10	0	0	152	0.97	0	0.00	5	0.03	0.99	0.66

Table A1. Summary Statistics. Columns 6 and 7 summarize the number of counts and percentage of choosing probability 1 for allocation 1. Columns 8 and 9 summarize the number of counts and percentage of choosing probability 0 for allocation 1. Columns 10 and 11 summarize the number of counts and percentage of choosing interior probability for allocation 1. Column 12 summarizes mean probability to implement the Allocation 1, and Column 13 summarizes mean probability for interior probabilities to implement the Allocation 1.

Condition	Self1	Other1	Self2	Other2	1	2	3	4	5	6	7	8	9	10
1	20	0	0	20										
2	16	4	4	16	0.001									
3	0	20	0	0	0.033	0.076								
4	4	16	0	0	0.468	0.002	0.155							
5	16	4	0	0	0.009	0.000	0.000	0.001						
6	20	0	0	0	0.001	0.000	0.000	0.000	0.044					
7	0	20	0	10	0.001	0.897	0.100	0.002	0.000	0.000				
8	4	16	2	8	0.001	0.898	0.058	0.001	0.000	0.000	0.797			
9	16	4	8	2	0.581	0.001	0.111	0.861	0.002	0.000	0.001	0.001		
10	20	0	10	0	0.413	0.000	0.004	0.125	0.064	0.001	0.000	0.000	0.172	
11	10	10	0	0	0.021	0.000	0.000	0.003	0.735	0.024	0.000	0.000	0.005	0.124

Table A2. P-values of Proportion Test for Comparing Interior Choice Proportion across Conditions.

Appendix B: Axioms in Saito (2013)

We demonstrate that the two axioms, namely, Quasi-comonotonic Independence and Probability Certainty Independence, imply the monotonicity of the combination preference in p for $\big((x_1, x_2), p; (0,0), (1-p)\big)$. The two axioms are as follows:

Quasi-comonotonic Independence: For all $p \in (0,1]$, and (x_1, x_2), (y_1, y_2), (z_1, z_2) that are pairwise comonotonic, $(x_1, x_2) \succcurlyeq (y_1, y_2)$ iff $p(x_1, x_2) + (1-p)(z_1, z_2) \succcurlyeq p(y_1, y_2) + (1-p)(z_1, z_2)$.

Probability Certainty Independence: For all $p \in (0,1]$, and (x_1, x_2), (y_1, y_2), (z, z), $(x_1, x_2) \succcurlyeq (y_1, y_2)$ iff $\big((x_1, x_2), p; (z, z), (1-p)\big) \succcurlyeq \big((y_1, y_2), p; (z, z), (1-p)\big)$.

Intuitively, the Quasi-comonotonic Independence axiom states that the preference over deterministic allocations satisfies the usual independence axiom separately in the upper and lower triangles, which directly implies that the preference over deterministic allocations is monotonic along straight lines passing 0 because all of the allocations along the line belong to either the upper or lower triangle. When taken together with the Probability Certainty Independence axiom, it would imply the monotonicity of combinational preference. Formally, suppose we have $(x_1, x_2) \succ (0,0)$, Quasi-comonotonic Independence implies $(x_1, x_2) \succ p(x_1, x_2) + (1-p)(0,0)$. By Probability Certainty Independence, we have $\big((x_1, x_2), q; (0,0), (1-q)\big) \succ \Big(\big(p(x_1, x_2) + (1-p)(0,0)\big), q; (0,0), (1-q)\Big)$. As it holds for any p and q, it implies $\big((x_1, x_2), p; (0,0), (1-p)\big) \succ \big((x_1, x_2), q; (0,0), (1-q)\big)$ if $p > q$ for the probabilistic social preference, which in turn predicts corner choices for all of the treatments $\big((x_1, x_2), (0,0)\big)$. The argument in situation $(x_1, x_2) \prec (0,0)$ is similar.

Appendix C: Predictions of the Behavioral Model

Assume the utility function for deterministic allocations takes the following form:

$$x_1 + \gamma(x_1 + x_2) - \alpha(\max\{x_1 - x_2, 0\})^2 - \beta(\max\{x_2 - x_1, 0\})^2,$$

and the combinational utility is a weighted average $\delta * \Phi_{ex-ante} + (1-\delta) * \Phi_{ex-post}$.

For condition $(x_1, x_2; 0,0)$ with $x_1 < x_2$, the utility is

$$\delta * \left(px_1 + \gamma p(x_1 + x_2) - \beta\big(p(x_1 - x_2)\big)^2\right) +$$
$$(1-\delta) * (p * (x_1 + \gamma(x_1 + x_2) - \beta(x_1 - x_2)^2) + (1-p) * 0)$$

and we obtain the following FOC characterizing the optimal choice of p:

$$\delta * (x_1 + \gamma(x_1 + x_2) - 2\beta p(x_1 - x_2)^2) +$$
$$(1-\delta) * (x_1 + \gamma(x_1 + x_2) - \beta(x_1 - x_2)^2) = 0^{\cdot}$$

The optimal solution is $\frac{x_1+\gamma(x_1+x_2)-(1-\delta)*\alpha(x_1-x_2)^2}{2\delta\beta(x_1-x_2)^2} = \frac{x_1+\gamma(x_1+x_2)}{2\delta\beta(x_1-x_2)^2} - \frac{1-\delta}{2\delta}$. The optimal solution for the case $x_1 > x_2$ is similar, with α replacing β in the above expression.

For condition $(x_1, x_2; 0.5x_1, 0.5x_2)$ with $x_1 < x_2$, the utility is as follows:

$$\delta * \left(0.5(1+p)x_1 + 0.5\gamma(1+p)(x_1 + x_2) - \beta\big(0.5(1+p)(x_1 - x_2)\big)^2\right) +$$
$$(1-\delta) * \begin{pmatrix} p * (x_1 + \gamma(x_1 + x_2) - \beta(x_1 - x_2)^2) + \\ (1-p) * \left(0.5x_1 + 0.5\gamma(x_1 + x_2) - \beta\big(0.5(x_1 - x_2)\big)^2\right) \end{pmatrix}$$

and we obtain the following FOC:

$$\delta * (0.5x_1 + 0.5\gamma(x_1 + x_2) - 0.5\beta(1+p)(x_1 - x_2)^2) +$$
$$(1-\delta) * \left(0.5x_1 + 0.5\gamma(x_1 + x_2) - \frac{3}{4}\beta(x_1 - x_2)^2\right) = 0^{\cdot}$$

We obtain the optimal solution $\frac{x_1+\gamma(x_1+x_2)}{\delta\beta(x_1-x_2)^2} - \frac{3+\delta}{4\delta}$. Similarly, we obtain the optimal solution for case $x_1 < x_2$ with α replacing β in the above expression.

The optimal chosen probabilities may lie in the interior or the corner, which depends on parameter values. It is possible to have $\frac{x_1+\gamma(x_1+x_2)}{\delta\beta(x_1-x_2)^2} - \frac{3+\delta}{4\delta} > \frac{x_1+\gamma(x_1+x_2)}{2\delta\beta(x_1-x_2)^2} - \frac{1-\delta}{2\delta}$ given $\frac{x_1+\gamma(x_1+x_2)}{2\beta(x_1-x_2)^2} > \frac{1+3\delta}{4}$. If we have $\frac{x_1+\gamma(x_1+x_2)}{\delta\beta(x_1-x_2)^2} - \frac{3+\delta}{4\delta} > 0 > \frac{x_1+\gamma(x_1+x_2)}{2\delta\beta(x_1-x_2)^2} - \frac{1-\delta}{2\delta}$, a subject chooses $p = 0$ in $(x_1, x_2; 0,0)$ while an interior probability in $(x_1, x_2; 0.5x_1, 0.5x_2)$. Moreover, we have optimal chosen probabilities decreasing from the upper to the lower triangle if $\alpha < \beta$. Thus, this behavioral model could be compatible with the observed behavior.

Appendix D: Experimental Instructions and Decision Sheets

Experimental Instructions

In this decision making experiment, the task involves a pair of participants, **yourself** and **the other participant** in this room. Decisions to make are regarding possible payment for both of you as shown the decision table example below. Note that the numbers here are for illustrative purpose only.

Example 1

Allocation 1		*Allocation 2*	
You	*Other*	*You*	*Other*
7	8	10	0
P:		***1-P:***	

In this decision, there are two allocations: Allocation 1, you get $7 and the other participant gets $8; Allocation 2, you get $10, and the other participant also gets $0. You are asked to choose a probability ***P*** to implement Allocation 1 and ***1-P*** to implement Allocation 2. You can choose any probability including 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.

Example 2

Allocation 1		*Allocation 2*	
You	*Other*	*You*	*Other*
3	5	5	3
P:		***1-P:***	

In this decision, there are two allocations: Allocation 1, you get $3 and the other participant gets $5; Allocation 2, you get $5, and the other participant also gets $3. You are asked to choose a probability ***P*** to implement Allocation 1 and ***1-P*** to implement Allocation 2. You can choose any probability including 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.

You will make a number of choices similar as the examples. There is neither correct nor wrong answer to the tasks, and you choose your preferred probability for each of the decision tables. At the end of the experiment, we will randomly choose one participant to implement one of his or her choices, and match him/her to the other participant in this room.

The probability will be implemented by drawing one card from a set of 10 cards numbered from 1 to 10. If you choose ***P*** to be 0, Allocation 1 will be not implemented and Allocation 2 will be implemented regardless of the card you draw. If you choose ***P*** to be 0.1, Allocation 1 will be implemented if you draw number 1, otherwise Allocation 2 will be implemented. If you choose ***P*** to be 0.2, Allocation 1 will be implemented if you draw number 1 or 2, otherwise Allocation 2 will be implemented. If you choose ***P*** to be 0.3, Allocation 1 will be implemented if you draw number 1, 2, or 3, otherwise Allocation 2 will be implemented. And so on.

Exercise

While calculating payoffs seems easy, it is important that everyone understands. So, below we ask you to calculate the payoffs of both players for some specific examples. After you finish, we will go over the correct answers together.

Exercise 1.

Allocation 1		*Allocation 2*	
You	*Other*	*You*	*Other*
7	8	10	0
P: 0.4		***1-P:*** 0.6	

Suppose the table above is chosen for implementation for you, and you choose 0.4 for Allocation 1 and 0.6 for Allocation 2 for this decision.

At the end of the experiment, a card is randomly drawn from a set of 10 cards numbered from 1 to 10.

If the card drawn is 3, your payment will be ____, and the payment of the other participant will be ____.

If the card drawn is 9, your payment will be ____, and the payment of the other participant will be ____.

Exercise 2.

Allocation 1		*Allocation 2*	
You	*Other*	*You*	*Other*
3	5	5	3
P: 1		***1-P:*** 0	

Suppose the table above is chosen for implementation for you, and you choose 1 for Allocation 1 and 0 for Allocation 2 for this decision.

At the end of the experiment, a card is randomly drawn from a set of 10 cards numbered from 1 to 10.

If the card drawn is 3, your payment will be ____, and the payment of the other participant will be ____.

If the card drawn is 9, your payment will be ____, and the payment of the other participant will be ____.

This is the end of the instruction. Should you have any question, please raise your hand.

Sample Decision Sheet

Allocation 1		*Allocation 2*	
You	*Other*	*You*	*Other*
0	20	0	0
P:		***1-P:***	

[Note: Other decision sheets are presented in a similar manner. The decision sheets are randomly presented to each subject.]

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