5-13-2022

Motives for Cooperation in the One-Shot Prisoner's Dilemma

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13 May 2022

Abstract

We investigate the motives for cooperation in the one-shot Prisoner's Dilemma (PD). A prior study finds that cooperation rates in one-shot PD games can be ranked empirically by the social surplus from cooperation. That study employs symmetric payoffs from cooperation in simultaneous PD games. Hence, in that setting, it is not possible to discern the motives for cooperation since three prominent social welfare criteria, social surplus (efficiency) preferences, Rawlsian maximin preferences, and inequity aversion make the same predictions. In the present paper, we conduct an experiment to identify which of these social preferences best explains differences in cooperation rates and to study the effects of the risk of non-cooperation.

Keywords: Cooperation; Prisoner's Dilemma; Inequity aversion; Social surplus; Social preferences

JEL Classifications: C92, D82, D81, M40

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* We thank Megan Luetje for recruiting experimental participants, and the Economic Science Institute at Chapman University for their financial support. We also thank Jack Stecher, Nat Wilcox, and workshop participants at the Society for the Advancement of Economic Theory, Economic Science Association, and Chapman University for their helpful comments.

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1. Introduction

The prisoner's dilemma is among the most studied strategic interactions in the social sciences. It has found applications in fields as diverse as evolutionary biology (Axelrod and Hamilton, 1981), microeconomics (Mas Colell, Whinston, and Green, 1995), and political science (Rapoport, 1974). It has been used to study cooperative behavior between dyads, firms, and nations, and it holds a central place in game theory for epitomizing the conflict between individual rationality and social welfare.

For players with social preferences, the prisoner's dilemma presents a risk-reward tradeoff: Cooperating, especially in one-shot anonymous interactions, is inherently risky, and players may trade off the expected payoff from cooperating against the risk that the other player does not cooperate. As we consider behavior in both simultaneous and sequential prisoner dilemma games, we can observe if a risk-reward tradeoff, characteristic of many decisions in finance, extends to social preferences in games like the prisoner's dilemma by observing whether the mere presence of the risk that the other player defects reduces cooperation.

The prisoner's dilemma itself arises in various contexts related to finance. As one prominent example, Kyle and Wang (1997) consider a game of delegated fund management between two competing funds. In their model, fund managers have either rational beliefs or are overconfident (in the sense of having excessively tight distributions of the private signals that they receive). They find that "For some parameter specifications, there exists a unique Prisoner's Dilemma Nash equilibrium, in which both funds hire overconfident managers and yet both make lower expected profits than if they hire rational managers" (p. 2074).

Aggarwal and Samwick (1999) investigate the role of performance-based incentives in compensation contracts for managers. They observe that "The use of contracts based on own- and rival-firm performance creates the usual Prisoner's Dilemma among Cournot competitors" (p. 2012).

Glode et al. (2012) model financial expertise as an arms race. They comment, "why do we see financial firms, whose major business is to intermediate and facilitate trading, investing vast resources in expertise that speeds and improves their ability to acquire and process information about the assets they trade? In our model, the acquisition of expertise becomes a prisoner's dilemma" (p. 1726). In the context of the preceding examples, cooperation and the specific motive for cooperation might be very important. Managers who can work cooperatively with their competitors might escape the prisoner's dilemma under certain conditions. These conditions can, in turn depend on whether managers have conditional efficiency preferences (aiming to maximize the surplus of both firms) or whether they have inequity-averse preferences (aiming to minimize the differences in their profits).

The motive underlying cooperation is often unknown. The broad theoretical and empirical literature on the prisoner's dilemma has focused on explaining how cooperation can emerge and be sustained. This literature has provided an explanation for why people cooperate in infinitely repeated games (via the folk theorem) or games in which players can build reputations or when players care about reciprocity (Dufwenberg & Kirchsteiger, 2004; Smith & Wilson, 2017). However, many social interactions occur only once or are anonymous. People often cooperate in such situations (e.g., tipping at a restaurant in a foreign city, tossing coins into a pauper's violin case, paying a voluntary contribution when visiting a museum with free admission). Despite the large literature on the prisoner's dilemma, it has not been clear why people often cooperate if the game is played only once. Indeed, in such cases, there is no consensus on the primary motive driving cooperation.

Three prominent motives for cooperation in the one-shot anonymous prisoner's dilemma are based on models of social preferences: i) a utilitarian concern for efficiency (maximizing players' total surplus), ii) an egalitarian concern for equal outcomes (minimizing the differences in payoffs between players), and iii) a Rawlsian concern (Rawls, 1971; Charness and Rabin, 2002) for aiding the person who is 'worst off' (maximizing the minimum payoff across players).

Recently, Charness et al. (2016) have observed that social surplus from mutual cooperation increases cooperation in the one-shot prisoner's dilemma. However, in their experiment, the payoffs from mutual cooperation were always symmetric. Thus, it is unclear if cooperation is due primarily to efficiency concerns based on social surplus or to the equity of payoffs from cooperation or to a Rawlsian type of maximin welfare criterion. Each of these motives for cooperation makes the same predictions in the experiment by Charness et al. (2016).

In the present paper, we investigate the motives for cooperation in the one-shot prisoner's dilemma. In particular, we conduct an experiment that enables us to distinguish between the predictions of three welfare criteria: (conditional) efficiency preferences, inequity aversion, and Rawlsian maximin preferences. The experiment employs three settings for measuring social preferences: A dictator game, a one-shot simultaneous prisoner's dilemma game and a one-shot sequential prisoner's dilemma game. Our primary research questions are:

(i) Are social preferences consistent across different elicitation procedures (in particular, across different social environments)?
(ii) Can the prisoner's dilemma be effectively used to elicit and test different models of social preferences?
(iii) What are the predominant motives underlying cooperation in the one-shot prisoner's dilemma?

In a review of social preference experiments, Cooper and Kagel (2014) take a 'second look' at dictator games (games in which one player decides how much of an endowment to give to an anonymous recipient). They note that an advantage of the dictator game is that it eliminates a role for reciprocity or strategic uncertainty to influence behavior. However, they also review evidence suggesting that dictator games are sensitive to demand effects (with subjects feeling that the experimenter expects them to give away *some* money). Moreover, the dictator game does not involve a non-trivial decision for both players and it may not be characteristic of many real-world social interactions. As Dhami (2016) writes, "Despite its popularity, the dictator game might not be a particularly good game to test alternative theories that require even a modicum of strategic interaction." This observation further motivates our interest in measuring social preferences in a setting where both players make non-trivial decisions.

We also consider how cooperation differs between simultaneous and sequential prisoner's dilemma games to isolate the effect of risk on cooperation. Charness et al. (2016) employ only a simultaneous prisoner's dilemma. Miettinen et al. (2020) employ only a sequential prisoner's dilemma. Classical game-theoretic analysis based on purely selfish preferences and models based on inequity aversion, efficiency preferences, or Rawlsian preferences each predict no difference between simultaneous and sequential prisoner's dilemma games as they do not account for the strategic risk that the other player might not cooperate.

In our experiment, we employed both simultaneous and sequential prisoner dilemma games in a within-subject design in which we elicited participants' beliefs about others' strategies. We thereby moved beyond the standard dictator game format to investigate social preferences in a game where both participants have non-trivial decisions to make that affect their joint welfare.

We implemented six different prisoner dilemma games with the structures shown in Figure 1. Four of the games shown in Panel A have symmetric payoff structures for mutual cooperation: For games 1 through 4 the payoff pair (x, y) for the row and column players, respectively, was (3,3), (6,6), (4,4), and (4,6), respectively. For games 5 and 6 shown in panel B, we scale up all payoffs and pair (*x,y*) was (20,20) and (20,30), respectively. Throughout the paper, we will refer to the six games with unique values of x, y as $G(x, y)$.

	Cooperate (C)	Defect (D)
Cooperate (C)	x, y	1,7
Defect (D)	7,1	2,2

Panel A: The Base Prisoner's Dilemma

	Cooperate (C)	Defect (D)
Cooperate (C)	x, y	5,35
Defect (D)	35,5	10,10

Panel B: The Scaled-Up Prisoner's Dilemma

Figure 1: Prisoner Dilemma Games

All participants played all six games in four scenarios: (i) both participants in a pair move simultaneously, (ii) the participant was the first-mover where their partner sees the choice before choosing, (iii) the participant chose contingent on the partner having cooperated, and (iv) the participant chose contingent on the partner having defected.

Our results suggest that the one-shot prisoner's dilemma provides a simple and natural setting for eliciting social preferences. While we find that cooperation is greater in $G(6,6)$ than in $G(4,4)$ than in $G(3,3)$, preferences for social surplus cannot explain the observed results when payoffs are asymmetric. For example, cooperation rates are significantly higher for the row player in game $G(4,4)$ than in game $G(4,6)$, as predicted by inequity aversion and contrary to efficiency and Rawlsian preferences. We also observe very similar cooperation rates (34.7% versus 36%) for the column player in $G(4,4)$ versus $G(4,6)$. This finding is also consistent with inequity aversion in which the column player trades off a lower payoff in $G(4,4)$ relative to $G(4,6)$ for lower inequality in $G(4,4)$. The findings for the simultaneous 'scaled' up games are also more consistent with inequity aversion than with efficiency or Rawlsian preferences since the cooperation rates are nominally higher for the 'equitable' game than for the efficient game, although the differences are not always significant.

In the sequential prisoner's dilemma, given the first-mover has cooperated, cooperation rates are significantly higher for the column player in $G(4,6)$ than in game $G(4,4)$. This behavior also holds for the scaled-up game, and is consistent with all social preferences we consider except for purely selfish preferences. For the row player there is slightly higher (but non-significant) cooperation for the 'equitable' game for both the basic and the scaled-up payoffs.

The first mover consistently cooperated more in the symmetric payoff games such as $G(4{,}4)$ than in asymmetric games such as $G(4{,}6)$ that had the same payoff. This observation also holds for the scaled-up games where the first mover cooperated more in $G(20{,}20)$ than in $G(20{,}30)$. Thus, behavior in the simultaneous game and in the first mover and second-mover roles of the sequential game appears to be most consistent with an inequity aversion motive.

Our experiment suggests that it is inequality from mutual cooperation rather than social surplus from mutual cooperation that is the primary driver of cooperation in the one-shot prisoner's dilemma (at least in a simultaneous move game). In particular, the participants earning larger asymmetric payoffs behave as if maximizing efficiency, while participants earning smaller asymmetric payoffs behave as if holding inequity concerns. Social preferences are consistent across two important elicitation formats: in dictator games--via the social value orientation, and in the prisoner dilemma game. Beliefs are correlated with social preferences.

2. Background and Hypotheses

2.1. Background

While many studies have investigated cooperation in the prisoner's dilemma, few have conducted both a simultaneous and a sequential prisoner's dilemma game. A notable exception is the experimental paper by Ahn et al. (2007) which investigates both a simultaneous and a sequential prisoner's dilemma game within subjects. For each of their three payoff matrices, they find that second-movers are more likely to cooperate conditionally on first-mover cooperation than they are to cooperate in the corresponding simultaneous-move game. However, the experiment by Ahn et al. (2007) does not vary the total surplus from cooperation, a central feature of the Charness et al. (2016) study and of our own experiment. Moreover, they do not investigate different motives for cooperation in their experiment. In the design of Ahn et al. (2016), each subject participated in a single simultaneous move game and a single sequential move game (in each of the roles of first-mover, second-mover conditional on first-mover cooperation, and second-mover conditional on first-mover defection). Our design enables us to observe behavior within subjects across six simultaneous games and six equivalent sequential games by providing feedback only after all decisions from all games had been submitted.

Capraro et al. (2014) study a one-shot public goods game and find evidence of simple allocation heuristics used by study participants such as allocating 50% of one's endowment to the public good. Yamakawa et al. (2016) study repeated public goods games and find evidence of strategic motives for cooperation. Dreber et al. (2014) similarly find evidence of strategic (payoff-maximizing) motives for cooperation in repeated games. By studying the one-shot prisoner's dilemma, our experiment avoids continuous strategies (which rules out simple allocation heuristics or focal points such as allocating 50%). In addition, our experiment rules out strategic motives for cooperation that can exist in repeated games. Instead, we use the prisoner's dilemma as a device to estimate and evaluate models of social preferences. Other motives such as reputation and reciprocity have been proposed to explain cooperation in repeated or non-anonymous interactions, but such motives have no bite in the simultaneous one-shot anonymous prisoner's dilemma.

In our experiment, the simultaneous game does not involve reciprocity, but it does involve strategic uncertainty. We can control for strategic uncertainty by also eliciting players' probabilistic beliefs about the likelihood the player they are matched with will cooperate. The sequential game does not involve strategic uncertainty for the second-mover as the second-mover knows the decision of the first-mover. However, it might involve a concern for reciprocity if the second-mover views cooperation as a means of reciprocating a first-mover's decision to cooperate.

Participants provide responses to a series of games before receiving any feedback and are paid for only one game, providing an information environment and incentives characteristic of a one-shot anonymous interaction. Our study considers a series of dictator games, a simultaneous and a sequential Prisoner's Dilemma and employs an incentive-compatible method for eliciting beliefs in the simultaneous games. Charness et al. (2016) do not conduct a dictator game nor do they conduct a sequential prisoner's dilemma. Miettinen et al. (2020) do not conduct a dictator game nor do they conduct a simultaneous prisoner's dilemma. To our knowledge, our study is the first to conduct all three types of games and we do so in a within-subject design.

Our approach also adds to the literature on the measurement of social preferences in strategic interactions. For instance, equity and efficiency have been studied in 'dictator games' although dictator games have been critiqued as not being characteristic of 'real-world' social interactions and for not providing *both* players with a non-trivial decision that affects both of their payoffs. In contrast, the prisoner's dilemma provides both players with a non-trivial trade-off between material self-interest and the prospect of mutual cooperation, and thus the prisoner's dilemma is thought to be characteristic of many real-world strategic interactions. Like the dictator game, the prisoner's dilemma still retains the feature of having a dominant strategy of defection for purely selfish agents.

2.2. Hypotheses

Cooperation in social dilemmas can emerge for many different reasons. For infinitely repeated games, the folk theorem establishes that cooperation can be supported as equilibrium for purely self-interested agents. When games are repeated, a player's reputation or a norm of reciprocity may also help to induce cooperation. However, neither pure self-interest (in the sense of maximizing only one's own payoff), nor reputation can explain cooperation in anonymous one-shot games. That cooperation often does seem to emerge in such settings is thus a puzzle for classical game theory.

Charness et al. (2016) study cooperation in anonymous one-shot prisoner dilemmas and finds evidence that 'social surplus from cooperation' explains systematic cooperation and defection. To illustrate their findings, consider the 2x2 game in Panel A of Figure 1 where $x = y$. The row player (Player 1) chooses between cooperating (choosing 'top') or defecting (choosing 'bottom'), while the column player (Player 2) chooses between cooperating (choosing 'left') or defecting (choosing 'right'). Charness et al. (2016) use values $x \in \{3,4,5,6\}$ and find that cooperation increases as x increases from approximately 23% when $x = 3$ to 60% when $x = 6$. Since the social surplus $(x + y)$ increases as x increases, Charness at al. conclude that it is social surplus *from cooperation* that drives cooperation in the (anonymous, one-shot) prisoner's dilemma.

The explanation suggests a 'conditional efficiency' motive: players care about maximizing the social surplus when the other player cooperates. Yet while an explanation for cooperation based on efficiency can explain the experimental findings, the findings can also be explained by other prominent models of social preferences such as inequity aversion (Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000) or by a Rawlsian preference for helping the person who is worst off (Rawls 1971, Charness and Rabin, 2000). Since $x = y$ in symmetric games, there is no inequity that arises when both players cooperate, nor is any player worse off than the other under mutual cooperation. This observation leads to a fundamental question: Which motive best explains cooperation in the one-shot prisoner's dilemma?

For prisoner's dilemma games that differ only in the payoffs from mutual cooperation, the Charness et al. (2016) explanation for ranking cooperation rates across games nicely summarizes observed behavior. However, it is not clear whether it continues to hold when there are payoff asymmetries from mutual cooperation. One alternative approach to ranking cooperation rates is the following: suppose agents consider both their own monetary payoff from cooperation as well as the risk of cooperating. The risk of cooperating can be parameterized as the probability that the other player does not cooperate. It seems plausible that the risk from cooperation increases as the difference in payoffs, $|x - y|$, increases. This could reflect a belief that others are less likely to cooperate if cooperation leads to an inequitable outcome, or it may reflect the possibility that symmetric payoffs from cooperation serve as a focal point for coordinating on the cooperative outcome.

We consider rankings of the predicted cooperation rates due to three prominent motives for cooperation: a 'conditional' efficiency motive, inequity aversion, and Rawls' maximin criterion. We employ games of the form in Figure 1, where it is not necessarily the case that payoffs are symmetric. Our comparisons are implementations of the game in Figure 1 in which $(x, y) = (3,3)$, $(4,4)$, $(4,6)$, and $(6,6)$. The three games with symmetric payoffs from mutual cooperation can be used as a test to replicate the Charness et al. (2016) results. Our primary interest is in comparing the games involving payoffs of \$4 or \$6.

Formally, we consider four parameterized preference models in addition to the non-parametric approach to ranking cooperative outcomes in our predictions. Imagine there are player types who behave according to a utility function that is affected by the decision maker's payoff x and potentially the other's payoff y:

1. **Strictly Selfish Preferences:** $U(x, y) = x$
2. **Conditional Efficiency Preferences:** $U(x, y) = (1 - \rho)x + \rho(x + y)$, where $\rho \in [0,1]$ if the other is believed to cooperate and $\rho = 0$ if the other is believed to defect.
3. **Inequity Aversion:** $U(x, y) = (1 - \alpha)x - \alpha\,|x - y|$, where $\alpha \in [0,1]$
4. **Rawlsian Maximin Preferences:** $U(x, y) = (1 - \theta)x + \theta Min(x, y)$, where $\theta \in [0,1]$

The strictly selfish model is parameter-free while the three social preference models are specified to each have a single parameter that is in the unit interval. The parameter in each model has a natural interpretation. For inequity aversion (with inequity indexed by the absolute difference in payoffs $|x - y|$), the single parameter α ranges from strictly selfish preferences ($\alpha = 0$) to caring only about inequity ($\alpha = 1$). For conditional efficiency preferences (based on the sum of payoffs $x + y$), the single parameter ρ ranges from strictly selfish preferences ($\rho = 0$) to caring only about maximizing social surplus ($\rho = 1$) when the other player is believed to cooperate. For Rawlsian maximin preferences, which is based on maximizing the minimum payoff, $\min(x, y)$, the single parameter θ ranges from strictly selfish preferences ($\theta = 0$) to caring only about maximizing the minimum payoff of either player ($\theta = 1$).

2.3. Predictions Based on Type

We predict ordinal cooperation rates (i.e., the ranking of cooperation rates) across games. Let $C(a, b)$ denote the average cooperation rate of players earning a from mutual cooperation (where the other player earns b from cooperating, holding the remaining payoffs constant across games). For the game in Figure 1 with cooperation rate $C(4,6)$, we have $a = 4$, $b = 6$ for the row player in game $G(4,6)$, whereas $a = 6, b = 4$ for the column player in that game (with analogous notation for game $G(20,30)$). In all other games, $a = b$. We return to Figure 1 to consider how our games might help to distinguish among the three prominent motives for cooperation that we study.[3] In particular, for players who earn a from cooperating in a game with cooperation rate $C(a, b)$, the falsifiable implications of preference models 2, 3, and 4, above, are as follows:

For conditional efficiency preferences, for *any* $\rho \in (0,1)$, we have the unambiguous prediction that (1) holds if players believe the other player will cooperate:

(1) Conditional Efficiency: $C(6,6) > C(6,4) > C(4,6) > C(4,4)$

Under conditional efficiency preferences, each inequality in (1) is predicted to be strict, and so the difference in cooperation rates should be statistically significant in each case. The inequalities in (1) hold since for cooperation rates $C(6,6)$ and $C(6,4)$, we have $a = 6$ from cooperating in both games but the surplus $a + b$ is larger in game $G(6,6)$. For cooperation rates $C(6,4)$ and $C(4,6)$, we have $a + b = 10$ in both games but a is larger in $G(6,4)$. For cooperation rates $C(4,6)$ and $C(4,4)$, we have $a = 4$ in both games but $a + b$ is larger in game $G(4,6)$.

For players with inequity-averse preferences, for *any* $\alpha \in (0,1)$, we have the unambiguous prediction that (2) holds:

(2) Inequity Aversion: $C(6,6) > C(6,4)$, $C(4,4) > C(4,6)$

The inequalities in (2) hold since for cooperation rates $C(6,6)$ and $C(6,4)$, we have $a = 6$ from cooperating in both games but inequity, $|a - b|$, is smaller in game $G(6,6)$. For cooperation rates $C(4,4)$ and $C(4,6)$, we have $a = 4$ from cooperating in both games but $|a - b|$ is smaller in game $G(4,4)$.

[3] The following strict rankings of cooperation rates implicitly assume that the distribution of social preference parameters is such that *at least one player* in the sample has parameter values that imply $U(6,6) > U(6,4)$ (for conditional efficiency, Rawlsian, and inequity-averse preferences) and that at least one player in the sample has parameter values such that $U(4,4) > U(6,4)$ for inequity aversion.

Note that we cannot unambiguously compare the cases of the column player in $G(6,4)$ versus $G(4,4)$ since the former has a higher personal payoff but the latter has lower inequity. This comparison will thus depend on the parameter value for α.

For players with Rawlsian maximin preferences, for *any* $\theta \in (0,1)$, we have the unambiguous prediction that (3) holds:

(3) Rawlsian Preferences: $C(6,6) > C(6,4) > C(4,4) = C(4,6)$

The inequalities in (3) hold since for cooperation rates $C(6,6)$ and $C(6,4)$, we have $a = 6$ from cooperating in both games but the lowest payoff from cooperating is smaller in game $G(6,4)$. For cooperation rates $C(6,4)$ and $C(4,4)$, the lowest payoff from cooperating is 4 in both games, but a is larger in game $G(6,4)$. For cooperation rates $C(4,4)$ and $C(4,6)$, the lowest payoff from cooperating is 4 in both games and $a = 4$ in both games.

Note that the predictions in (1), (2), and (3) diverge for the comparison between the games $G(4,4)$ and $G(4,6)$. We highlight below the key predictions:

Summary of Hypotheses:

Cooperation of row players

H1a: Conditional efficiency	$C(4,6) > C(4,4)$ for any $\rho \in (0,1)$
H1b: Inequity aversion	$C(4,6) < C(4,4)$ for any $\alpha \in (0,1)$
H1c: Rawlsian preferences:	$C(4,6) = C(4,4)$ for any $\theta \in (0,1)$

Cooperation of column players

H2a: All three models	$C(6,6) > C(6,4)$ for any $\rho, \alpha, \theta \in (0,1)$
H2b: Conditional efficiency and Rawlsian preferences	$C(6,4) > C(4,4)$

Cooperation of both players

H2c: All three models	$C(6,6) > C(4,4) > C(3,3)$ for any $\rho, \alpha, \theta \in (0,1)$

From the above testable hypotheses, failure of H1a would falsify the explanation based on conditional efficiency preferences, failure of H1b falsifies the explanation based on inequity aversion, failure of H1c falsifies the explanation based on Rawlsian preferences. Failure of H2a or H2b would falsify all three motives for cooperation. Failure of H2d would falsify conditional efficiency and Rawlsian preferences but does not necessarily falsify the explanation based on inequity aversion.

The comparison between the games $G(4,6)$ and $G(4,4)$ can thus distinguish between the predictions of conditional efficiency, inequity aversion, and Rawlsian maximin preferences.

In addition, we can test whether the strategic risk of noncooperation might play a role in the sequential one-shot prisoner's dilemma by investigating the following hypothesis:

H3: $C(x,y)$ is greater for the second-mover conditional on first-mover cooperation than for the equivalent simultaneous move game.

In our experiment, we have two additional predictions. First, our approach suggests the possibility of using the prisoner's dilemma game as a legitimate measure of social preferences. The common approach based on the dictator game or social value orientation has the limitation that both players do not face a non-trivial strategic decision. Our methodology enables us to estimate models of social preferences (including the three models described above) directly from choices in the prisoner's dilemma. We also include a dictator game in the form of a social value orientation task at the end of our experiment and offer the following hypothesis:

> **H4a**: Cooperation in the prisoner's dilemma games will be positively correlated with pro-social behavior in the social value orientation task.
>
> Finally, we entertain a hypothesis regarding players' beliefs:
>
> **H4b**: A player's beliefs about the likelihood the other player will cooperate in the prisoner's dilemma games will be positively correlated with the player's own pro-social behavior in the social value orientation task.

For H4b, one might not think that beliefs about cooperation in the prisoner's dilemma will matter for giving in the dictator game. However, such a correlation seems at least plausible if social preferences and beliefs are not independent. In a world where people with pro-social preferences think others are pro-social, and people with purely self-interested preferences think others are purely self-interested, such a correlation would be predicted.

3. Methods

One hundred and fifty undergraduate students at a private California university participated in the experiment with either 12 or 14 participants per session. Each participant was seated in a cubicle with a computer and could not see the screens or faces of the other participants. Participants were read the instructions out loud and followed along with their own printed copy of the instructions (see Appendix 8.1). These instructions are included in the supplementary material. After proceeding through the instructions, participants participated in the four main parts of the experiment and were subsequently paid their earnings in cash prior to leaving the lab. The average amount earned per participant was $22.44 including a $7 participation payment. Sessions lasted less than one hour.

In Part I, participants were each randomly and anonymously matched with another participant in the room and made choices in six prisoner's dilemma games simultaneously (without knowing the other player's actions). These games were displayed to participants as shown in Figure 2, in which each participant chooses either Top (T) or Bottom (B). That choice is described as Left (L) or Right (R) for the randomly matched partner. In Figure 2, four of the six payoff matrices are symmetric, while two of the payoff matrices (Table 4 and Table 6) had asymmetric payoffs from mutual cooperation. Half of the participants were randomly assigned the version shown in Figure 2 (and so received the larger payoff from mutual cooperation in Tables 4 and 6), while half of the participants were randomly assigned another version of the same payoff tables in Figure 2 where the payoffs of mutual cooperation for the asymmetric games were reversed.[4]

Table 1	L	R
T	**You: 3** , Other 3	**You: 1**, Other 7
B	**You: 7** , Other 1	**You: 2** , Other 2
	Choose T or B	

Table 3	L	R
T	**You: 4** , Other 4	**You: 1**, Other 7
B	**You: 7** , Other 1	**You: 2** , Other 2
	Choose T or B	

Table 5	L	R
T	**You: 20** , Other 20	**You: 5**, Other 35
B	**You: 35** , Other 5	**You: 10** , Other 10
	Choose T or B	

Table 2	L	R
T	**You: 6** , Other 6	**You: 1**, Other 7
B	**You: 7** , Other 1	**You: 2** , Other 2
	Choose T or B	

Table 4	L	R
T	**You: 6** , Other 4	**You: 1**, Other 7
B	**You: 7** , Other 1	**You: 2** , Other 2
	Choose T or B	

Table 6	L	R
T	**You: 30** , Other 20	**You: 5**, Other 35
B	**You: 35** , Other 5	**You: 10** , Other 10
	Choose T or B	

Figure 2: The Six Payoff Tables from the Experiment

After submitting their choices for the simultaneous games, but before receiving feedback, each participant was asked to guess, for each payoff table, how many of the students in the room with the other version of the tables chose L. For instance, in sessions with 14 participants, the participants were asked to guess how many of the 7 students they could be matched with chose L. For each participant, one of the six guesses made by that participant was randomly selected by the computer, with each guess being equally likely to be selected. If a participant correctly guessed the number of others that chose L in the selected pair, that participant received an additional $5.[5]

In Part II of the experiment, participants were each randomly and anonymously matched with another participant in the room and each participant made choices in the same six games from Part I, but now as the first-mover (knowing that the other player's actions would be taken after learning the first-mover's actions), and in the same six games as the second-mover (after knowing the action of the other player). Feedback was not provided until all participants made choices in

[4] An alternative design choice would be to present each of the six games one at a time instead of presenting all six games at one time. There are tradeoffs in this presentation choice: sequential choices can introduce unanticipated order effects, while simultaneous choices may cause players to consider differences in games otherwise unnoticed. Given that all six games were explicitly showed in the instructions before participants made choices, we opted to show all games at once.

[5] We solicit beliefs after choices were made to avoid affecting cooperation. Other studies examining the prisoner's dilemma game find that participants were significantly less likely to cooperate in a prisoner's dilemma game where their beliefs about what others would do were first elicited than never elicited (Croson 2000). In the next part of our experiment, participants made choices conditional on knowing their partner moved first and cooperated or knowing their partner moved first and defected, which theoretically is independent of beliefs about their partner's cooperation.

all 18 games (six simultaneous games, six sequential games as the first-mover, and six sequential games as the second-mover). By not providing feedback until all choices were submitted and by randomly and anonymously matching participants, our setup enabled us to conduct the experiment within participants while preserving the essential properties of a one-shot anonymous interaction.

In Part III of the experiment, participants allocated money between themselves and another randomly, anonymously matched participant in the room in a standard version of the social value orientation (SVO) task which essentially involves a series of 15 dictator games (Crosetto, Weisel, & Winter, 2012). In each dictator game, participants choose from a set of 9 possible allocations of money between themselves and the person they are paired with. Part III enables us to compare social preferences from the prisoner's dilemma game to a more conventional tool for measuring social preferences. After making all 15 decisions, one of the participants in each pair is randomly selected to be the 'decider' and one of the decider's 15 allocation decisions is randomly selected to be implemented. The selection of the decider and the selection of the allocation decision to be implemented do not depend on the participants' choices.

In Part IV of the experiment, participants responded to a new version of the cognitive reflection test (Thomson and Oppenheimer, 2016) and provided responses to a short demographic survey asking their age, gender, and political affiliation.[6]

The experiment was programmed in z-Tree (Fischbacher, 2007). To determine payouts, each participant was randomly matched with another participant in the room for each block of six games, of which one game would be randomly selected for payment. Participants were paid for the outcome of one randomly selected simultaneous game or for one randomly selected sequential move game. There was a 50% chance that the simultaneous move game was selected for the pair and a 50% chance that the sequential move game was selected for the pair for payment. If the simultaneous move game was selected for payment, each of the six games was equally likely to be selected for payment. If the sequential move game was selected for payment, there was a 50% chance that a given participant within each pair was selected as the first-mover and the other person in the pair was the second-mover and a 50% chance that the participant was selected as the second-mover and the other person in the pair was the first-mover. If the sequential move game was selected for payment, each of the six games was equally likely to be selected for payment.

[6] A new version of the cognitive reflection test (CRT) was used because the original version of Frederick (2005) and the more recent extension of Toplak et al. (2014) have been used in other experiments at the laboratories and may be familiar to the participants in the subject pool.

4. Findings

4.1. Overall statistics

Table 1 Findings in Prisoner Games

Panel A: Cooperation Rates Across All Games

	Games					
Simultaneous Game	$G(3,3)$	$G(6,6)$	$G(4,4)$	$G(4,6)$	$G(20,20)$	$G(20,30)$
Row Players with Smaller Asymmetric Payoffs	0.307	0.493	0.373	0.240	0.307	0.280
	(0.054)	(0.058)	(0.056)	(0.05)	(0.054)	(0.052)
Column Players with Larger Asymmetric Payoffs	0.267	0.507	0.347	0.360	0.293	0.227
	(0.051)	(0.058)	(0.055)	(0.056)	(0.053)	(0.049)
Sequential Game (First-mover)						
Row Players with Smaller Asymmetric Payoffs	0.387	0.493	0.453	0.373	0.400	0.360
	(0.057)	(0.058)	(0.058)	(0.056)	(0.057)	(0.056)
Column Players with Larger Asymmetric Payoffs	0.293	0.547	0.453	0.373	0.387	0.293
	(0.053)	(0.058)	(0.058)	(0.056)	(0.057)	(0.053)
Sequential Game (After First-mover Cooperates)						
Row Players with Smaller Asymmetric Payoffs	0.333	0.573	0.373	0.347	0.360	0.293
	(0.055)	(0.057)	(0.056)	(0.055)	(0.056)	(0.053)
Column Players with Larger Asymmetric Payoffs	0.267	0.573	0.400	0.573	0.373	0.573
	(0.051)	(0.057)	(0.057)	(0.057)	(0.056)	(0.057)
Sequential Game (After First-mover Defects)						
Row Players with Smaller Asymmetric Payoffs	0.040	0.013	0.013	0.053	0.027	0.027
	(0.023)	(0.013)	(0.013)	(0.026)	(0.019)	(0.019)
Column Players with Larger Asymmetric Payoffs	0.080	0.067	0.080	0.067	0.027	0.027
	(0.032)	(0.029)	(0.032)	(0.029)	(0.019)	(0.019)

Note: Mean (standard error of mean) cooperation rate reported. Each cell has 75 observations.

Panel B: Beliefs in Simultaneous Game

	0.517	0.498	0.507	0.479	0.593	0.583
Row players beliefs of column players	(0.040)	(0.040)	(0.040)	(0.038)	(0.042)	(0.039)
	0.527	0.598	0.583	0.518	0.622	0.597
Column players beliefs of row players	(0.044)	(0.045)	(0.043)	(0.044)	(0.044)	(0.045)

Note: Mean (standard error of mean) belief reported. Each cell 75 observations.

4.2. Analysis of behavior in simultaneous games

We start with the cooperation rate of the row player in the simultaneous versions of $G(4,6)$ versus $G(4,4)$, where the personal payoff is 4. The cooperation rate for the asymmetric game is 24.0%, while for the symmetric game it is 37.3%. The cooperation for the symmetric game is significantly greater (Wilcoxon signed-rank test: Z = 2.67, p < .01). This difference is only consistent with inequity aversion preferences. We reject H1a and H1c but fail to reject H1b.

We compare the cooperation rate of the column player in the simultaneous versions of $G(6{,}6)$ versus $G(4{,}6)$ where the personal payoff is 6 in both games, and in $G(4{,}6)$ versus $G(4{,}4)$, where the personal payoff differs by 2. The cooperation rate for $G(6{,}6)$ was 50.7% and for $G(4{,}6)$ was 36.0%. The cooperation for the symmetric game is significantly greater (Wilcoxon signed-rank test: Z = 2.52, p = .012). The cooperation rate for $G(4{,}4)$ was 34.7% and for $G(4{,}6)$ was 36.0%, and the difference is insignificant. These results are only consistent with inequity aversion. We reject H2b but fail to reject H2a.

When we compare the cooperation rates of $G(3{,}3)$, $G(4{,}4)$ and $G(6{,}6)$, we find the rates are 30.7%, 37.3%, 49.3% for the row player, and 26.7%, 34.7%, 50.7% for the column player. The increasing differences are significant for both the row player (Friedman test: $Q(2) = 15.26, p < .01$) and the column player (Friedman test: $Q(2) = 20.33, p < .01$). These results are consistent with Charness et al. (2016): if we look only at the symmetric games, then the increase in cooperation is consistent with conditional efficiency, but also with inequity inversion and Rawlsian preferences. We fail to reject H2c.

4.3. Analysis of behavior in simultaneous versus sequential games

H3 predicts that cooperation rates will be greater for the second-mover in the sequential version of a game where the first-mover is hypothetically observed cooperating than in the simultaneous version of the game. We plot the average difference in cooperation between the simultaneous and sequential games in Figure 3. In all games, the average cooperation was weakly larger for the second-mover in the sequential games. The summed differences per participant were significantly larger than zero (Wilcoxon: $Z = 2.61, p < .01$).

In the simultaneous games, holding one player's payoff constant, we have seen that cooperation decreases when the payoff for the other player decreases. The other player seems to anticipate this decrease as reflected in their beliefs. For example, the row player's cooperation in $G(4{,}4)$ (37.3%) is greater than in $G(4{,}6)$ (24%) and the column player's belief about the row player significantly decreases from 58.3% to 51.8% for those games, respectively (Wilcoxon: $Z = 3.42, p < .01$). The row player's cooperation in scaled-up versions $G(20{,}20)$ and $G(20{,}30)$ slightly decreases from 30.7% to 28%, and the column player's beliefs of the row player insignificantly decrease from 62.2% to 59.7% for those games, respectively. The column player's cooperation in $G(6{,}6)$ is greater than in $G(4{,}6)$, and the row player's beliefs of the column player marginally decrease from 50.7% to 47.9%, respectively (Wilcoxon: $Z = 1.89, p = .058$). These results are consistent with players in the simultaneous games desiring to cooperate but cognizant of the strategic risk of noncooperation increasing when payoffs are asymmetric. While not predicted this suggests that cooperation is an increasing function of the expected payoff from cooperating but decreasing in strategic risk. Not only do players exhibit choices consistent with inequity aversion, but their beliefs are also consistent with others being inequity averse.

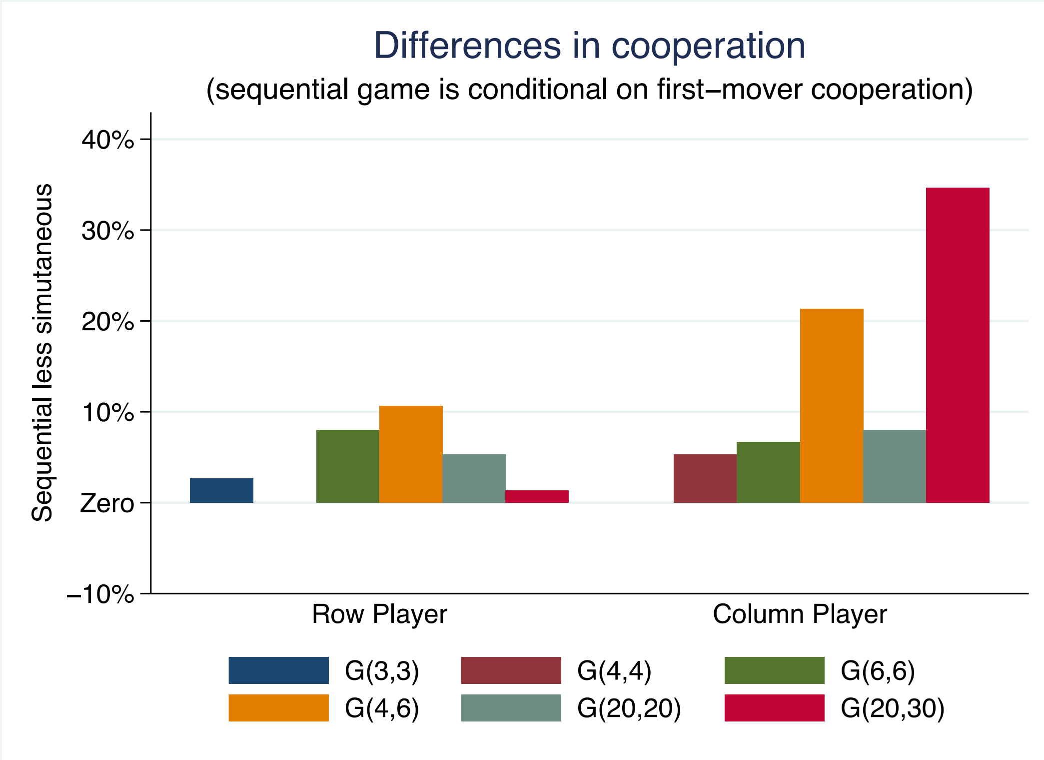


Figure 3: Difference between cooperation in simultaneous versus sequential games

4.1. Cooperation, beliefs, and SVO

The Social Value Orientation (SVO) task consists of 15 dictator games where for each game the participant chooses between allocations. For example, the participant chooses between option A paying $8 to themselves and $8 to the paired other, or option B paying $10 to themselves and $5 to the other (Murphy, Ackermann, & Handgraaf, 2011).

Within the SVO framework, people may vary in why they choose different allocations between themselves and another person. The participant may desire to maximize their own payoff (consistent with pure self-interest), minimize the difference between their own and the other person's payoff (consistent with inequality aversion), or maximize the joint payoffs (consistent with efficiency). Using the 15 dictator game choices, an SVO angle is constructed where the measure is smallest for selfish choices, larger for inequity-averse choices, and largest for efficiency choices. That is, the angle is larger for pro-social behavior.

To falsify hypothesis H4, we examine the correlation between the SVO angle, participants' cooperative behavior, and beliefs about others' cooperation. The results are reported in Table 2.

Table 2: Correlation Matrix

	Beliefs	Cooperation	SVO	CRT	Politics	Gender
Cooperative Behavior	**0.257**	-				
Social Value Orientation	*0.192*	**0.490**	-			
Cognitive Reflection Test	-0.084	0.063	-0.093	-		
Political Affiliation	-0.070	-0.022	-0.131	0.001	-	
Gender	-0.135	0.043	-0.081	0.081	0.097	-
Age	0.149	*0.192*	0.003	0.003	0.015	**0.218**

Note: Beliefs are averaged over all simultaneous games and cooperation is averaged over the simultaneous and second-mover conditional upon first-mover cooperation. **Bold**: significant at p < 0.01; *Italics*: significant at p < 0.05 (2-tailed Pearson correlation test).

Hypothesis H4a stated that cooperation in the prisoner's dilemma games will be positively correlated with pro-social behavior in the social value orientation task. Examining the correlation between the SVO angle and cooperation in simultaneous and second-mover prisoner dilemma games, we see the correlation reported in Table 2 is significant and positive ($p < .01$). A greater SVO angle was consistent with greater prosocial behavior in the 15 dictator games (i.e., inequity aversion and efficiency preferences). This finding is consistent with Capraro et al. (2014) who find a correlation between behavior in the one-shot continuous strategy prisoner dilemma and behavior in a dictator game.

Hypothesis H4b stated participants' beliefs about the likelihood the other player will cooperate in the prisoner's dilemma games will be positively correlated with the player's own pro-social behavior in the social value orientation task. We find that the correlation between the SVO angle and beliefs of other cooperation in the simultaneous prison dilemma games is significant and positive ($p = .019$). We fail to reject hypotheses H4a and H4b. Hypothesis H4b was not studied by Capraro et al. (2014) as they did not measure beliefs.

Using the predictions laid out in section 2.3, we classify participants as one of the four types using the observed behavior. Helpful in this exercise is observing what the participant chose in games $G(4,6)$ versus $G(4,4)$ or $G(6,6)$ and the scaled-up versions $G(20,30)$ versus $G(30,30)$.[7] This classification exercise yields some participants who made an equal number of decisions

[7] A decision in the simultaneous game or the second-mover game conditional upon first-mover cooperation was consistent for a type when the participant's decision to cooperate for the pair of games met the following criteria:

	$G(3,3)$ vs $G(4,4)$	$G(4,4)$ vs $G(4,6)$	$G(6,6)$ vs $G(4,6)$	$G(20,20)$ vs $G(20,30)$
Selfish	No cooperation	No cooperation	No cooperation	No cooperation
Inequity	$C(3,3) \leq C(4,4)$	$C(4,4) \geq C(4,6)$	$1 = C(6,6) \geq C(4,6)$ $1 = C(6,6) \geq C(6,4)$	$C(20,20) \geq C(20,30)$
Efficiency	$0 = C(3,3) \leq C(4,4)$	$C(4,4) \leq C(4,6)$ $C(4,4) \leq C(6,4)$	$C(6,6) \leq C(4,6)$ $C(6,6) \leq C(6,4)$	$C(20,20) \leq C(20,30) = 1$
Rawlsian	$C(3,3) \leq C(4,4)$	$C(4,4) = C(4,6)$ $C(4,4) \leq C(6,4)$	$C(6,6) \leq C(4,6)$ $C(6,6) \leq C(6,4)$	$C(20,20) = C(20,30)$ $C(20,20) \leq C(30,20)$

consistent with inequity inversion and Rawlsian maximin, as well as some participants who had a three-way tie (denoted as other). We compare this classification to the SVO measure.

Table 3:Average SVO Angle for Different Types in the Prisoner's Dilemma

Classification	Selfish	Other	Rawlsian	Inequity/Rawls	Inequity	Efficiency
SVO angle	7.95	18.05	23.69	25.06	27.25	28.48

It is thus interesting and encouraging that those individuals who maximize efficiency in the Prisoner's dilemma also have the highest average SVO angles in the dictator game task. As shown in Table 3, selfish types in the prisoner's dilemma have the lowest average SVO angles in the dictator games. This suggests that selfish types are consistent across prisoner's dilemma and dictator games, and that inequity and efficiency types are each consistent across prisoner's dilemma and dictator games. The SVO angle was intended to separate selfish, inequity-averse, and efficiency types but does not distinguish between Rawlsian and inequity-averse types. Hence, we do not have hypotheses a priori about whether inequity-averse or Rawlsian types are more pro-social, although the above table indicates that inequity-averse types in the prisoner's dilemma are more prosocial in the dictator game tasks (higher mean SVO angle) than those who were classified as Rawlsian types in the prisoner's dilemma.

5. Parametric Estimation of Social Preferences

We compute models to ascertain the fit of any one or more posited utility functions on the observed behavior and beliefs. For the parameter of each utility function, our model assumes the parameter is distributed from zero to one. The details of the model construction are reported in Appendix 8.2.

If we assume the probability distribution function (PDF) of the parameter in the utility function (α, ρ or θ) on the unit interval is

$$f(x) = \left(\frac{1}{x} + \frac{1}{1-x}\right) PDF\ [Normal\ Distribution[\mu\ , \sigma], log\ (1-x) - log\ (x)]$$

then best-fit results are reported in Table 4. A comparable Beta Distribution was created by fitting 10,000 random variates sampled from the reported fitted mean (μ) and variance (σ) values.

Table 4: Parametric Estimates of Utility Parameters

Model	Log Likelihood Fit	Precision	Utility Parameter Values
1. Selfish Preferences x	-1,694	2.2	NA
2. Inequity Aversion $(1-\alpha)x - \alpha\ Abs(x-y)$	-1,102	14.8	μ_α= 1.17 σ_α= 1.60 ≈Beta[0.83, 1.78] with mean of 0.31, variance 0.06

3. Efficiency Preferences $(1-\ \rho)x+\rho(x+y)$	-1,399	8.9	μ_ρ= -0.23 σ_ρ= 3.22 ≈Beta[0.48, 0.44] with mean of 0.53, variance 0.13
4. Rawlsian Maximin Preferences $(1-\theta)x+\theta Min(x,y)$	-1,121	11.6	μ_θ= 0.79 σ_θ= 2.04 ≈Beta[0.67, 1.03] with mean of 0.39, variance 0.09

This suggests that if there are homogenous preferences then inequity aversion best fits the data, as it has the lowest log-likelihood and highest precision. The increase in fit for models 2-4 in comparison to selfish preferences is significant (the cumulative probability beyond *z* for the χ^2 distribution with 2 degrees of freedom, where *z* is the increase in log-likelihood), all three comparisons yield $p<.001$.

Of course, it is plausible that preferences are heterogeneous and a mixture model without any inequity averse types might best fit the observed behavior. To see if this is possible, we create four mixture models with either all or only three of the preferences. As shown in Table 5, model 4 has the best fit and includes all four preferences. However, the fit is nearly identical to model 3 where there are no conditional efficiency types. The worst fit is model 2, where there are no inequity averse types.

Table 5: Parametric Estimates of Multiple Utility Parameters

		Model 1	Model 2	Model 3	Model 4
Selfish Parameters	Precision Proportion	24.9 24.5%	20.9 29.1%	24.2 15.9%	27.4 19.4%
Inequity Parameters	Precision Mu Sigma Proportion	9.4 -0.04 1.95 45.3%		8.9 0.72 0.88 39.9%	12.7 0.77 0.66 31.55%
Efficiency Parameters	Precision Mu Sigma Proportion	14.5 -2.18 2.80 30.2%	3.6 -0.71 0.14 27.1%		5.9 -0.37 2.49 15.6%
Rawlsian Maximin Parameters	Precision Mu Sigma Proportion		16.4 -0.37 2.66 43.8%	23.7 0.48 2.47 44.2%	22.4 -0.83 2.18 33.5%
Log likelihood		-1,024	-1,027	-974	-973

6. Conclusion

We studied the effects of social surplus, inequality, and information on cooperation in simultaneous and sequential prisoner's dilemma games. Experimentally, we found behavior to differ significantly between simultaneous and sequential games with sequential games generating greater cooperation. Consistent with the predictions of conditional efficiency preferences, Rawslian preferences, and inequity aversion, cooperation increased with social surplus for games with symmetric payoffs, as in Charness et al. (2016). However, inconsistent with efficiency and Rawlsian preferences, but consistent with the predictions of inequality aversion, we observed lower cooperation rates by players with disadvantageous inequality, even in games with a higher social surplus. Other factors such as reputation and reciprocity have been proposed to explain cooperation in repeated or non-anonymous interactions, but these factors have no role in the simultaneous one-shot anonymous prisoner's dilemma.

The evidence from comparing the simultaneous and sequential games is consistent with players accounting for the risk of defection and making a risk-return tradeoff as in traditional financial decisions. Such a tradeoff provides one reason why cooperation rates are lower in the simultaneous move game relative to the second-movers in the equivalent sequential game which eliminates the risk from cooperating.

We find social preferences are consistent across two important elicitation formats: in dictator games--via the social value orientation, and in the prisoner dilemma game. Beliefs are also correlated with social preferences. These results suggest that participants' choices in appropriately constructed prisoner dilemma games can be used to provide an alternative measure of social preferences.

7. References

Aggarwal, R.K., & Samwick, A.A. (1999). Executive compensation, strategic competition, and relative performance evaluation: Theory and evidence. *Journal of Finance*, 54, 1999-2043.

Ahn, T. K., Lee, M., Ruttan, L., & Walker, J. (2007). Asymmetric payoffs in simultaneous and sequential prisoner's dilemma games. *Public Choice*, *132*(3–4), 353–366. https://doi.org/10.1007/s11127-007-9158-9

Axelrod, R. (1967). Conflict of interest: an axiomatic approach. *Journal of Conflict Resolution*, *11*(1), 87–99. https://doi.org/10.1177/002200276701100107

Axelrod, R., & Hamilton, W. D. (1981). The evolution of cooperation. *Science*, *27*(211), 1390–1396.

Bolton, G.E., & Ockenfels, A. (2000) ERC: A theory of equity, reciprocity, and competition. *American Economic Review*, 90, 166-193.

Capraro, V., Jordan, K.J. & Rand, D.G. (2014). Heuristics guide the implementation of social preferences in one-shot Prisoner's Dilemma experiments. *Scientific Reports*. 4:6790.

Charness, G., & Rabin, M. (2002). Understanding social preferences with simple tests. *The Quarterly Journal of Economics*, *117*(3), 817-869.

Charness, G., Rigotti, L., & Rustichini, A. (2016). Social surplus determines cooperation rates in the one-shot Prisoner's Dilemma. *Games and Economic Behavior*, *100*, 113–124. https://doi.org/10.1016/j.geb.2016.08.010

Crosetto, P., Weisel, O., & Winter, F. 2012. A Flexible z-Tree Implementation of the Social Value Orientation Slider Measure (Murphy et al. 2011). *Political Behavior: Cognition*.

Croson, R.T.A. (2000), Thinking like a game theorist: factors affecting the frequency of equilibrium play, *Journal of Economic Behavior & Organization,* 41(3): 299-314.

Dave, C., Eckel, C. C., Johnson, C. A., & Rojas, C. (2010). Eliciting risk preferences: When is simple better? *Journal of Risk and Uncertainty*, *41*, 219–243.

Dreber, A., Fudenberg, D., Rand, D.G. (2014). Who cooperates in repeated games: The role of altruism, inequity aversion, and demographics. *Journal of Economic Behavior and Organization*, 98, 41-55.

Dufwenberg, M., & Kirchsteiger, G. (2004). A theory of sequential reciprocity. *Games and Economic Behavior*, *47*(2), 268–298. https://doi.org/10.1016/j.geb.2003.06.003

Fischbacher, U. (2007). Ztree- Zurich Toolbox for Ready-made Economic Experiments, *Experimental Economics*, 10 (2), 334–352.

Glode, V., Green, R.C., & Lowery, R. (2012). Financial expertise as an arms race. *Journal of Finance*, 67, 1723-1759.

Kyle, A.S., & Wang, F.A. (1997). Speculation duopoly with agreement to disagree: Can overconfidence survive the market test? *Journal of Finance*, 52, 2073-2090.

Lambertini, L., & Rossini, G. (1998). Product homogeneity as a prisoner's dilemma in a duopoly with R&D. *Economics Letters*, 58, 297-301.

Miettinen, T., Kosfeld, M., Fehr, E., & Weibull, J. (2020). Revealed preferences in a sequential prisoners' dilemma: A horse-race between six utility functions. *Journal of Economic Behavior and Organization*, 173, 1-25.

Moisan, F., ten Brincke, R., Murphy, R. O., & Gonzalez, C. (2018). Not all Prisoner's Dilemma games are equal: Incentives, social preferences, and cooperation. *Decision*, *5*(4), 306–322. https://doi.org/10.1037/dec0000079

Murphy, R. O., Ackermann, K. A., & Handgraaf, M. J. J. 2011. Measuring social value orientation. *Judgment and Decision Making*, *6*, 771-781.

Rapoport, A. (1967). A Note on the "Index of Cooperation" for Prisoner's Dilemma. *The Journal of Conflict Resolution*, *11*(1), 100–103. https://doi.org/10.2307/172934?ref=search-gateway:ac3fd44843b0091273c52b22cf219fd3

Rapoport, A. (1974). *Conflict in man-made environment.* [Harmondsworth, Eng, Baltimore]: Penguin Books.

Smith, V. L., & Wilson, B. J. (2017). Sentiments, Conduct, and Trust in the Laboratory. *Social Philosophy and Policy*, *34*(1), 25–55. https://doi.org/10.1017/S0265052517000024

Toplak, M. E., West, R. F., & Stanovich, K. E. (2014). Assessing miserly information processing: An expansion of the Cognitive Reflection Test. *Thinking & Reasoning*. Retrieved from https://www.tandfonline.com/doi/abs/10.1080/13546783.2013.844729

Yamakawa, T., Okano, Y., & Saijo T. (2016). Detecting motives for cooperation in public goods experiments. *Experimental Economics*, 19, 500-512.

8. Appendix

8.1. Experimental Instructions

This is an experiment in the economics of decision-making. Various research agencies have provided funds for this research. The currency used in the experiment is experimental dollars (ED), expressed with a '$'. Unless you're told otherwise, this currency will be converted at a rate of 1 ED to 1 U.S. dollar. At the end of the experiment, your earnings will be paid to you in private and in cash. It is very important that you remain silent and do not look at others' monitors. If you have any questions or need assistance of any kind, please raise your hand and an experimenter will come to you. If you talk, laugh, exclaim out loud, etc., you will be asked to leave and you will not be paid. We expect, and appreciate, that you adhere to these policies.

Today's Experiment

In today's experiment there will be four parts.

1. In Part I you will be partnered with another randomly selected person in this experiment. You will both make decisions at the same time in a task which we will call the Joint Task.
2. In Part II you will be partnered with another randomly selected person in this experiment in another version of the Joint Task. One of you will be the first-mover, who makes their decision first. After the first-mover decides, the second person sees the first-mover's decisions and then makes their decision.
3. In Part III you will be partnered with another randomly selected person in this room. Both of you will make decisions regarding how to divide an amount of dollars at the same time. One of your, or the other person's, decisions will be randomly selected to be implemented. For Part III the exchange rate will be that 20 ED are worth 1 U.S. dollar.
4. In Part IV you will be asked to answer questions and complete a survey while we process your payment. You will be paid in cash.

During all parts of the experiment, you will be anonymous. That is, while in Parts 1 – III, the other person may know what you decided, they will not know who they are partnered with. Also, you might know what the other person decided, but will not know who the person is.

Any decision you make in any part of the experiment will NOT affect your payoff or choices in other parts of the experiment.

After everyone makes their decisions for all parts, we will randomly pay you for Part I or for Part II. You will also be paid for Part III and for Part IV. Your decisions will NOT affect if Part I or Part II is randomly selected for payment.

Before we describe the parts of the experiment in detail, let's describe the Joint Task used in Part I and Part II.

The Joint Task

In the Joint Task, one person decides top or bottom, and the other decides left or right. The two decisions dictate both persons' payoffs as shown in the example below:

Other Person's Decision: Left or Right (L or R)

Your Decision: Top or Bottom (T or B)

Table 4	L	R
T	**You: 4** , Other 6	**You: 1**, Other 7
B	**You: 7** , Other 1	**You: 2** , Other 2

Choose T or B

In this example, if you choose Top and the other chooses Left, then you will receive $4 and the other person will receive $6. However, if you choose Top and the other chooses Right, then you will receive $1 and the other person will receive $7.

Alternatively, if you choose Bottom and the other chooses Left, you will receive $7 and the other will receive $1. However, if you choose Bottom and the other chooses Right you will receive $2 and the other will receive $2.

In the example above, the payoffs are described from the perspective of the person who receives $4 when Top and Left are chosen. From the perspective of the person who receives $6 when the Top and Left are chosen, the payoffs are presented as shown below.

Other Person's Decision: Left or Right (L or R)

Your Decision: Top or Bottom (T or B)

Table 4	L	R
T	**You: 6** , Other 4	**You: 1**, Other 7
B	**You: 7** , Other 1	**You: 2** , Other 2

Choose T or B

Everyone in this experiment will decide Top or Bottom. This choice will be described as Left or Right to the person you are partnered with. There is an equal chance your payoff tables are those in Version A at the end of these instructions, or those in Version B at the end of these instructions.

Before we proceed, we would like to ask you to answer some questions to be sure you understand the Joint Task. Please refer to the payoffs below when answering these questions. In a few minutes an experimenter will come back into the room and review the correct answers.

Other Person's Decision: Left or Right (L or R)

Your Decision: Top or Bottom (T or B)	Table 6	L	R
	T	**You: 20** , Other 30	**You: 5**, Other 35
	B	**You: 35** , Other 5	**You: 10** , Other 10

Choose T or B

The table above shows another example. Please answer the following questions about this table:

If you choose Top, and the other person chooses Right,

1. How much are your payoffs? ______
2. How much are the other's payoffs? ______

If you choose Bottom, and the other person chooses Right,

3. How much are your payoffs? ______
4. How much are the other's payoffs? ______

If you choose Bottom, and the other person chooses Left,

5. How much are your payoffs? ______
6. How much are the other's payoffs? ______

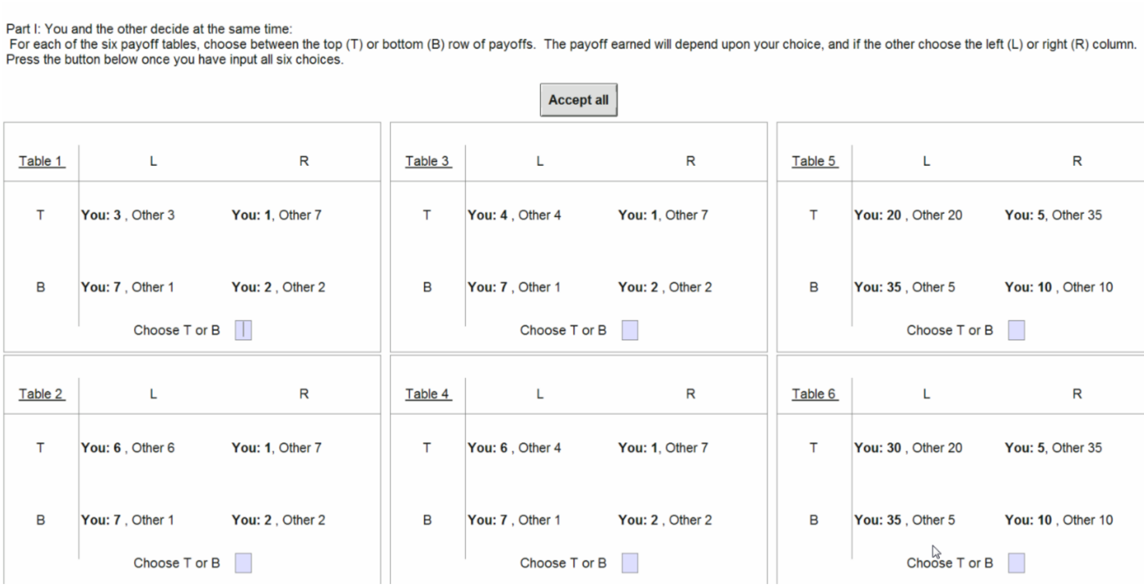
If you choose Top, and the other person chooses Left,

7. How much are your payoffs? ______
8. How much are the other's payoffs? ______

Part I: Both make decisions at the same time

We will ask you to make decisions for six different versions of the Joint Task, where the payoffs for each task will be different. To distinguish the different payoffs, we'll describe the payoffs as coming from Table 1 through Table 6.

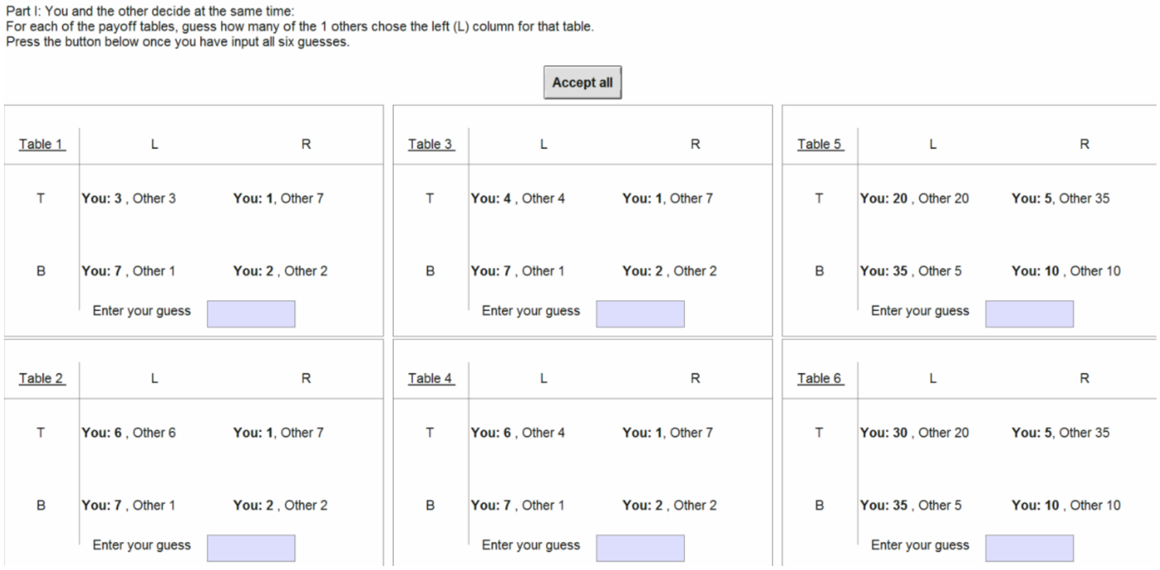
In addition to being on your screen, these six tables are included in the last page of these instructions. For each of the six tables, we want you to tell us if you choose the payoffs from the top row, or from payoffs for the bottom row. For example, you might see the following on your screen:



While at most only one of these tables will be selected for your payment, we want you tell us what you would decide for each of the tables. Your choices will NOT affect which table is randomly selected for payment. Once you have entered either T or B (for top or bottom row, respectively) in each of the six boxes, please press the 'Accept All'. The experiment cannot proceed until everyone has pressed this button.

Part I: Guess what others decided

For this part of the experiment, we want you to guess what others decided in each of the six tables for the Joint Task. Half of the people in this room receive the payoffs described in the six tables as the 'other' while the other half receive the payoffs described as 'you'. Of those who receive the payoffs described as 'other', we want you to guess how many decided they wanted payoffs from the Left column. So, in each of the six tables, we want you to input a number from zero to half the people in this room. For example, you might see the following on your screen if there are only two people participating:



Part I: You and the other decide at the same time:
For each of the payoff tables, guess how many of the 1 others chose the left (L) column for that table.
Press the button below once you have input all six guesses.

Accept all

Table 1	L	R
T	You: 3 , Other 3	You: 1, Other 7
B	You: 7 , Other 1	You: 2 , Other 2
	Enter your guess	

Table 3	L	R
T	You: 4 , Other 4	You: 1, Other 7
B	You: 7 , Other 1	You: 2 , Other 2
	Enter your guess	

Table 5	L	R
T	You: 20 , Other 20	You: 5, Other 35
B	You: 35 , Other 5	You: 10 , Other 10
	Enter your guess	

Table 2	L	R
T	You: 6 , Other 6	You: 1, Other 7
B	You: 7 , Other 1	You: 2 , Other 2
	Enter your guess	

Table 4	L	R
T	You: 6 , Other 4	You: 1, Other 7
B	You: 7 , Other 1	You: 2 , Other 2
	Enter your guess	

Table 6	L	R
T	You: 30 , Other 20	You: 5, Other 35
B	You: 35 , Other 5	You: 10 , Other 10
	Enter your guess	

After everyone makes their decisions, one of these tables will be randomly selected for each person. If you guessed the right number, you will receive $5, otherwise, you will receive nothing. While only one of these guesses will be selected for payment, we want you to guess for each of the six tables. Your guess will NOT affect which table is randomly selected. Once you have entered a number in each of the six boxes, please press the 'Accept All' button. The experiment cannot proceed until everyone has pressed this button.

Part II: Decisions are made sequentially

In Part II, you and a new person you are partnered with will make decisions in the Joint Task for six different payoff tables—the same tables as in Part I. However, in Part II one person will be the first-mover and make a decision, and then that decision is shown to the other person who is the second-mover, who then makes a decision.

Before you find out if you will be the first-mover or the second-mover, we want you to tell us what you would do if you were the first-mover, and then what you would do if you were the second-mover. Your choices will NOT affect whether you are randomly selected to be the first-mover or the second-mover. Also, your choices will NOT affect which table is randomly selected for payment.

When asked to make your decisions if you are the first-mover, the screen will look similar to Part I. You will make six decisions, one for each of the six tables, knowing your choice will be told to the second-mover before the second-mover makes their choice. Once you have entered either T or B (for top or bottom row, respectively) in each of the six boxes, please press the 'Accept All' button. The experiment cannot proceed until everyone has pressed this button.

When asked to make your decisions if you are the second-mover, you will be asked to choose Top or Bottom if you know that the other person you are paired with has already chose Left or Right. So you will make 2 decisions for each of the six tables, one decision knowing that the first-mover chose L, and another knowing that the first-mover chose R.

As the second-mover, half of the payoffs in your table will be in italicized font to denote these payoffs are not available. For example, consider payoffs from Table 4 knowing the first-mover chose Left. If you choose the top row, you receive $4 and the other receives $6. If you choose the bottom row, you receive $7 and the other receives $1. The payoffs in the right column are NOT available given that the other person already chose Left, and so they are italicized.

Table 4	L	R
T	**You: 4** , Other 6	*You: 1, Other 7*
B	**You: 7** , Other 1	*You: 2, Other 2*

Choose T or B

As the second-mover, you will then be asked to choose Top or Bottom if you knew that the other person already chose Right. For example, the payoffs from Table 4 now look as shown below. The payoffs in italics are not available given that the other person chose Right. If you choose the top row, you receive $1 and the other receives $7. If you choose the bottom you receive $2 and the other receives $2.

Table 4	L	R
T	*You: 4, Other 6*	**You: 1**, Other 7
B	*You: 7, Other 1*	**You: 2** , Other 2

Choose T or B

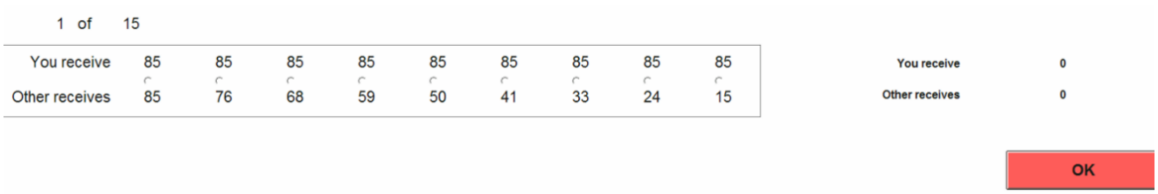
First, we will ask you to choose top or bottom for all six tables assuming the first-mover choose Left. Once you have entered either T or B (for top or bottom row, respectively) in each of the six boxes, please press the 'Accept All'. The experiment cannot proceed until everyone has pressed this button.

Next, we will ask you to choose top or bottom for all six tables assuming the first-mover chose Right. Once you have entered either T or B (for top or bottom row, respectively) in each of the six boxes, please press the ‘Accept All’ button. The experiment cannot proceed until everyone has pressed this button

Part III: Allocating Money between Yourself and Another

In Part III you will be paired with another randomly selected person in this room. It is likely that the person will NOT be the same person you were paired with within Part I or II. Both of you will make decisions at the same time, but only one person’s decision will count. You will choose a pair of payments for you and the person you are paired with. *For Part III, the exchange rate is 20 ED to 1 U.S. dollar. That is, 20 experimental dollars are worth $1 U.S. dollar.*

In each of 15 decisions, you will be asked to indicate which of the nine pairs of payments you prefer. To do so, click the circle corresponding to the pair of payments you prefer. Once you have made your selection, please click the “OK” button.



While we will pay you for one of the decisions, we want you to tell us which pair of payments you prefer for all 15 decisions if you get to decide. After everyone has made their choices, either you or the person you are randomly paired with will randomly be the decider. One of the decider’s choices will be randomly selected and you will each be paid according to the pair of payments chosen by the decider. For example, if you are selected to be the decider and if decision 1 shown above is selected, and if you chose the pair (85, 50), then you will receive $4.25 (1/20 of 85) and the other person will receive $2.50 (1/20 of 50). Your choices will NOT affect whether you are the decider. Your choices will NOT affect which of the 15 decisions will be selected for payment.

Part IV: Questions and Survey

In Part IV you will be asked to answer several questions and then complete a survey while we process your payment. Part IV is a single-person task that offers a chance to earn up to an additional $2 by answering the questions correctly. Your responses to Part IV do not depend on any other person’s responses.

Payment for Today's Experiment

Your choices in any part of the experiment do NOT affect your payment in any other part of the experiment. Once you have completed the questions and survey from Part IV, you will be paid in cash for your cumulative earnings over all parts of the experiment. To recap, in addition to the $7 you will receive for participating, you will be paid for:

I. One randomly selected Joint Task in Part I, or one randomly selected Joint Task in Part II. For each pair, there is a 50% chance Part I is selected by the computer, and a 50% chance part II is selected.
   a. If Part I is selected, you and the other person will be paid for one of six tables, where each table has a 1/6 chance of being selected by the computer.
   b. If Part II is selected, there is a 50% chance you are the first-mover and the other person is the second-mover, or a 50% chance the other is the first-mover and you are the second-mover. You and the other person will be paid for one of six tables, where each table has a 1/6 chance of being selected by the computer.

II. One randomly selected guess in Part I. Each guess has a 1/6 chance of being selected by the computer. If you correctly guessed the number of others that chose Left in the selected pair, you will receive $5.

III. One randomly selected choice of the choices in Part III. There is a 50% chance the computer selects you to be the decider, and a 50% chance the computer selects the other person you were paired with for Part III. Each of the deciders' choices has a 1/15 chance of being selected.

IV. Up to $2 for answering questions correctly.

While we are processing your payment, you will be asked to complete a short survey and wait until your name is called. When it is, bring your belongings and walk to the cashier's window in the front of the laboratory. Leave the instructions and pencil on your desk. You will be paid in cash as described above.

Sequence of Today's Experiment

- Part I: Joint Task deciding simultaneously.
- Part I: Guessing what others choose.
- Part II: Joint Task deciding sequentially.
- Part III: Choosing allocations
- Part IV: Questions and survey

A Check of Your Understanding

Finally, please respond to the following quiz questions so that we can be sure that you understand the instructions.

Please write T or F (True or False) as your answer to each of the following questions based on your understanding of the instructions.

1. You will be paid for all six versions of the Joint Task (T/F)? ________
2. You will be paid for only one of your six guesses in Part I (T/F)? _________
3. You and the other will be paid for one of the Joint Tasks in Part I (where you both decide at the same time) or one of the Joint Tasks in Part II (where decisions are sequential) (T/F)? _____
4. In Part II you make decisions as if you are the first-mover, and then decisions as if you are the second-mover (T/F)? ______
5. In Part III you will be paired with the same person as you were in Parts I and II (T/F)? _______
6. In Part III, either you or the person you are paired with will be randomly selected to be the decider (T/F)? ________
7. In Part III, you will be paid for 1 of the 15 decisions made by the decider (T/F)? _______

Payoff Tables - Version A

Table 1	L	R
T	**You: 3** , Other 3	**You: 1**, Other 7
B	**You: 7** , Other 1	**You: 2** , Other 2

Choose T or B

Table 3	L	R
T	**You: 4** , Other 4	**You: 1**, Other 7
B	**You: 7** , Other 1	**You: 2** , Other 2

Choose T or B

Table 5	L	R
T	**You: 20** , Other 20	**You: 5**, Other 35
B	**You: 35** , Other 5	**You: 10** , Other 10

Choose T or B

Table 2	L	R
T	**You: 6** , Other 6	**You: 1**, Other 7
B	**You: 7** , Other 1	**You: 2** , Other 2

Choose T or B

Table 4	L	R
T	**You: 6** , Other 4	**You: 1**, Other 7
B	**You: 7** , Other 1	**You: 2** , Other 2

Choose T or B

Table 6	L	R
T	**You: 30** , Other 20	**You: 5**, Other 35
B	**You: 35** , Other 5	**You: 10** , Other 10

Choose T or B

Payoff Tables – Version B

Table 1	L	R
T	**You: 3** , Other 3	**You: 1**, Other 7
B	**You: 7** , Other 1	**You: 2** , Other 2

Choose T or B

Table 3	L	R
T	**You: 4** , Other 4	**You: 1**, Other 7
B	**You: 7** , Other 1	**You: 2** , Other 2

Choose T or B

Table 5	L	R
T	**You: 20** , Other 20	**You: 5**, Other 35
B	**You: 35** , Other 5	**You: 10** , Other 10

Choose T or B

Table 2	L	R
T	**You: 6** , Other 6	**You: 1**, Other 7
B	**You: 7** , Other 1	**You: 2** , Other 2

Choose T or B

Table 4	L	R
T	**You: 4** , Other 6	**You: 1**, Other 7
B	**You: 7** , Other 1	**You: 2** , Other 2

Choose T or B

Table 6	L	R
T	**You: 20** , Other 30	**You: 5**, Other 35
B	**You: 35** , Other 5	**You: 10** , Other 10

Choose T or B

8.2. Log-Likelihood Models

Before specifying the probability of the observed choices, let's introduce notation, types of utility functions modeled, and payoffs

- Let *i* index the participant.
- Let *k* index the type, $k \in \{1,2,3,4\}$, where types are those who seem to behave according to:
  1. Strictly Selfish Preferences: $U(x, y) = x$
  2. Inequity Aversion: $U(x, y) = (1 - \alpha)x - \alpha\, Abs(x - y)$, where $\alpha \in [0,1]$
  3. Efficiency / Utilitarian Preferences: $U(x, y) = (1 - \rho)x + \rho(x + y)$, where $\rho \in [0,1]$ if the other is believed to be cooperative, else selfish preferences
  4. Rawlsian Maximin Preferences: $U(x, y) = (1 - \theta)x + \theta Min(x, y)$, where $\theta \in [0,1]$
- Let Φ_k be parameters for type *k* (i.e., $\Phi_1 = \emptyset$, $\Phi_2 = \alpha$, etcetera).
- Let *I* be an array of the elicited beliefs that others will behave cooperatively in simultaneous games indexed by $g \in \{1,2,3,4,5,6\}$, where each element is expressed as a percentage.
- Let $C_{i,g}, C_{j,g}$ be the payoffs for the participant *i* and partner *j* in game *g* when both cooperate.
- Let $N_{i,g}, N_{j,g}$ be the payoffs for the participant *i* and partner *j* in game *g* when both defect.
- Let T_g be the payoff for participant *i* who defects when the partner *j* cooperates.
- Let S_g be the payoff for participant *i* who cooperates when the partner *j* defects.
- Expected utility in simultaneous game *g* is given by:
  - $EU_g(Cooperation) = I_g U(C_{i,g}, C_{j,g}) + (1 - I_g)U(S_g, T_g)$
  - $EU_g(Defect) = I_g U(T_g, S_g) + (1 - I_g)U(N_{i,g}, N_{j,g})$
- Utility in conditional game *g*, where the other cooperates, is given by:
  - $U_g(Cooperation|C) = U(C_{i,g}, C_{j,g})$
  - $U_g(Defect|C) = U(T_g, S_g)$
- Utility in conditional game *g*, where the other defects, is given by:
  - $U_g(Cooperation|D) = U(S_g, T_g)$
  - $U_g(Defect|D) = U(N_{i,g}, N_{j,g})$

The probability that a participant of type k participates in simultaneous game g, conditional on beliefs I is given by:

$$P_k(I_g, \lambda_k) = \frac{1}{1 + \exp\left[-\frac{\lambda_k}{U^*_{k,g}}\left(EU(Cooperative) - EU(Defect)\right)\right]} \quad (1)$$

The probability that a participant of type k participates in game g, conditional knowing the other cooperated is given by:

$$P_k(\lambda_k|C) = \frac{1}{1 + \exp\left[-\frac{\lambda_k}{U^*_{k,g}}\left(U(Cooperative|C) - U(Defect|C)\right)\right]} \quad (2)$$

The probability that a participant of type k participates in game g, conditional knowing the other defected is given by:

$$P_k(\lambda_k|D) = \frac{1}{1 + \exp\left[-\frac{\lambda_k}{U^*_{k,g}}\left(U(Cooperative|D) - U(Defect|D)\right)\right]} \quad (3)$$

Where λ_k is a precision parameter for type *k* and $U^*_{k,g}$ is the difference in the largest and smallest utility for type k in game g given the support of the parameters (unit interval).

Let the array X_i be the 18 choices made by participant *i* (six in the simultaneous games, six in the conditional upon cooperated games, and six in the conditional upon defected games). Then the probability of those choices, contingent on being type *k* is given by:

$$\begin{aligned} P_k(\lambda_{k,} \Phi_k | X_i) = & \prod_{g=1}^{6}\left(x_g^i P_k(I_g, \lambda_k) + (1 - x_g^i)\left(1 - P_k(I_{ng}, \lambda_k)\right)\right) \\ & \times \prod_{g=1}^{6}\left(x_{g+6}^i P_k(\lambda_k|C) + (1 - x_{g+6}^i)(1 - P_k(\lambda_k|C))\right) \\ & \times \prod_{g=1}^{6}\left(x_{g+12}^i P_k(\lambda_k|D) + (1 - x_{g+12}^i)(1 - P_k(\lambda_k|D))\right) \end{aligned} \quad (4)$$

For each subject, the probability is integrated over the unit interval with the PDF shown below using numerical integration.

$$\int_0^1 P_k\left(\lambda_{k,}\Phi_k \middle| X_i\right) f(\Phi_k) d\Phi_k \approx \sum_{z=1}^{n} \omega(\Phi_k^z) P_k\left(\lambda_{k,}\Phi_k^z \middle| X_i\right) f(\Phi_k^z) \equiv P_k^i\left(\lambda_{k,}\mu_k, \sigma_k \middle| X_i\right) \tag{5}$$

$$f(\Theta_k) = \left(\frac{1}{\Theta_k} + \frac{1}{1-\Theta_k}\right) PDF\,[Normal\ Distribution[\mu_k\ , \sigma_k], log\ (1-\Theta_k) - log\ (\Theta_k)]$$
$$= \left(\frac{1}{\Theta_k} + \frac{1}{1-\Theta_k}\right) \frac{e^{-\frac{log\ (1-\Theta_k) - log\ (\Theta_k) - \mu_k}{2\sigma_k^2}}}{\sqrt{2\,\pi}\sigma_k}$$

where $\Phi_k^z, \omega(\Phi_k^z)$ are the abscissa and weight, respectively, at node z.

The log of the individual choices is summed over all subjects (S) to arrive at the log-likelihood model for type k:

$$LL_k\left(\lambda_{k,}\mu_k, \sigma_k \middle| X\right) = \sum_{i=1}^{S} Log[P_k^i\left(\lambda_{k,}\mu_k, \sigma_k \middle| X_i\right)] \tag{7}$$

A mixture model considers that some proportion of the population makes choices as if one type, while others make choices as if another type, etc… in a set of types denoted as K with $M\ > 1$ types.

$$LL_K\left(\overrightarrow{\lambda_k}, \overrightarrow{\mu_k}, \overrightarrow{\sigma_k}, \overrightarrow{\pi_k} \middle| X\right) = \sum_{i=1}^{S} Log[\sum_{k \in K} \pi_k\ P_k^i\left(\lambda_{k,}\mu_k, \sigma_k \middle| X_i\right)] \tag{8}$$

where $\overrightarrow{\lambda_k}$ and $\overrightarrow{\pi_k}$ are vectors of length M and $\overrightarrow{\mu_k}$ and $\overrightarrow{\sigma_k}$ are vectors of length $M-1$ as the selfish preference type has no parameter value.