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Abstract

We introduce a novel approach to studying behavior in repeated games–one that is based on the psychology of play. Our approach is based on the following six "aspects" of a player's behavior: round-1 cooperation, lenience, forgiveness, loyalty, leadership, and following. Using a laboratory experiment, we explore how aspects are correlated between each other in a given repeated game, how they are correlated with behavior at various histories in a given repeated game, and how each aspect is correlated across different repeated games. We also investigate whether two players' aspects from a given repeated game tend to predict the frequency of the cooperate-cooperate outcome if these two players are matched to play either the same kind of repeated game or an altogether different repeated game. An important feature of our study is that it addresses the question of cross-game prediction.

Keywords: repeated games, prisoner's dilemma, experiment, cooperation

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1 Introduction

Game Theory captures behavior in a repeated game through the notion of a strategy, which describes how a player behaves at each possible history.[1] Unfortunately, as we know from folk theorems, many strategies can be part of a subgame perfect Nash equilibrium, so that little can be said theoretically about the strategies players will use. Theory aside, one might hope to estimate empirically which strategies players actually use. However, strategies are notoriously difficult to estimate (more on this below). Furthermore, even if one could reliably estimate players' strategies in a particular repeated game, the estimation results may have no predictive power for other repeated games. For example, in the case of the repeated Prisoner's Dilemma (RPD), changing the payoffs of the stage game or, if the game is indefinitely repeated, the continuation probability can lead to big changes in behavior. Thus, it is not clear how estimated strategies in an RPD with a given set of parameters would be informative about play in an RPD with a different set of parameters. The problem is even more acute if one wishes to make predictions across repeated games with different stage games–strategies from one repeated game may not even be defined in another repeated game.

The current paper introduces a novel approach to studying behavior in repeated games–one that is based on the psychology of play. In particular, we study behavior after different histories, after each of which it has a relatively clear interpretation from a psychological point of view. We call (our measures of) behavior after these histories "aspects" of behavior. For each player i, we consider six aspects. The first aspect is round-1 cooperation[2] ($C1$), which is defined as the probability that i cooperates at the start of the game. A second aspect is lenience (Len), which is defined as the probability that i cooperates in round 2 after she cooperated while the other player defected in round 1. The remaining four aspects, which will be defined formally later, are forgiveness ($Forg$), loyalty ($Loyal$), leadership ($Lead$), and following ($Foll$).

[1]Formally, our approach applies to finitely, infinitely, or indefinitely repeated games. However, we hesitate to say that our conclusions extend to finitely repeated games because (i) our experiment is based on indefinitely repeated games (which are similar to infinitely repeated games) and (ii) finitely repeated games involve some very different issues related to backward induction. Thus, our focus is on infinitely and indefinitely repeated games.

[2]For now think of an RPD. Although in our experiment we also include another repeated game, the language of "cooperate" and "defect" will extend to that game.

In Game Theory, psychological considerations are entirely absent. Yet, it seems plausible that notions such as loyalty, lenience, forgiveness, etc., play a prominent role in how a player thinks about her own and the other player's behavior. The main idea behind our paper is to try to more carefully define and experimentally study such notions. Given the theoretical difficulties in the standard game-theoretic analysis of repeated games as well as the practical difficulties of estimating actual strategies and making cross-game predictions, the hope is that an approach based on the psychology of play could yield additional insights. In particular, our approach can be useful in several ways.

First, studying behavior after certain histories gives us information about players' strategies. This information is only partial because we still don't know how players would behave at many histories. Nevertheless, because behavior after the histories we consider has a relatively clear interpretation from a psychological point of view, it might have a disproportionately large impact on play for the rest of the game. For example, when a player is not loyal, this sends a very clear signal to the other player.

More concretely, what kind of information can we obtain about players' strategies based on our aspects? One thing to look at is the value of each aspect in a given repeated game, averaged across players. Looking at how often players cooperate in round 1, are lenient, are forgiving, etc. provides us with summary statistics of their behavior. Perhaps more importantly, we can look at how the various aspects are correlated. Are players who cooperate in round 1 more frequently also more loyal? Are players who are more loyal also more lenient? Although the average values of each aspect are probably tied to the particular repeated game, one might hope that (some of the) the correlations between aspects hold in different repeated games, thus revealing more universal relationships.

Second, although we consider only histories after which behavior has a clear psychological interpretation, similar psychological considerations might arise at many other histories in the repeated game. For example, although we define *Len* based on how often a player cooperates in round 2 after she cooperated while the other player defected in round 1, one might conjecture that whether a player cooperates in round $r \geq 3$ after she cooperated while the other player defected in round $r - 1$ is to some extent also a matter of lenience. If we find a positive correlation between a given aspect and behavior at other histories at which similar psychological considerations arise, then this aspect is informative about players' behavior at those other histories as well.

Third, we can address the issue of cross-game prediction by asking whether aspects are correlated across different repeated games. That is, are players with relatively high values of a given aspect in one repeated game (say, an RPD) more likely to have relatively high values of that aspect in a different repeated game (say, a different parameterization of the RPD or a repeated game with an altogether different stage game)?

Fourth, staying with the issue of cross-game prediction, we can ask whether two players' aspects, as computed based on several periods play of a given repeated game, help predict the frequency of the cooperate-cooperate outcome if these two players are matched to play either the same repeated game in a new period or an altogether different repeated game.[3]

Finally, an important question of general interest is about whether there is any relationship between how a person plays a repeated game and her individual characteristics. To address this question, one must "measure" behavior in the repeated game. Our aspects provide summary measures of an individual's play in a repeated game and, thus, allow one to conduct a nuanced exploration of any possible connections between behavior in repeated games and individual characteristics.

To study these issues, we conducted a laboratory experiment consisting of two treatments. In Treatment 1, subjects attended two sessions that were one week apart. In session 1, subjects played for several periods a two-player repeated game based on a "Mini-Bertrand" stage game, a three-price version of the regular Bertrand game. Following this, subjects played for several periods a version of the RPD, denoted RPD1 (to distinguish it from other parameterizations of the RPD used in Treatment 2). In session 2, subjects performed an array of tasks meant to measure individual characteristics that are popular in Economics.[4]

[3] We use "period" to refer to play of a whole repeated game. Within each repeated game there are multiple "rounds".

[4] These characteristics are: risk attitude, time preference, trust, trustworthiness, altruism, strategic skills in one-shot matrix games, compliance with first-order stochastic dominance, and ability to plan ahead. We explore the relationship between how a person plays a repeated game and her individual characteristics in Davis et al. (2013). The data from session 2 is analyzed in that paper.

In Treatment 2, subjects attended two sessions that were two weeks apart. In session 1, subjects played for several periods another version of the RPD, denoted RPD2. In session 2, subjects played for several periods a third version of the RPD, denoted RPD3.

Our main results are the following. First, within a given repeated game, $C1$ and $Loyal$ as well as $C1$ and $Foll$ tend to be correlated. Second, again within a given repeated game, each aspect (especially, $Loyal$ and $Foll$) tends to be correlated with behavior at other histories at which similar psychological considerations arise. Third, turning to cross-game prediction, we find that $C1$, Len, $Foll$, and, to a lesser extent, $Forg$ and $Loyal$ tend to be correlated across repeated games. Fourth, two players' values of $Loyal$ and $Foll$, as computed based on several periods play of a given repeated game, tend to predict the frequency of the cooperate-cooperate outcome if these two players are matched to play the same repeated game in a new period. Fifth, two players' values of $Loyal$, as computed based on several periods play of a given repeated game, tend to predict the frequency of the cooperate-cooperate outcome if these two players are matched to play an altogether different repeated game. Finally, with the possible exception of $Loyal$, we find little evidence that a player's aspects are related to her earnings in any given repeated game.

An potentially important limitation of our study is that we measure subjects' aspects with error. As a result, when we estimate correlations between various aspects or run regressions with aspects as independent variables, the estimates will suffer from attenuation bias–they will typically be biased toward zero. The upshot is that our study is biased towards negative results. Thus, any positive findings carry even more weight while negative findings must be viewed with skepticism.

The remainder of the paper is organized as follows. Section 2 provides a literature review. In section 3, we explain the experimental design. In section 4, we formally define our aspects. Section 5 contains the data analysis. Section 6 offers some concluding remarks.

2 Literature Review

The literature on repeated games is enormous and we cannot hope to do it justice here. We merely mention important strands in this literature as well as the most relevant papers. We focus on infinitely and indefinitely repeated games.

Much of the theoretical literature is concerned with folk theorems according to which infinitely repeated games have many (subgame-perfect) Nash equilibria.[5] Another strand of the theoretical literature tries to deal with the multiplicity of equilibria, say, based on evolutionary stable strategies[6] or bounded rationality.[7]

There is also a large experimental literature. Much of it examines the conditions that facilitate the emergence of cooperation.[8] The experimental literature most closely related to our paper attempts to estimate the strategies subjects are using. Kurzban and Houser (2001, 2005) classify subjects as cooperators, reciprocators, or free-riders in the context of a circular Public Good game (which is similar to an indefinitely repeated Public Good game).[9] In the context of RPD games, Dal Bó and Frechétte (2011a) estimate that only two strategies, "always defect" and "tit-for-tat," account for most subjects' behavior.[10] In a cleverly designed experiment, Dal Bó and Frechétte (2011b) employ a variation of the strategy method in RPD games. The main finding is that the majority of subjects choose a small number of simple, one-period-memory strategies, the most popular ones being "always defect," "grim-trigger," and "tit-for-tat." Engle-Warnick and Slonim (2006) estimate the strategies used in an indefinitely repeated Trust game.[11] They find that the grim-trigger strat-

[5]For example, see Aumann and Shapley (1994), Rubinstein (1979), Rubinstein (1994), Fudenberg and Maskin (1986), Osborne and Rubinstein (1994, ch. 8).

[6]For example, see Axelrod and Hamilton (1981), Boyd and Lorberbaum (1987), Boyd (1989), Kim (1994), and Bendor and Swistak (1997).

[7]See Rubinstein (1986) and Abreu and Rubinstein (1988).

[8]For example, Dal Bó and Frechétte (2011a) study the effects of experience as well as of whether the cooperative action can be sustained in equilibrium and/or is risk dominant. Aoyagi and Frechétte (2009) study the effect of imperfect monitoring. Blonski, Ockenfels, and Spagnolo (2007) consider the effect of the "sucker payoff." Some earlier studies examining the conditions that facilitate cooperation include Roth and Murnighan (1978), Murnighan and Roth (1983), Holt (1985), Feinberg and Husted (1993), and Palfrey and Rosenthal (1994).

[9]Burlando and Guala (2005) classify subjects as cooperators, reciprocators, or free-riders in a finitely repeated Public Good game.

[10]Aoyagi and Frechétte (2009) estimate the strategies subjects use in RPD games when monitoring is imperfect. Fudenberg, Rand, and Dreber (2010) estimate the strategies subjects use in RPD games when intended actions are implemented with noise.

[11]The paper also looks at the strategies used in a finitely repeated Trust game.

egy explains most first-movers' behavior and a small number of strategies seems to explain second-movers' behavior.[12]

Although estimating strategies seems like a very reasonable approach, it also has some important limitations. From an econometric point of view, the main limitation arises from the fact that we observe how each player behaves only at a limited number of histories and, for most of those histories, we have only few observations even if the player played the repeated game many times (because in each repeated game play tends to go down different paths in the game tree). To perform the estimation, one needs to start out by specifying a set of candidate strategies, the crucial assumption being that this set is correctly specified, i.e., that it doesn't omit empirically relevant strategies.[13] Second, as already mentioned, even if one could reliably estimate players' strategies in a particular repeated game, the estimation results may have no predictive power if one changes the parameters of the repeated game or uses an altogether different stage game.

In the current paper, rather than trying to pin down the exact strategies players are using, we less ambitiously focus on what we call aspects of players' behavior. This could allow us to gain useful insights into behavior in repeated games without making econometric specification assumptions. Importantly, our approach has something to say about cross-game prediction. Having said this, we would like to emphasize that we view our approach as complementary to the existing literature. Behavior in repeated games is complicated and multiple approaches are warranted.

3 Experimental Design

Our laboratory experiment consisted of two treatments and each subject participated in only one of the two treatments. In Treatment 1, subjects attended two sessions that were one week apart. In Treatment 2, subjects attended two sessions that were two

[12]See also Engle-Warnick, McCausland, and Miller (2004) who propose a Bayesian method for estimating repeated game strategies, as well as Camera, Casari, and Bigoni (2010) who estimate the strategies used in an RPD game. Davis et al. (2010) classified subjects based on behavior in repeated oligopoly games and studied the effect of group composition on cooperation.

[13]This set is typically small. For example, Dal Bó and Frechétte (2011a) restrict attention to six strategies. Some studies start out with a larger set of strategies (e.g., Engle-Warnick and Slonim (2006)) and reduce this set by trading off in an essentially ad hoc manner goodness-of-fit against a penalty for having more strategies.

weeks apart. In each treatment, subjects were grouped into cohorts, and subjects from the same cohort typically attended sessions 1 and 2 together. In Treatment 1, there were 92 participants who attended the first session and were grouped in three cohorts of roughly equal size; 87 of these participants returned for the second session.[14] In Treatment 2, there were 85 participants who attended both sessions and were grouped in four cohorts of roughly equal size.[15]

Subjects were undergraduate students at Virginia Commonwealth University (VCU). The experiment was conducted at the Experimental Laboratory for Economics and Business Research at VCU. Each session in Treatment 1 lasted around 2 hours; each session in Treatment 2 lasted around 70-90 minutes. The experiment was programmed and conducted with the software z-Tree (Fischbacher (2007)). Below, we describe each treatment in detail.[16]

3.1 Treatment 1

In session 1 of Treatment 1, we used an RMB game and an RPD game, denoted RPD1. The stage games are shown in the top two panels of Figure 1. The Mini-Bertrand stage game is an especially designed version of a regular Bertrand game in which players are allowed to post only three prices–a high price (H), a medium price (M), and a low price (L).[17,18]

Subjects played one practice RMB and thirteen RMB games for cash and, after that, one practice RPD1 and thirteen RPD1 games for cash.[19] In each period, subjects were randomly and anonymously matched into pairs that remained fixed for the whole repeated game being played that period. Each repeated game had a continuation

[14]We also conducted a pilot of Treatment 1 with 12 participants. We exclude the pilot data from the analysis.

[15]In Treatment 2, four subjects attended only one session. These subjects are excluded from the analysis.

[16]Session 2 from Treatment 1 is described in detail in Davis et al. (2013). See footnote 4.

[17]In a regular repeated Bertrand game with many possible prices, it is less clear how to define our aspects.

[18]The payoffs in the Mini-Bertrand matrix can be obtained from a typical Bertrand game in which firms with zero production costs are choosing whether to post a price of 1, 2, or 3 when facing a market demand function $D(\cdot)$ with $D(1) = 40$, $D(2) = 30$, and $D(3) = \frac{80}{3}$.

[19]In the first cohort, subjects played 15 RMB games for cash and 14 RPD1 games for cash. For comparability with the other cohorts, we exclude the last two RMB games and the last RPD1 game from the data analysis.

RMB
$\delta = 0.93$

	H	M	L
H	40,40	0,60	0,40
M	60,0	30,30	0,40
L	40,0	40,0	20,20

RPD1
$\delta = 0.93$

	C	D
C	40,40	0,60
D	60,0	20,20

RPD2
$\delta = 0.75$

	C	D
C	34,34	12,50
D	50,12	25,25

RPD3
$\delta = 0.93$

	C	D
C	10,10	0,15
D	15,0	5,5

Figure 1: Stage games and continuation probabilities, δ. Payoffs are in ECU. The exchange rate for the RMB and RPD1 was 500 ECU/$1. The exchange rate for the RPD2 and RPD3 was 100 ECU/$1.

probability of $\delta = 0.93$ in each round (also shown in Figure 1).[20] In any round during a repeated game, except in round 1, each subject could see the choices she and the other subject had made in all previous rounds of the repeated game.

A subject's earnings in a given period equaled the sum of the experimental currency units (ECU) earned in all rounds of the repeated game being played that period. A subject's total earnings for the session equaled a $6 show-up fee plus the accumulated earnings from all periods, converted at an exchange rate of 500 ECU/$1. Average earnings for the session (including the show-up fee) equaled $24.29.[21,22]

[20]To facilitate comparison across cohorts, game lengths were drawn in advance, and the same game lengths were used in each cohort. The lengths of the thirteen RMB games were 5, 16, 15, 3, 2, 10, 6, 13, 4, 20, 5, 10, and 17 rounds. The lengths of the thirteen RPD1 games were 3, 5, 26, 5, 24, 4, 6, 4, 4, 14, 9, 6, and 25 rounds.

[21]In each round, subjects also had to forecast the current-round choice of the other player and obtained 5 ECU for each correct forecast. This feature of our design was included because we were initially interested in issues that turned out to be peripheral to the final version of this paper. Subjects' forecasts are excluded from the analysis. Subjects' earnings from forecasts made up only a small portion of their total earnings–on average, earnings from forecasts equalled $1.99 (and the maximum was $2.34).

[22]To guarantee that subjects would return for session 2, they were paid only $10 from their earnings at the end of session 1. The balance, plus any earnings in session 2, were paid to them at the end of session 2.

At the start of the session, the experimenter read the instructions aloud as subjects read along, seated at their computer terminals.[23] After clarifying questions, subjects completed a short understanding test. Experimenters walked around checking subjects' quizzes, answering questions, and explaining mistakes. In case a subject made a mistake, extra care was taken to make sure she understood the task.

3.2 Treatment 2

In session 1 of Treatment 2, subjects played a particular RPD game, denoted RPD2. In session 2, which occurred two weeks later, we used another RPD game, denoted RPD3. The stage games are shown in the bottom two panels of Figure 1. The continuation probabilities in the RPD2 and RPD3 were 0.75 and 0.93, respectively, and are also shown in Figure 1. The RPD3 is identical to the RPD1 except that, in the RPD3, the stage game payoffs from the RPD1 are scaled by a factor of 0.25 in ECU terms and 1.25 in dollar terms.[24]

Each of the two sessions in Treatment 2 was identical to the first session in Treatment 1 except that (i) subjects played only one kind of repeated game (namely, the RPD2 in session 1 and the RPD3 in session 2), (ii) subjects played that repeated game once for practice and after that 20 times for cash[25], and (iii) the exchange rate was 100 ECU/$1. Average earnings for the first session, including the $6 show-up fee, equaled $26.07. Average earnings for the second session, including the $6 show-up fee, equaled $27.03.[26]

There were two reasons for having Treatment 2, both of which have to do with the issue of cross-game prediction. First, we wanted to make sure that any conclusions we draw regarding this issue are not based solely on Treatment 1, where both repeated games are played in the same session, but also on Treatment 2, where both repeated games are played in sessions that are temporally quite far apart. Second, we wanted to

[23]The instructions are in the appendix.

[24]The purpose of the scaling was to keep the earnings per session similar across treatments.

[25]To facilitate comparison across cohorts, game lengths were drawn in advance, and the same game lengths were used in each cohort. The lengths of the twenty RPD2 games were 3, 3, 8, 6, 2, 3, 2, 1, 5, 3, 1, 4, 3, 2, 1, 2, 6, 3, 5, and 8 rounds. The lengths of the twenty RPD3 games were 26, 4, 9, 3, 16, 3, 29, 1, 17, 19, 9, 2, 2, 8, 27, 18, 4, 13, 17, and 10 rounds.

[26]To guarantee that subjects would return for the second session, they were paid only $10 from their earnings at the end of the first session. The balance, plus any earnings in the second session, were paid to them at the end of the second session.

look at another pair of games different from the RMB-RPD1 pair used in Treatment 1.[27]

3.3 Some Remarks on the Selection of Games

In choosing the two repeated games used in a given treatment, a main consideration was to have games that are quite different from each other. This is important because (i) it allows us to have more confidence in the generalizability of our conclusions and (ii) the issue of cross-game prediction is interesting only if the repeated games under consideration are not too "similar".

In both the RMB and RPD1 in Treatment 1, the most cooperative action (i.e., H/C in the RMB/RPD1) can be sustained as part of a subgame-perfect Nash equilibrium. Nevertheless, the stage game in the RMB and the stage game in the RPD1 are very different strategically. In the latter, D is a dominant strategy for each player. In the former, there is a unique Nash equilibrium in which both players choose L, but there is no dominant strategy. This suggests, but does not guarantee, that the RMB and RPD1 games are in some sense also quite different from each other.

In Treatment 2, the stage games in the RPD2 and RPD3 are very similar from a theoretical point of view–in both, D is a dominant action. Furthermore, in both the RPD2 and RPD3, cooperation can be sustained as part of a subgame-perfect Nash equilibrium. Nevertheless, the RPD2 and RPD3 differ theoretically in that in the RPD3 cooperation is risk dominant in the sense defined by Dal Bó and Frechétte (2011a) while in the RPD2 it is not.[28] Furthermore, later we will directly compare behavior between the RPD2 and RPD3 and we will show that there are large differences in behavior.[29] Thus, theory aside, even just looking at empirical play, the RPD2 and RPD3 seem like very different games.

[27] The instructions for session 1 in Treatment 2 are in the appendix. The instructions for session 2 are very similar and are available upon request.

[28] Dal Bó and Frechétte (2011a) define risk dominance in the RPD based on a simplified version of the game in which only the always-defect and grim-trigger strategies are available. In particular, cooperation is risk dominant if, in this simplified game, the grimm-trigger strategy is a best response to the other player choosing the always-defect or grimm-trigger strategy with equal probability. This definition is based on Blonksi and Spagnolo (2001).

[29] Because in the RMB and RPD1 the stage games have a different number of available actions, directly comparing empirical play is more tricky. Also, risk dominance is not defined for the RMB.

4 Aspects of Behavior

Consider an RPD game with two players, i and j. Let C stand for "cooperate" and D for "defect." Let (UV, XY,...) denote a history in which i played U and j played V in round 1, i played X and j played Y in round 2, etc., where U,V,X,Y $\in$ {C,D}.

There do exist summary measures of behavior in the RPD. Prime examples are the overall frequency of cooperation, lenience and forgiveness as defined by Dreber, Fudenberg, and Rand (2011)[30], as well as deviation, signaling, and follow on as defined by Sabater-Grande and Georgantzis (2002).[31]

These measures are quite intuitive, but are difficult to interpret for two reasons. First, they lump together histories at which behavior has a potentially very different interpretation from a psychological point of view. To take an extreme example, the overall frequency of cooperation lumps together cooperation at histories as diverse as the empty history, the history consisting of ten rounds of mutual cooperation, and the history consisting of ten rounds of mutual defection.

A second, related reason has to do with the fact that players with different strategies tend to go down different paths in the game tree and, hence, tend to face different histories. In particular, let us say that (i) a given measure is defined based on behavior at, say, histories h and h', (ii) behavior at h and h' has a very different interpretation, and (iii) i tends to face h more often while i' tends to face h' more often. Then, one cannot meaningfully compare the behavior of i and i' using this measure.

One of our main goals in defining our aspects was to minimize the role of these two reasons that obscure interpretation. For each subject i, we consider the following aspects.

- Round-1 cooperation ($C1$): the probability with which i plays C in round 1. Thus, $C1$ is about how a player starts off the game.

- Lenience (Len): the probability with which i plays C at history (CD). Thus,

[30]Lenience is defined as the frequency with which i cooperates at history (CD) or at histories of the sort (CC,...,CC,CD). Forgiveness is defined as the frequency with which i cooperates at histories in which (i) she chose C in the first round, (ii) in at least one previous round, she chose C while j chose D and (iii) in the immediately previous round she played D. These measures are similar in spirit to our aspects Len and $Forg$, which are defined below. In fact, these measures helped inspire our approach.

[31]See Sabater-Grande and Georgantzis (2002) for details.

Len is about not immediately retaliating after a unilateral defection by the other player.

- Forgiveness (*Forg*): the probability with which i plays C at history (CD,DC). Thus, *Forg* is about returning to cooperation after punishing the opponent for a unilateral defection, which the opponent was quick to correct.

- Loyalty (*Loyal*): the probability with which i is not weakly first to play D in a game that starts out with (CC).[32,33] Thus, *Loyal* is about not breaking a streak of mutual cooperation.

- Leadership (*Lead*): the probability with which i is weakly first to play C in a game that starts out with (DD).[34] Thus, *Lead* is about breaking a streak of mutual defections by being the first to cooperate.

- Following (*Foll*): the probability with which i plays C at history (DC). Thus, *Foll* is about switching from D to C in response to the opponent playing C.[35]

Each of $C1$, *Len*, *Forg*, and *Foll* is about behavior at a single history, so that the two reasons for unclear interpretation mentioned above are mute. *Loyal* is about behavior at histories of the sort (CC), (CC,CC), (CC,CC,CC), etc. At these histories, behavior presumably has a similar interpretation from a psychological point of view. Further, although different players may face these histories with different frequencies[36], *Loyal* can be interpreted in a uniform way across players based on the product of the probability of playing C at (CC), (CC,CC), (CC,CC,CC), etc.[37] Analogous

[32] Conditional on the game having at least two rounds.

[33] "weakly first" allows the possibility that both players play the given action simultaneously.

[34] Conditional on the game having at least two rounds.

[35] $C1$, *Len*, *Forg*, and *Foll* are defined based solely on i's strategy. *Loyal* and *Lead* also depend on the distribution of strategies in the population. For example, if everyone except i always plays C at history (DD), it will be difficult for i to be weakly first to play C, so that *Lead* will tend to have a low value for i.

[36] For example, someone who always defects at (CC) will never face (CC,CC).

[37] To be precise, let $p_2, p_3, \ldots$ be the probability that i plays C at history (CC), (CC,CC), $\ldots$, respectively. Let R be the random length of the repeated game and Z be the first round in which a random opponent would break a streak of mutual cooperation that started in round 1 (Z can be infinity). *Loyal* equals $\prod_{r=2}^{r=min\{R,Z\}} p_r$, averaged over R and Z.

remarks apply to *Lead*. As a result, each aspect has a relatively clear interpretation from a psychological point of view.[38]

In the RMB game, we define our aspects exactly as above except that we take "C" to stand for "H" and "D" to stand for "L" or "M." This modification means that a sequence (UV, XY,...), where U,V,X,Y $\in$ {C,D} and there is at least one D, actually lumps together more than one history. For example, (CD) lumps together the histories (HM) and (HL). As a result, the interpretation of Len, $Forg$, $Lead$, and $Foll$ is somewhat less clean than in the RPD games. The hope is that i playing H at the different histories that are lumped together has a similar interpretation. In particular, in the case of $Len/Forg/Foll$, the hope is that i playing H after (HL) and (HM)/(HL,LH), (HL,MH), (HM,LH), and (HM,MH)/(LH) and (MH) has a similar interpretation as lenience/forgiveness/following. We view this as quite realistic. In the case of *Lead*, things are a bit more tenuous because histories such as (LL,LL) and (LL,ML) get lumped together despite the fact that in the latter, one subject already displayed some leadership. However, we still view *Lead* as a reasonable measure.[39]

For each subject i and each repeated game she played (i.e., RMB, RPD1, RPD2, or RPD3), we estimate each aspect in that repeated game by computing the corresponding empirical frequencies, denoted by $\widehat{C1}$, $\widehat{Len}$, $\widehat{Forg}$, $\widehat{Loyal}$, $\widehat{Lead}$, and $\widehat{Foll}$. For example, if in the RPD1 i faced history (CD) 5 times and played C at that history 3 times, $\widehat{Len} = 0.6$.[40] In this regard, two remarks are in order. First, the empirical frequencies are obtained from i's behavior over several periods. (In the previous example, $\widehat{Len}$ was defined based on five periods.) Thus, either one has to

[38] We say "relatively clear" because, when talking about the psychology of play, one cannot avoid some fuzziness. For example, $C1$ may be about one's willingness to risk being the "sucker" or one's trust that the opponent will cooperate; *Len* may be about suppressing one's anger or about making a strategic decision to tolerate some misbehavior by the opponent in order to avoid a "war"; $Forg$ may be about getting over one's anger or about making a strategic decision to try to reestablish mutual cooperation, etc.

[39] An additional issue that applies to all aspects in the RMB is that there is no distinction between the probability with which a subject plays L and M. For example, a high probability of M and a high probability of L in round 1 contribute equally to a low value of $C1$.

[40] Note that some of these empirical frequencies may not be defined for i. For example, if in the RPD1 i never faced history (CD), $\widehat{Len}$ is not defined. In the RMB/RPD1/RPD2/RPD3, $\widehat{C1}$ is defined for 100/100/100/100 percent of subjects, $\widehat{Len}$ is defined for 80/80/80/79 percent of subjects, $\widehat{Forg}$ is defined for 34/36/47/33 percent of subjects, $\widehat{Loyal}$ is defined for 80/90/68/96 percent of subjects, $\widehat{Lead}$ is defined for 74/34/85/16 percent of subjects, and $\widehat{Foll}$ is defined for 71/47/87/34 percent of subjects.

	RMB	RPD1	RPD2	RPD3
$\widehat{C1}$	13	13	20	20
$\widehat{Len}$	3.92	2.86	5.21	2.81
$\widehat{Forg}$	1.39	1.61	1.73	1.46
$\widehat{Loyal}$	5.24	8.51	4.52	15.09
$\widehat{Lead}$	3.35	2.13	6.67	1.50
$\widehat{Foll}$	4.46	4.93	4.72	5.45

Figure 2: Number of observations based on which each aspect is estimated, averaged across subjects for which the given empirical frequency is defined.

make the implicit assumption that the probabilities in the definitions of each aspect are constant across periods[41] or, alternatively, one could view these probabilities as average probabilities across periods.

Second, for a given subject, each of $\widehat{C1}$, $\widehat{Len}$, $\widehat{Forg}$, $\widehat{Loyal}$, $\widehat{Lead}$, and $\widehat{Foll}$ is often computed based on a small number of observations. (Figure 2 shows the number of observations based on which each aspect is estimated, averaged across subjects for which the given empirical frequency is defined.) This means that each aspect will be measured with error. As a result, when we estimate correlations between various aspects or run regressions with aspects as independent variables, the estimates will suffer from attenuation bias–they will typically be biased toward zero.[42] Thus, whenever our estimates are statistically and economically significant, we can view this as quite strong evidence that the actual correlations/slope effects do exist and are probably even larger. On the other hand, whenever our estimates are not statistically and economically significant, this cannot be viewed as strong evidence that the actual correlations/slope effects are negligible.

[41]Although this assumption is clearly a simplification, it is reassuring that, in our experiment, aggregate behavior in a given repeated game does not shift much between early and late periods. In the RMB/RPD1/RPD2/RPD3, the aggregate frequency of C in the first and last five periods equals 0.45 and 0.53/0.69 and 0.73/0.34 and 0.30/0.70 and 0.87, respectively.

[42]Looking at the number of observations based on which each aspect is estimated in Figure 2, it seems that the attenuation bias would tend to be worst for Len, $Forg$, and $Lead$.

5 Results

We proceed to the data analysis. We start by providing some summary statistics. Next, we consider how the different aspects are correlated between each other in each repeated game. Then, we consider whether our aspects are related to behavior at other histories in the same repeated game. After that, we address the issue of cross-game prediction in two ways. First, we consider whether each aspect is correlated between the RMB and RPD1 as well as between the RPD2 and RPD3. Second, we ask whether two players' aspects, as computed based on several periods play of a given repeated game, help predict the frequency of the CC outcome (i.e., the outcome in which both players choose C in the RPD or H in the RMB) if these two players are matched to play either the same repeated game in a new period or an altogether different repeated game. Finally, we consider whether a subject's earnings are related to her aspects.

5.1 Summary Statistics

Figure 3 shows, for the RMB, RPD1, RPD2, and RPD3, the value of each aspect, averaged across subjects. For completeness sake, the figure also reports the frequency with which each subject played C (denoted by $\widehat{C}$), averaged across subjects.

The following observations are worth making. First, for each aspect and $\widehat{C}$, there are considerable differences between the RPD2 and RPD3, confirming that these two repeated games are in some sense very different from each other.[43]

Second, with the possible exception of *Loyal*, which is consistently high, each aspect varies considerably across repeated games. Moreover, the pattern of variation seems to make sense: the average value of each aspect is higher in the RPD1 and RPD3 than in the RPD2. (Recall that in the former two repeated games cooperation is risk dominant while in the latter it is not.)

Third, it seems noteworthy that the average magnitudes of five of the six aspects can be ranked in a uniform way across all four repeated games, namely, on average: $\widehat{Loyal} > \widehat{C1} > \widehat{Forg} > \widehat{Len} > \widehat{Lead}$. $\widehat{Foll}$ almost fits in this ranking, except that it cannot be compared unambiguously to $\widehat{Forg}$ and $\widehat{Len}$.

[43] For each aspect except for *Lead*, the difference between the RPD2 and RPD3 is statistically significant at the 5-percent level (using a paired t-test).

	RMB	RPD1	RPD2	RPD3
$\widehat{C1}$	0.57	0.77	0.43	0.88
	(0.38)	(0.35)	(0.37)	(0.24)
$\widehat{Len}$	0.49	0.56	0.26	0.40
	(0.41)	(0.45)	(0.35)	(0.43)
$\widehat{Forg}$	0.56	0.64	0.41	0.57
	(0.48)	(0.49)	(0.48)	(0.46)
$\widehat{Loyal}$	0.73	0.81	0.78	0.91
	(0.39)	(0.32)	(0.36)	(0.17)
$\widehat{Lead}$	0.33	0.50	0.13	0.27
	(0.36)	(0.43)	(0.25)	(0.42)
$\widehat{Foll}$	0.42	0.60	0.43	0.59
	(0.40)	(0.44)	(0.43)	(0.44)
$\widehat{C}$	0.46	0.68	0.32	0.78
	(0.27)	(0.25)	(0.23)	(0.21)

Figure 3: Aspect averages across subjects. Sample standard errors in parentheses.

5.2 Correlation between Aspects

We now consider how the different aspects are correlated between each other in each repeated game. Line 1/2/3/4 in each cell of Figure 4 shows the correlation between the aspect to the left of the cell and the aspect above the cell in the RMB/RPD1/RPD2/RPD3. For example, we see that the correlation between $\widehat{Lead}$ and $\widehat{Foll}$ in the RPD2 is 0.04. (The numbers in parentheses show the number of subjects based on which the relevant correlation is computed.)

Although the correlations between aspects in a particular repeated game may be of some interest, we are more interested in correlations that systematically exist in different repeated games. Although deciding when such systematic correlations exist based on the observed correlations is necessarily ad hoc, as a practical matter, we say that two aspects are systematically correlated if (i) the correlations in at least three of the four repeated games are of the same sign and are statistically significant at the 5-percent level[44] and (ii) there are no two statistically significant correlations at the 5-percent level that have different signs. Based on this definition, we obtain the

[44]This three-out-of-four criterion also ensures that we would not conclude that there is systematic correlation between two aspects based solely on one of the two treatments.

	$\widehat{C1}$	$\widehat{Len}$	$\widehat{Forg}$	$\widehat{Loyal}$	$\widehat{Lead}$	$\widehat{Foll}$
$\widehat{C1}$	1 (92) 1 (92) 1 (85) 1 (85)					
$\widehat{Len}$	0.41*** (74) 0.11 (74) -0.09 (68) -0.09 (67)	1 (74) 1 (74) 1 (68) 1 (67)				
$\widehat{Forg}$	-0.05 (31) 0.39** (33) 0.09 (40) -0.20 (28)	-0.08 (31) 0.08 (33) 0.25 (40) -0.03 (28)	1 (31) 1 (33) 1 (40) 1 (28)			
$\widehat{Loyal}$	0.58*** (74) 0.72*** (83) 0.38*** (58) 0.45*** (82)	0.40*** (67) 0.16 (73) -0.08 (56) -0.04 (67)	0.35* (29) 0.17 (33) 0.29* (35) 0.24 (28)	1 (74) 1 (83) 1 (58) 1 (82)		
$\widehat{Lead}$	0.15 (68) 0.37** (31) 0.13 (72) 0.41 (14)	0.03 (50) 0.53* (14) 0.11 (55) 0.48 (7)	0.10 (20) . (4) -0.09 (29) . (0)	-0.29** (50) 0.43** (22) -0.19 (45) 0.14 (11)	1 (68) 1 (31) 1 (72) 1 (14)	
$\widehat{Foll}$	0.32** (65) 0.06 (43) 0.47*** (74) 0.42** (31)	0.12 (47) 0.32 (26) 0.15 (57) 0.09 (18)	0.17 (21) -0.24 (13) 0.53*** (32) 1*** (3)	0.17 (47) 0.20 (34) 0.38*** (47) -0.05 (28)	0.11 (61) 0.30 (29) 0.04 (68) 0.76*** (13)	1 (65) 1 (43) 1 (74) 1 (31)

Figure 4: Correlations between aspects. Line 1/2/3/4 in each cell shows the correlation between the aspect to the left of the cell and the aspect above the cell in the RMB/RPD1/RPD2/RPD3. The numbers in parentheses show the number of subjects based on which the relevant correlation is computed. "." means either that there are fewer than two subjects for whom the two relevant aspects are defined or that there was no variation in one of the aspects. */**/*** indicates statistical significance at the 10/5/1 percent level.

	RMB	**RPD1**	**RPD2**	**RPD3**
$\widehat{Len}$ vs. $\widehat{Len}'$	0.61*** (73)	0.50*** (73)	-0.07 (62)	-0.05 (64)
$\widehat{Forg}$ vs. $\widehat{Forg}'$	0.46** (19)	0.31 (28)	0.04 (11)	0.38 (17)
$\widehat{Loyal}$ vs. $\widehat{Loyal}'$	0.66*** (70)	0.45*** (79)	0.65*** (40)	0.21* (69)
$\widehat{Lead}$ vs. $\widehat{Lead}'$	0.21* (68)	0.39** (31)	0.42*** (72)	0.36 (14)
$\widehat{Foll}$ vs. $\widehat{Foll}'$	0.41*** (64)	0.40*** (43)	0.45*** (69)	0.55*** (27)

Figure 5: Aspects and behavior at other histories. The numbers in parentheses show the number of subjects based on which the relevant correlation is computed. */**/*** indicates statistical significance at the 10/5/1 percent level.

following result.

Result 1 *The following pairs of aspects are systematically correlated: (i) $\widehat{C1}$ and $\widehat{Loyal}$ as well as (ii) $\widehat{C1}$ and $\widehat{Foll}$.*

For these pairs of aspects, the magnitude of the correlations is economically significant. Because of the attenuation bias, we must remain largely agnostic regarding whether other pairs of aspects are correlated in a systematic way.[45]

5.3 Aspects and Behavior at Other Histories

Our aspects are about behavior at a limited set of histories. Nevertheless, similar psychological considerations might arise at many other histories in the repeated game, so that our aspects might be informative about players' behavior at those other histories as well. To explore this possibility, we compute alternative measures to $\widehat{Len}$, $\widehat{Forg}$, $\widehat{Loyal}$, $\widehat{Lead}$, and $\widehat{Foll}$: $\widehat{Len}'$, $\widehat{Forg}'$, $\widehat{Loyal}'$, $\widehat{Lead}'$, and $\widehat{Foll}'$, respectively. Each of these alternative measures is computed based on histories at which, to some extent, similar psychological considerations might arise as at the histories based on which the respective original aspect is computed.[46,47]

In particular, for each player i, the alternative measures are defined as follows:

[45]Informally eye-balling Figure 4, one might be inclined to say that some kind of systematic correlation also exists between $\widehat{Loyal}$ and $\widehat{Forg}$ as well as between $\widehat{Foll}$ and $\widehat{Forg}$.

[46]The alternative measures are theoretically less clean than our original aspects in that the alternative measures lump together behavior at quite diverse histories.

[47]We did not compute an alternative measure to $\widehat{C1}$ because it is not obvious at which histories similar psychological considerations arise as at the initial history.

- $\widehat{Len}'$: frequency with which i played C after i played C and the other player, j, played D in the last round, excluding observations from round 2.[48]

- $\widehat{Forg}'$: frequency with which i played C after (i) i played C and j played D two rounds ago and (ii) i played D and j played C in the last round, excluding observations from round 3.

- $\widehat{Loyal}'$: frequency with which i played C after both players played C in the last round, excluding observations when both players played C in all previous rounds.

- $\widehat{Lead}'$: frequency with which i played C after both players played D in the last round, excluding observations when both players played D in all previous rounds.

- $\widehat{Foll}'$: frequency with which i played C after i played D and j played C in the last round, excluding observations from round 2.

Figure 5 reports, for each repeated game, the correlation between each aspect and the respective alternative measure. With two exceptions, all correlations are positive. Similar to what we did earlier, we say that an aspect and the corresponding alternative measure are systematically correlated if (i) the correlations in at least three of the four repeated games are positive and are statistically significant at the 5-percent level and (ii) there is no statistically significant correlation at the 5-percent level that is negative. Based on this, we obtain the following result.

Result 2 *The following pairs consisting of an aspect and the corresponding alternative measure are systematically correlated: (i) $\widehat{Loyal}$ and $\widehat{Loyal}'$ as well as (ii) $\widehat{Foll}$ and $\widehat{Foll}'$.*

In addition, $\widehat{Lead}$ and $\widehat{Lead}'$ miss the bar for systematic correlation only slightly with a correlation in the RMB that is significant only at the 10-percent level. $\widehat{Forg}$

[48]We exclude observations from round 2, so that $\widehat{Len}'$ is defined based on histories that do not include the history based on which $\widehat{Len}$ is defined. If $\widehat{Len}$ and $\widehat{Len}'$ were defined based on overlapping histories, it would not be surprising to find a positive correlation between these two measures. Analogous adjustments are made to the remaining four alternative measures below.

	RMB vs. RPD1	RPD2 vs. RPD3
$\widehat{C1}$	0.53*** (92)	0.35*** (85)
$\widehat{Len}$	0.49*** (63)	0.42*** (57)
$\widehat{Forg}$	0.10 (17)	0.48** (18)
$\widehat{Loyal}$	0.52*** (70)	0.15 (57)
$\widehat{Lead}$	0.21 (28)	0.24 (13)
$\widehat{Foll}$	0.49*** (39)	0.47*** (31)

Figure 6: Correlation for each aspect across repeated games. */**/*** indicates statistical significance at the 10/5/1 percent level.

and $\widehat{Forg}'$ are also not too far from the bar for systematic correlation with p-values in the RPD1 and RPD3 of 0.11 and 0.14, respectively. $\widehat{Len}$ and $\widehat{Len}'$ are positively correlated in a statistically significant way in two of the four repeated games. Our overall conclusion based on Figure 5 is that our aspects tend to be related to play at other histories in a given repeated game.

5.4 Correlation of Each Aspect across Repeated Games

In this section we turn to the issue of cross-game prediction by asking whether each aspect is positively correlated across repeated games. That is, do players with a relatively high value of a given aspect in one repeated game tend to have a relatively high value of that aspect in another repeated game. Figure 6 reports the relevant correlations for each aspect between the RMB and RPD1 as well as between the RPD2 and RPD3. Based on the figure, we can state the following.

Result 3 *For each aspect, the correlation is positive both between the RMB and RPD1 as well as between the RPD2 and RPD3. For each of $\widehat{C1}$, $\widehat{Len}$, and $\widehat{Foll}$, the correlation is statistically significant (at the 1-percent level) for both pairs of repeated games. For each of $\widehat{Forg}$ and $\widehat{Loyal}$, the correlation is statistically significant (at the 5-percent level) only for one pair of repeated games.*

Moreover, all statistically significant correlations are also economically significant.

The discrepancy in the size of the correlation of $\widehat{Forg}$ in the two pairs of repeated games (0.10 vs. 0.48) could be due to the fact that both correlations are computed based on a small number of subjects. Most puzzling is the discrepancy in the size of the correlation of $\widehat{Loyal}$ in the RMB-RPD1 and the RPD2-RPD3 pairs of games (0.52 vs. 0.15, respectively). On could conjecture that the latter correlation is lower because the RPD2 and RPD3 are played with a two-week break in between. However, observe that there is no clear tendency for the correlations in the second column of Figure 6 to be lower than the correlations in the first column. Our overall conclusion based on Figure 6 is that our aspects do tend to be positively correlated across repeated games.

5.5 Can Players' Aspects Predict the Frequency of the CC Outcome?

Consider two subjects, i and j, who are matched together to play a repeated game. Let $FreqCC$ denote the frequency of the CC outcome in that repeated game and, for each aspect, let a subscript i/j indicate that we are referring to i's/j's aspect. (For example, $\widehat{Len}_i$ refers to i's lenience.) For $l \in \{i, j\}$, let $MiLen_l/MiForg_l/MiLoyal_l/MiLead_l/MiFoll_l$ be a dummy that equals 1 if $Len_l/Forg_l/Loyal_l/Lead_l/Foll_l$ is not defined and equals 0 otherwise.

We run the following OLS regression:

$$\begin{aligned} FreqCC \;=\;& \beta_0 + \beta_1(\widehat{C1}_i + \widehat{C1}_j) + \beta_2(\widehat{Len}_i + \widehat{Len}_j) + \beta_3(\widehat{Forg}_i + \widehat{Forg}_j) + \\ & \beta_4(\widehat{Loyal}_i + \widehat{Loyal}_j) + \beta_5(\widehat{Lead}_i + \widehat{Lead}_j) + \beta_6(\widehat{Foll}_i + \widehat{Foll}_j) + \\ & \beta_7(MiLen_i + MiLen_j) + \beta_8(MiForg_i + MiForg_j) + \beta_9(MiLoyal_i + MiLoyal_j) + \\ & \beta_{10}(MiLead_i + MiLead_j) + \beta_{11}(MiFoll_i + MiFoll_j) + \varepsilon, \end{aligned} \tag{1}$$

where ε is the idiosyncratic error term.[49]

A problem arises because, whenever not all aspects are defined for both subjects (something that happens very often), we lose an observation. To avoid this, for the purposes of running regression (1), we adopt the convention that a missing value of a

[49] Given that which subject is i and which j is arbitrary, the regression above implicitly imposes the natural assumption the the coefficient on a given aspect/dummy for i and the coefficient on same aspect/dummy for j are the same.

FreqCC from:	**RMB, periods 8-13**	**RPD1, periods 8-13**	**RPD2, periods 11-20**	**RPD3, periods 11-20**	**RMB**	**RPD1**	**RPD2**	**RPD3**
indep. variables from:	**RMB, periods 1-7**	**RPD1, periods 1-7**	**RPD2, periods 1-10**	**RPD3, periods 1-10**	**RPD1**	**RMB**	**RPD3**	**RPD2**
$\widehat{C1}_i + \widehat{C1}_j$	0.61***	-0.01	0.37***	0.07	-0.13	0.28***	0.33***	0.08
	(0.18)	(0.10)	(0.10)	(0.09)	(0.08)	(0.08)	(0.08)	(0.06)
$\widehat{Len}_i + \widehat{Len1}_j$	0.02	-0.04	-0.00	-0.05**	0.23***	-0.00	0.04	0.04
	(0.05)	(0.05)	(0.03)	(0.02)	(0.05)	(0.03)	(0.03)	(0.03)
$\widehat{Forg}_i + \widehat{Forg}_j$	-0.02	0.09*	-0.03	0.03	-0.11***	0.06	0.10***	0.07***
	(0.07)	(0.05)	(0.05)	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)
$\widehat{Loyal}_i + \widehat{Loyal}_j$	0.10	0.32***	0.11**	0.29***	0.32***	0.10**	-0.06	0.20***
	(0.07)	(0.05)	(0.04)	(0.05)	(0.05)	(0.04)	(0.07)	(0.04)
$\widehat{Lead}_i + \widehat{Lead}_j$	-0.10*	0.16***	-0.12***	-0.19**	0.08**	-0.02	0.02	-0.13***
	(0.06)	(0.05)	(0.04)	(0.09)	(0.04)	(0.04)	(0.05)	(0.05)
$\widehat{Foll}_i + \widehat{Foll}_j$	0.09*	0.25***	0.10***	0.13**	0.08**	0.18***	0.05	-0.05
	(0.05)	(0.05)	(0.04)	(0.06)	(0.03)	(0.03)	(0.03)	(0.03)
$MiLen_i + MiLen_j$	0.06	-0.10**	0.02	-0.03	0.21***	0.07*	0.00	-0.14***
	(0.06)	(0.05)	(0.03)	(0.02)	(0.05)	(0.04)	(0.03)	(0.04)
$MiForg_i + MiForg_j$	0.12**	0.20***	0.02	0.04	-0.26***	0.11***	0.03	0.02
	(0.06)	(0.06)	(0.04)	(0.03)	(0.05)	(0.04)	(0.03)	(0.03)
$MiLoyal_i + MiLoyal_j$	0.12*	0.04	0.07*	-0.39***	0.09**	0.01	0.04	0.18***
	(0.07)	(0.07)	(0.04)	(0.10)	(0.05)	(0.05)	(0.06)	(0.04)
$MiLead_i + MiLead_j$	-0.17**	0.24***	-0.02	-0.10***	0.13**	-0.09**	-0.15***	-0.02
	(0.07)	(0.06)	(0.05)	(0.04)	(0.05)	(0.03)	(0.03)	(0.04)
$MiFoll_i + MiFoll_j$	0.04	0.17***	0.05	0.08	0.17***	0.14***	0.09***	-0.03
	(0.08)	(0.05)	(0.05)	(0.05)	(0.04)	(0.04)	(0.03)	(0.04)
Constant	-0.58***	-0.73***	-0.37***	0.28*	-0.25**	-0.13	-0.28**	0.45***
	(0.20)	(0.14)	(0.12)	(0.17)	(0.11)	(0.10)	(0.13)	(0.10)
Observations	276	276	420	410	598	598	840	820
R-squared	0.38	0.62	0.36	0.60	0.32	0.26	0.09	0.13

Figure 7: Regressions of *FreqCC* on both players' aspects. Robust standard errors in parentheses. */**/*** indicates statistical significance at the 10/5/1 percent level.

given aspect for a given subject is replaced by 0. To understand this convention and the functional specification above, assume that, say, Len_l is not missing ($l \in \{i, j\}$). Then, β_2 captures the effect on *FreqCC* of increasing the value of Len_l. If $\widehat{Len_l}$ is missing, $MiLen_l = 1$ and β_7 allows for the possibility that $FreqCC$ differs between the case when $\widehat{Len_l}$ is missing and is artificially set to 0 and the case when $\widehat{Len_l}$ is not missing and really does equal 0. The logic is analogous for aspects other than $\widehat{Len_l}$.[50,51]

We would first like to investigate whether players' aspects in a given repeated game help predict $FreqCC$ across periods for the same repeated game. To do this for the RMB/RPD1/RPD2/RPD3, we run regression 1 with players' aspects computed based on periods 1-7/1-7/1-10/1-10 and $FreqCC$ computed based on periods 8-13/8-13/11-20/11-20. The first four columns in Figure 7 report the results.

Similar to what we did earlier, we say that an aspect systematically predicts the frequency of the CC outcome across periods for a given repeated game if (i) the corresponding coefficient estimates in at least three of the first four columns in Figure 7 are of the same sign and are statistically significant at the 5-percent level and (ii) of these four coefficient estimates, there are no two that are statistically significant at the 5-percent level and have different signs. Based on this, we can state:

Result 4 *Loyal and $Foll$ systematically predict the frequency of the CC outcome across periods for a given repeated game.*

In addition, $C1$ also has a very strong, statistically significant impact on $FreqCC$ for one of the two games in each treatment.

Note that computing aspects based solely on the first half of the periods in which a given repeated game is played exacerbates the measurement error issues by roughly halving the numbers in Figure 2 as well as by reducing the number of subjects for which each aspect is defined. Thus, the estimated coefficients in Figure 7 are potentially heavily biased towards 0.

[50] The estimated coefficients on the dummy variables are not of particular interest. We report them merely for completeness.

[51] Given that each subject plays the same repeated game for several periods, each time against different opponents, there are complicated dependencies between periods. The OLS regression ignores such dependencies, which probably makes the statistical tests overly sensitive. Thus, the statistical significance of the estimated coefficients should be treated with caution.

Next, we explore whether players' aspects in a given repeated game help predict $FreqCC$ in an altogether different repeated game. To do this, we run regression (1) by taking $FreqCC$ and subjects' aspects from different repeated games. Columns 5-8 in Figure 7 reports the results.

Similar to earlier, we say that an aspect systematically predicts the frequency of the CC outcome across repeated games if (i) the corresponding coefficient estimates in at least three of the four last columns in Figure 7 are of the same sign and are statistically significant at the 5-percent level and (ii) of these four coefficient estimates, there are no two that are statistically significant at the 5-percent level and have different signs. Based on this, we can state:

Result 5 *Loyal systematically predicts the frequency of the CC outcome across repeated games.*

Eyeballing Figure 7, one might be inclined to say that $C1$ and $Foll$ also tend to predict to some extent the frequency of the CC outcome across repeated games. In the case of $Foll$, the evidence for this comes solely from Treatment 1.

One might have hoped that more aspects would systematically predict $FreqCC$ across periods in a given repeated game and across repeated games. We can think of three reasons this does not occur. First, because aspects are computed with measurement error, the estimated coefficients in Figure 7 (especially, in columns 1-4) tend to be biased toward zero. Second, aspects are imperfectly correlated across periods for the same repeated game and across different repeated games. Thus, a high value of, say, *Len* for a subject based on the first half of periods for a given repeated game does not necessarily imply a high value of *Len* in the second half of periods; similarly, a high value of *Len* for a subject based on one repeated game (say, the RMB) does not necessarily imply a high value of *Len* in another repeated game (say, the RPD1). Third, the theoretical link between aspects and $FreqCC$ is not quite clear (and may depend on the repeated game). For example, if a subject is very lenient, the other subject might exploit this, which leads to a low frequency of the CC outcome.

	RMB	**RPD1**	**RPD2**	**RPD3**
$\widehat{C1}$	1.27**	-0.49	-1.45*	1.52
	(0.50)	(0.58)	(0.80)	(1.62)
$\widehat{Len}$	-0.48*	-0.10	-0.11	0.94**
	(0.26)	(0.35)	(0.45)	(0.47)
$\widehat{Forg}$	0.78**	0.36*	-1.12***	1.14**
	(0.32)	(0.22)	(0.31)	(0.53)
$\widehat{Loyal}$	-0.22	0.74***	-0.23	3.10***
	(0.30)	(0.22)	(0.38)	(0.92)
$\widehat{Lead}$	-0.34	0.40	-0.64	-2.65*
	(0.31)	(0.30)	(0.40)	(1.37)
$\widehat{Foll}$	0.33	0.69***	0.22	1.44**
	(0.26)	(0.22)	(0.39)	(0.62)
MiLen	0.08	-0.10	1.40***	1.68***
	(0.25)	(0.45)	(0.41)	(0.40)
MiForg	0.86***	0.36	-1.36***	0.17
	(0.30)	(0.35)	(0.45)	(0.50)
MiLoyal	0.09	0.04	-0.94**	-1.89
	(0.28)	(0.42)	(0.41)	(1.56)
MiLead	-0.00	0.48	-0.43	-0.61
	(0.28)	(0.39)	(0.45)	(0.79)
MiFoll	0.44	1.00***	0.82	1.35**
	(0.34)	(0.27)	(0.55)	(0.63)
Constant	5.91***	7.57***	21.74***	15.51***
	(0.34)	(0.29)	(0.67)	(1.48)
Observations	92	92	85	85
R-squared	0.34	0.47	0.31	0.59

Figure 8: Regressions of *Earnings* on aspects. Robust standard errors in parentheses. */**/*** indicates statistical significance at the 10/5/1 percent level.

5.6 Aspects and Individual Profits

In this section, we consider the following question for each repeated game: Are a subject's earnings related to her aspects? To address this question we run the following regression:

$$\begin{aligned} Earnings &= \beta_0 + \beta_1 \widehat{C1} + \beta_2 \widehat{Len} + \beta_3 \widehat{Forg} + \beta_4 \widehat{Loyal} + \beta_5 \widehat{Lead} + \beta_6 \widehat{Foll} + \\ &\quad \beta_7 MiLen + \beta_8 MiForg + \beta_9 MiLoyal + \beta_{10} MiLead + \beta_{11} MiFoll + \varepsilon, \end{aligned}$$

where *Earnings* shows a subject's earnings in US dollars from all periods in which a given repeated game is played and the remaining variables are just as in regression (1), except that, because there is only one subject per observation, we have dropped the subscripts.

Figure 8 reports the results of this regression for each repeated game. Similar to earlier, we say that an aspect is systematically correlated with individual profits if (i) the corresponding coefficient estimates in at least three of the four columns in Figure 8 are of the same sign and are statistically significant at the 5-percent level and (ii) of these four coefficient estimates, there are no two that are statistically significant at the 5-percent level and have different signs. Based on this, we can state:

Result 6 *No aspect is systematically correlated with individual profits.*

Eyeballing Figure 8, one might be inclined to say that *Foll* and *Loyal* tend to display some kind of systematic correlation with individual profits.

6 Concluding Remarks

The current paper introduces a new approach to studying behavior in repeated games, one that is based on the psychology of play. In particular, we aim to carefully define and explore notions, such as loyalty, lenience, etc., that are likely to play a prominent role in how a player thinks about her own and her opponent's behavior.

A limitation of our paper is that aspects are measured with error, so that our study is biased toward negative results. Nevertheless, we do find some statistically and economically significant correlations between aspects in a given repeated game, between aspects and behavior at other histories in a given repeated game, as well as for a given aspect across repeated games. We also find that players' values of *Loyal* tend to predict the frequency of the CC outcome across periods for a given repeated game as well as across different repeated games. Players' values of *Foll* also tend to predict across periods for a given repeated game.

An important question is whether aspects capture intrinsic psychological propensities of players. Our findings do suggest that aspects capture psychological propensities that operate in a systematic way across different histories in a given repeated game (Result 2) and across different repeated games (Result 3). Nevertheless, we hesitate to claim that each aspect necessarily corresponds to a separate psychological propensity. For example, different aspects may be driven by some common, deeper psychological propensity.[52] Of course, completely different psychological propensities from those that our aspects capture may also be at work in repeated games.

A sceptic may argue that the correlations in Figures 5 and 6 as well as, especially, the slope coefficient estimates in Figure 7 would need to be larger for our approach to be useful. We largely share such scepticism. Our goal is not to present a new approach that definitely solves perennial problems in repeated games. We merely wish to propose and evaluate a novel, intuitive approach. The fact that, we do get some positive results is heartening. Given the importance of repeated games and the difficulty of making progress in the area, we believe our approach is worth considering and merits further study.

We see the following avenues for further research. First, it is worth thinking about designs that would allow more observations at the histories based on which our aspects are defined. This would reduce the measurement error. Second, one might think about whether some aspects need to be dropped, other aspects combined, and yet other aspects added. Third, given the limitations of a single study, in our experiment we could consider only a small number of repeated games. To what extent our results generalize to other repeated games is an open question, one that is also left for further

[52]In an earlier working paper version of the current paper, we proposed the hypothesis that players in repeated games can be ranked in a one-dimensional way based on a single "propensity to cooperate." Although the low correlations we observe between many aspects in Figure 4 may be due to the attenuation bias, they have nevertheless made us more sceptical of our initial hypothesis.

research.

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Instructions for Session 1 in Treatment 1

Welcome! This is an experiment in decision-making. Funding for this experiment has been provided by the National Science Foundation and Virginia Commonwealth University. The experiment consists of two sessions—one today and one next week. You are required to participate in both sessions. Each session is expected to last up to 2 hours.

For today's session, you will receive a $6 show-up fee. In addition, you will have the opportunity to earn Experimental Currency Units (ECU). ECU will be converted into dollars at a rate of 500 ECU=$1. Thus, your earnings in today's session will equal:

$$\$6 + \frac{1}{500}(\text{ECU earned in today's session})$$

You will receive only $10 in cash at the end of today's session. The remainder of your earnings from today's session will be paid to you at the end of next week's session. Note that you need to show up punctually for next week's session. If you fail to do so, any earnings from today's session over and above $10 will be lost. If you do show up punctually for next week's session, you will:

- be paid the remainder of your earnings from today's session;
- receive a $6 show-up fee for attending next week's session;
- have the opportunity to earn more money during next week's session.

Note that your decisions are likely to considerably affect your earnings. If you follow the instructions carefully and make good decisions, you can earn a considerable amount of money.

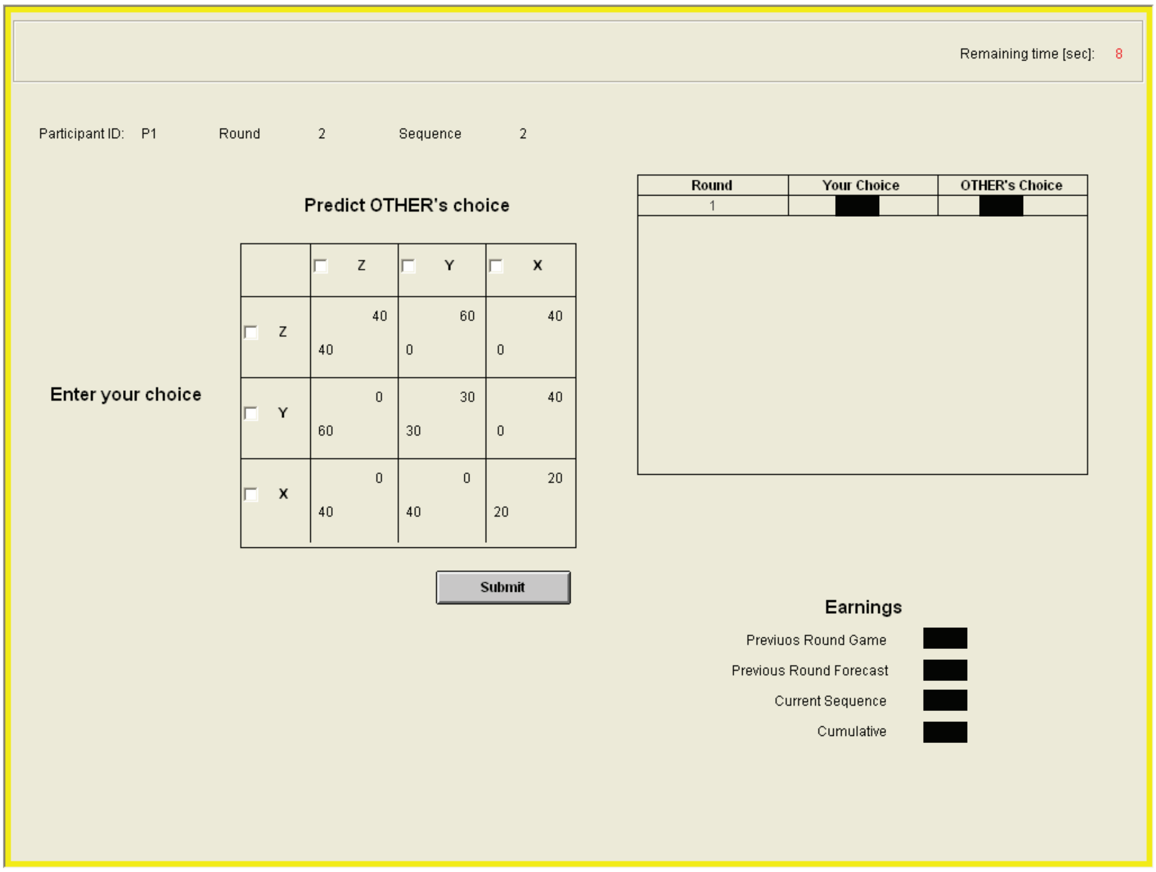
Caution: This is a serious experiment and talking, looking at others' screens, or exclaiming aloud are not allowed. Should you have any questions please raise your hand and an experimenter will come to you.

1. <u>Session Structure</u>

Today’s session is divided into a series of *sequences*. A *sequence* will consist of an indefinite number of *rounds*. At the beginning of each sequence, you will be matched with someone else in this room. You will remain matched with this same person for every round in the sequence. We will refer to the person you are matched with in a given sequence as OTHER.

2. <u>Tasks in each round</u>

In each round, you and OTHER will play the game shown below. In this game, each of you can make any one of three choices: X, Y or Z. You and OTHER will make your choices simultaneously without knowing each other’s choice.
In each round, you must also give your best forecast of what OTHER will choose.



3. <u>Earnings in each round</u>

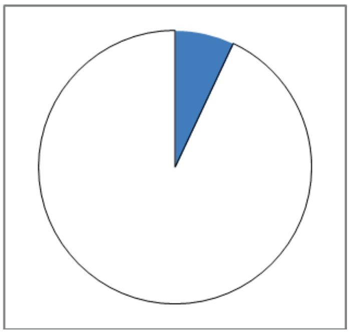
The ECU you earn in a round are determined based on the combination of your decision and OTHER’s decision. This combination determines a box in the table. Your earnings are listed in the lower left hand corner of the box. OTHER’s earnings are listed in the upper right corner.
In addition, remember that you will also need to give your best forecast of OTHER’s choice. We will pay you 5 ECU if this forecast is correct.

4. Earnings for each sequence and for the session
The earnings for a sequence will equal the sum of the earnings from all rounds within the sequence. Your earnings for the session will equal the sum of the earnings from all sequences (plus the show-up fee).

5. Information on the screen
In the upper-right corner of the screen, there will be a table showing the decisions you and OTHER made in previous rounds of the current sequence.
In the lower-right corner, you can see:
- your earnings from the combination of your decision and OTHER’s decision in the previous round;
- your earnings from your forecast of OTHER’s decision in the previous round;
- your earnings from all previous rounds of the current sequence;
- your cumulative earnings from the session so far (excluding your show-up fee).

6. Length of sequence
The number of rounds in a sequence will be determined randomly. In particular, after each round there is a 93% probability that the sequence continues and a 7% probability that the sequence ends. After a sequence ends, a new sequence is started.

One way to understand the above probabilities is to imagine that after each round the computer “spins a roulette wheel” like the one shown below. If the ball lands in the white area, the sequence continues; if it lands in the dark area, the sequence ends.



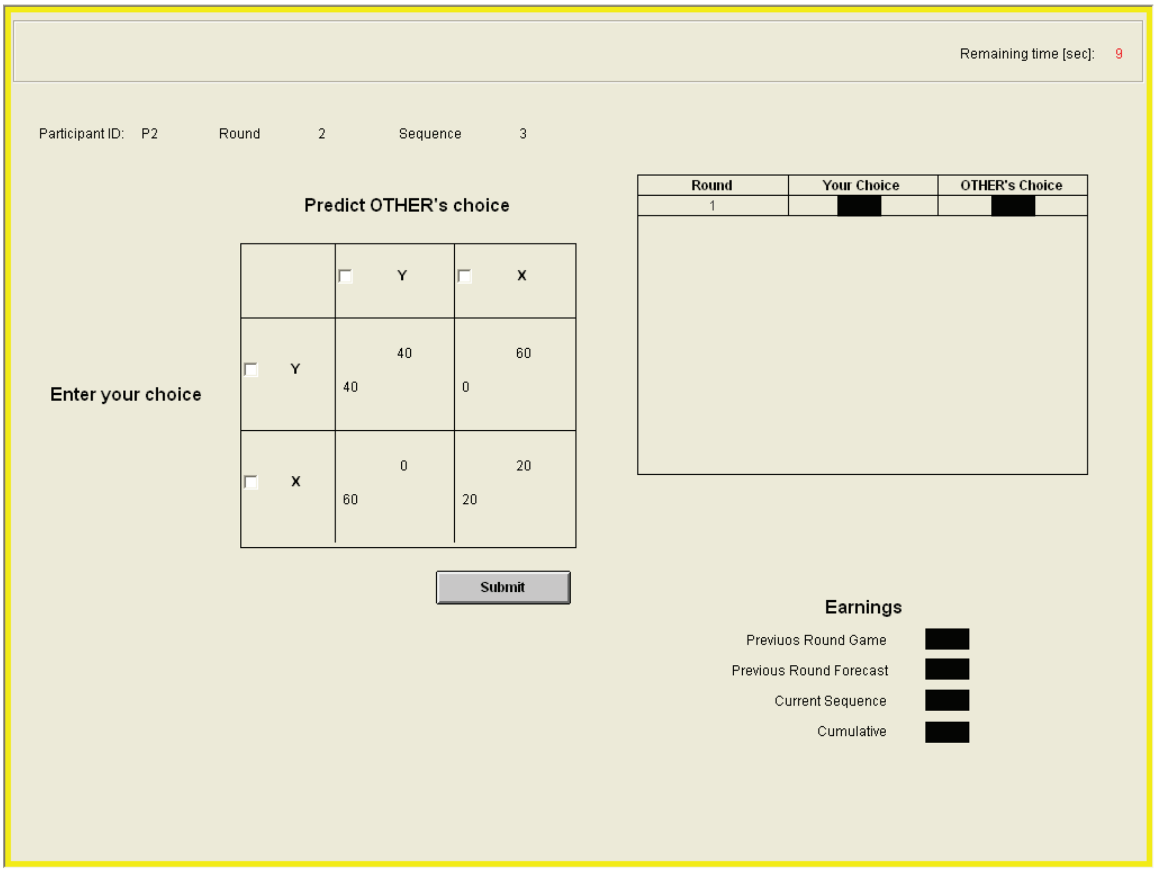
Note that after each round the probability of continuation is always 93%. In other words, regardless of whether the sequence just started or whether it has been going on for multiple rounds, the probability of continuation is always 93%.

7. Random re-matching
At the beginning of each new sequence, you are randomly re-matched with another person. This person will be different from the person you were matched with in the previous sequence.

8. Decision time
In each round, you will have 10 seconds to choose X, Y, or Z and to make your forecast of OTHER’s choice. Please do not take longer than that.

9. <u>Another game</u>

In later sequences, the game played will change to the one shown in the screenshot below. Everything else remains the same as with the previous game.



<u>Any questions</u>?

Questionnaire:

Prior to beginning please answer the following questions:

First, suppose you are playing the first game shown above.

1. If you choose X and OTHER chooses X, you will earn ______ ECU and OTHER will earn ______ ECU.
2. If you choose X and OTHER chooses Y, you will earn ______ ECU and OTHER will earn ______ ECU.
3. If you choose X and OTHER chooses Z, you will earn ______ ECU and OTHER will earn ______ ECU.
4. If you choose Y and OTHER chooses X, you will earn ______ ECU and OTHER will earn ______ ECU.
5. If you choose Y and OTHER chooses Y, you will earn ______ ECU and OTHER will earn ______ ECU.
6. If you choose Y and OTHER chooses Z, you will earn ______ ECU and OTHER will earn ______ ECU.
7. If you choose Z and OTHER chooses X, you will earn ______ ECU and OTHER will earn ______ ECU.
8. If you choose Z and OTHER chooses Y, you will earn ______ ECU and OTHER will earn ______ ECU.
9. If you choose Z and OTHER chooses Z, you will earn ______ ECU and OTHER will earn ______ ECU.
10. If your forecast is that OTHER will choose Z and OTHER actually chooses X, you will earn _____ ECU for your forecast.

Second, suppose you are playing the second game shown above.

1. If you choose X and OTHER chooses X, you will earn ______ ECU and OTHER will earn ______ ECU.
2. If you choose X and OTHER chooses Y, you will earn ______ ECU and OTHER will earn ______ ECU.
3. If you choose Y and OTHER chooses X, you will earn ______ ECU and OTHER will earn ______ ECU.
4. If you choose Y and OTHER chooses Y, you will earn ______ ECU and OTHER will earn ______ ECU.
5. If your forecast is that OTHER will choose Y and OTHER actually chooses Y, you will earn _____ ECU for your forecast.

Any questions?

Let's proceed with a practice sequence. In this practice sequence, you are not playing for real money. Also, you will be given longer to make your decisions in each round.

Instructions for Session 1 in Treatment 2

Welcome! This is an experiment in decision-making. Funding for this experiment has been provided by the National Science Foundation and Virginia Commonwealth University. The experiment consists of two sessions—one today and one in two weeks. You are required to participate in both sessions. Each session can last up to 1.5 hours.

For today's session, you will receive a $6 show-up fee. In addition, you will have the opportunity to earn money during the session. Thus, your earnings in today's session will equal:

$6 + money earned during today's session

You will receive only $10 in cash at the end of today's session. The remainder of your earnings from today's session will be paid to you at the end of the next session. Note that you need to show up punctually for the next session. If you fail to do so, any earnings from today's session over and above $10 will be lost. If you do show up punctually for the next session, you will:

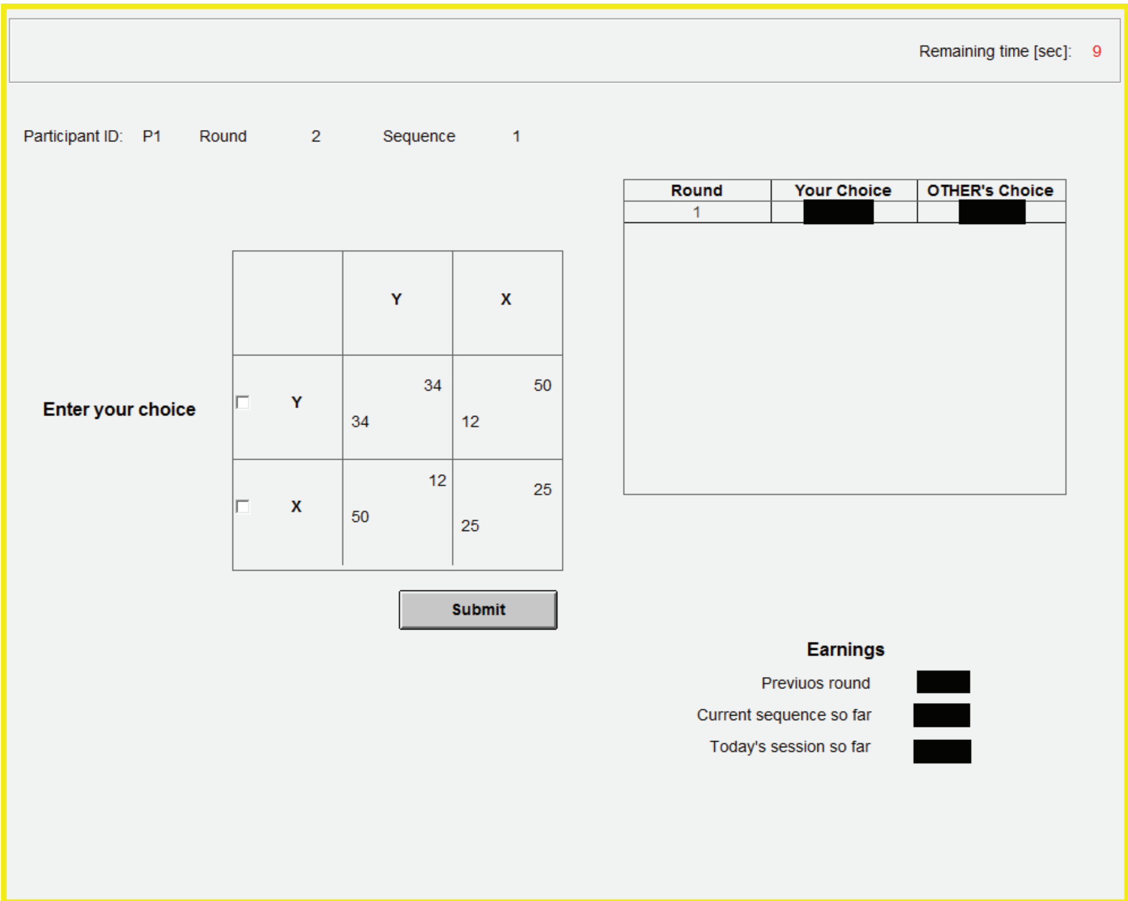
- be paid the remainder of your earnings from today's session;
- receive a $6 show-up fee for attending the next session;
- have the opportunity to earn more money during the next session.

Note that your decisions are likely to considerably affect your earnings. If you follow the instructions carefully and make good decisions, you can earn a considerable amount of money.

Caution: This is a serious experiment and talking, looking at others' screens, or exclaiming aloud are not allowed. Should you have any questions please raise your hand and an experimenter will come to you.

1. <u>Session Structure</u>
Today's session is divided into a series of *sequences*. A *sequence* will consist of an indefinite number of *rounds*. At the beginning of each sequence, you will be matched with someone else in this room. You will remain matched with this same person for every round in the sequence. We will refer to the person you are matched with in a given sequence as OTHER.

2. <u>Task in each round</u>
In each round, you and OTHER will play the game shown below. In this game, each of you can make any one of two choices: X or Y. You and OTHER will make your choices simultaneously without knowing each other's choice.



3. <u>Earnings in each round</u>
The money (in cents) you earn in a round are determined based on the combination of your decision and OTHER's decision. This combination determines a box in the table. Your earnings are listed in the lower left hand corner of the box. OTHER's earnings are listed in the upper right corner.

4. <u>Earnings for each sequence and for the session</u>

The earnings for a sequence will equal the sum of the earnings from all rounds within the sequence. Your earnings for the session will equal the sum of the earnings from all sequences (plus the show-up fee).

5. Information on the screen

In the upper-right corner of the screen, there will be a table showing the decisions you and OTHER made in previous rounds of the current sequence.

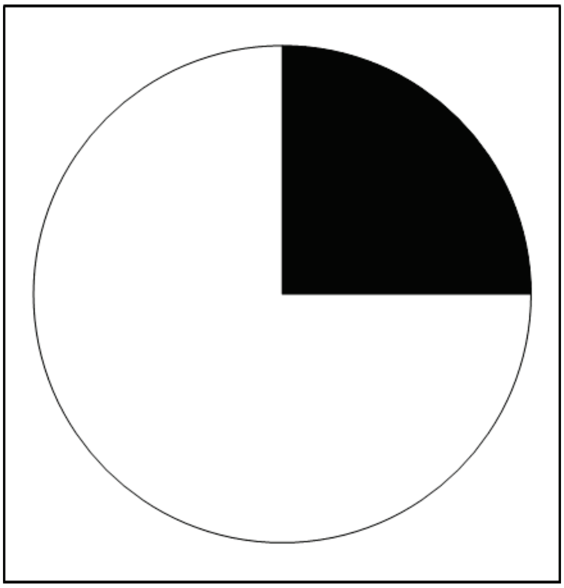
In the lower-right corner, you can see:

- your earnings from the combination of your decision and OTHER's decision in the previous round;
- your earnings from all previous rounds of the current sequence;
- your cumulative earnings from the session so far (excluding your show-up fee).

6. Length of sequence

The number of rounds in a sequence will be determined randomly. In particular, after each round there is a 75% probability that the sequence continues and a 25% probability that the sequence ends. After a sequence ends, a new sequence is started.

One way to understand the above probabilities is to imagine that after each round the computer "spins a roulette wheel" like the one shown below. If the ball lands in the white area, the sequence continues; if it lands in the dark area, the sequence ends.



Note that after each round the probability of continuation is always 75%. In other words, regardless of whether the sequence just started or whether it has been going on for multiple rounds, the probability of continuation is always 75%.

Also note that the lengths of previous sequences in no way affect the lengths of future sequences. For example, if a given sequence happens to be long, this says nothing about the length of the next sequence.

7. Random re-matching

At the beginning of each new sequence, you are randomly re-matched with another person. This person is very unlikely to be the same person as the one with whom you were matched in the previous sequence. Thus OTHER will always be the same person for all rounds in a given sequence, but will almost always be a new person in the next sequence.

8. Decision time

In each round, you will have 10 seconds to choose X or Y. Please do not take longer than that.

Any questions?

Prior to beginning please complete the following questionnaire.

Questionnaire:

Suppose you are playing the game shown above.

11. If you choose X and OTHER chooses X, you will earn ______ cents and OTHER will earn ______ cents.

12. If you choose X and OTHER chooses Y, you will earn ______ cents and OTHER will earn ______ cents.

13. If you choose Y and OTHER chooses X, you will earn ______ cents and OTHER will earn ______ cents.

14. If you choose Y and OTHER chooses Y, you will earn ______ cents and OTHER will earn ______ cents.

15. Suppose that, in a given round of a given sequence, OTHER is John Smith and suppose that the sequence continues after that round. Then, in the next round of the same sequence:
    a. OTHER will definitely still be John Smith.
    b. OTHER will most likely be someone else.

16. Suppose that, in a given round of a given sequence, OTHER is John Smith and suppose that the sequence ends after that round. Then, in the first round of the next sequence:
    a. OTHER will definitely still be John Smith.
    b. OTHER will most likely be someone else.

17. Suppose that you are in round 1 of a given sequence. The probability that the sequence ends after this round is:
    a. Less than 25 percent
    b. Exactly 25 percent
    c. More than 25 percent

18. Suppose that a sequence reaches round 100. The probability that the sequence ends after this round is:
    a. Less than 25 percent
    b. Exactly 25 percent
    c. More than 25 percent

Any questions?

Let's proceed with a practice sequence. In this practice sequence, you are not playing for real money. Also, you will be given longer to make your decisions in each round.

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