An Experimental Study of Public Information in the Asymmetric Partnership Game

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Abstract

This paper investigates public information in Markov games in a laboratory experiment on an asymmetric partnership game where two partners both exert effort to complete projects that only benefit one of them. The main results are that the effect of informativeness on effort goes in the opposite direction than predicted theoretically (Kloosterman 2015a), there is more effort when signals are more informative. However, the subjects do use the public signals as the theory predicts. These seemingly contradictory results are reconciled with the basin of attraction. Finally, a new way to look at strategies in infinite horizon games is also discussed.

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1 Introduction

Dynamic relationships that evolve over time describe many economic situations. In Markov games (also commonly called stochastic games), the evolution is stochastic so there is uncertainty about the future, and, in this setting, Kloosterman 2015a shows that public information about the future can have an impact on behavior. That paper shows that more informative signals (as defined by Blackwell 1951 and 1953) often decrease equilibrium payoffs through the way they alter beliefs about the future. Such beliefs are critical for supporting intertemporal incentives which use threats of punishment in future periods to deter deviations from cooperative outcomes in the current period.

This paper investigates this environment in a laboratory experiment. The main question is whether more informative signals decrease payoffs or not. Equally important is an examination of the fundamental channels through which this comparative static result is obtained. Do subjects use intertemporal incentives to deter deviations? And, to the extent that they do, do the public signals affect them as the theory predicts? Finally, as little is known about behavior in Markov games, it is interesting to simply look at what behaviors are systematic in this environment.

The Markov game used for the experiment is a new game which will be called the asymmetric partnership game. There are two players who work on a project each period. Each player has a binary choice; exert costly effort or shirk. The project is successful only if both players exert effort. The asymmetric part of this game is that a successful project only benefits one of the two players. The beneficiary is equally likely to be either player in each period and the players know the beneficiary of the project in the current period, but do not know the beneficiary in future periods. It is clear that if any project of this type was taken on in isolation, then mutual shirking would be the outcome. However, in the dynamic version, players may exert effort when they do not stand to benefit to induce effort from their partner in later periods in what is essentially a favor-trading scheme.

This game is modified with public information. Each period, the players get a public signal
that tells them the beneficiary in the next period. The signal is not perfect however, and the probability of mistakes is the main treatment variable (and increased benefit is the other treatment variable). The signals are correct 90% of the time in one treatment (Treatment M) and 60% of the time in the other (Treatment L).

In the asymmetric partnership game, the main question posed above becomes whether more informative signals decrease effort exertion or not. The parameters create a test of Theorem 2 from Kloosterman 2015a; effort in every period is only possible in equilibrium in Treatment L. Intuitively, the incentive constraint that determines whether this full effort outcome is possible is for the player who does not benefit from the current project and observes the signal that they are unlikely to benefit tomorrow either. This incentive constraint gets tighter if signals are more informative as it is then very unlikely that they will benefit tomorrow.

The main result from the experiment is that the comparative static actually goes the other way; more effort is exerted in Treatment M. In fact, while full effort is possible in Treatment L, there is very little effort exerted. An intermediate amount of effort is possible in Treatment M (i.e. effort after some signals but not after others), and subjects exert an intermediate amount of effort in this treatment leading to more total effort than in Treatment L.

Even though the comparative static goes the other way, the answer to both questions regarding the fundamental channels of how signals impact behavior is yes. Subjects use intertemporal incentives to exert effort, and the signals affect their behavior in the theoretically predicted way.

So how can the signals impact behavior correctly, and yet the comparative static is reversed? This can be explained with a concept called the basin of attraction that has been used by Dal Bó and Fréchette 2011 and 2014 to explain cooperation rates in the infinitely repeated prisoner’s dilemma. Some subjects are using intertemporal incentives whereas others are simply shirking. This creates strategic uncertainty, which decreases the attractiveness of effort. Importantly, it is shown that the decrease in attractiveness affects all signals in Treatment L, but only some signals in Treatment M. Thus, there is almost no effort in the former case and an intermediate amount of effort in the latter.
The asymmetric partnership game is a good experimental game due to some useful properties for investigating public information.\footnote{See the end of Section 2.2.} But additionally, it also corresponds to many real world relationships. For instance, employees may help each other on projects even though only one of them, the employee to which the project was assigned, gets the credit. The results of the experiment may be useful for managers who control quality of information by choosing when projects are assigned. Another example is two students who excel at different subjects helping each other with homework. Each student could do the homework of the subject they excel at on their own, so working jointly is not beneficial to them, but requires the help of the other student for the subject that they are not as good at. Again, the results may be useful for teachers who decide when to assign homework.

The experiment fits into the ever-growing literature on infinite horizon games in the laboratory. However, just a few experiments consider Markov games where the future is uncertain (Charness and Genicot 2007, Rojas 2012, Ruffle 2013, Cabral, Ozbay, and Schotter 2014, Roy 2014, and Kloosterman 2015b, Wilson and Vespa 2015).\footnote{See Dal Bó and Fréchette 2014 for a survey of infinitely repeated games where the horizon is infinite, but the future is necessarily certain.} Cabral et al 2014 and Roy 2014 consider games that are related to the asymmetric partnership game, but, because effort is only costly after success, there is not the same riskiness to effort that makes the basin of attraction a good theory of behavior. Also, except for Kloosterman 2015b and Wilson and Vespa 2015, beliefs about the future are constant in these studies. Public signals affect behavior by manipulating these beliefs so, while they each address very interesting questions, these other studies do not address the main questions here.

Two other related papers are Vespa 2014 and Saijo et al 2015. These papers consider a dynamic game that evolves according to the actions of players rather than the exogenous stochastic process considered here.

The rest of this paper is organized as follows. Section 2 presents the asymmetric partnership game and some theory. Section 3 discusses procedures for the experiment. Section 4 presents
results and Section 5 concludes. The instructions for the experiment are appended.

2 The Asymmetric Partnership Game

2.1 The Game and Public Information

There are two players who jointly undertake one project per period $t$ over an infinite horizon $t = 0, 1, 2, \ldots, \infty$. Each project can be described as a normal-form game where the players simultaneously decide to exert effort ($E$) or shirk ($S$). The payoff for $S$ is normalized to 0 while the cost of $E$ is $c > 0$. If both players exert effort, then the project is successful and it generates a benefit $k$. It is assumed that $k > 2c$ so successful projects are socially beneficial. The asymmetric part of the game is that the entire benefit accrues to just one of the players.

Using the name $B_1$ for the game where player 1 is the beneficiary and likewise for $B_2$, the payoff matrices for the two games are

<table>
<thead>
<tr>
<th></th>
<th>$E$</th>
<th>$S$</th>
<th>$E$</th>
<th>$S$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E$</td>
<td>$k - c, -c$</td>
<td>$-c, 0$</td>
<td>$-c, k - c$</td>
<td>$-c, 0$</td>
</tr>
<tr>
<td>$S$</td>
<td>$0, -c$</td>
<td>$0, 0$</td>
<td>$0, -c$</td>
<td>$0, 0$</td>
</tr>
</tbody>
</table>

The beneficiary of the project in each period is determined randomly and is equally likely to be either player. The realization of the beneficiary is observed at the beginning of the period. That is, players know the beneficiary of the current period’s project before they undertake it, but not the beneficiaries of projects in all future periods. Finally, players discount future payoffs at the common rate $\delta \in (0, 1)$.

Following the approach of Kloosterman 2015a, this asymmetric partnership game is modified with public signals. The set of signals is $\{b_1, b_2\}$ where $b_1$ is a signal that the beneficiary in the next period is player 1 and likewise for $b_2$. However, the signals are not perfect. Parametrized by noise $\epsilon \in (0, 1/2)$, the signal correctly predicts the beneficiary in the next period with probability
$1 - \epsilon$, but incorrectly predicts with probability $\epsilon$. One public signal is received each period before the players undertake the project.\(^3\)

The main goal is to compare outcomes when the asymmetric partnership game is played with signals of differing informativeness. With this setup, one set of signals, parametrized by $\epsilon$, is more informative than another set of signals, parametrized by $\epsilon'$, if and only if $\epsilon \leq \epsilon'$.\(^4\)

In the asymmetric partnership game with public information, the players know both the beneficiary of the project in the current period and the likely beneficiary of the project in the following period before they take an action. This is a Markov game with states given by the beneficiary and signal (e.g. $(B_1, b_1)$ is the state where player 1 is both the beneficiary today and likely beneficiary tomorrow).

For the analysis that follows, there are 4 states and 2 players so 8 different situations to consider. However, there is simplifying symmetry in this game. For example, $(B_1, b_1)$ for player 1 is equivalent to $(B_2, b_2)$ for player 2 so these two states can be pooled together. Similarly, pooling in other cases narrows down the number of distinct situations to 4. For this purpose, let $B$ and $N$ indicate whether the player is the current beneficiary or not. Likewise, let $b$ and $n$ indicate whether the public signal indicates the player is the more likely beneficiary next period or not. The four pooled states are $(B, b)$, $(B, n)$, $(N, b)$, and $(N, n)$. Table 1 summarizes them.

Note that, with this simplification, the players are in different, but matched, states each period. For example, if player 1 is in state $(B, b)$ then player 2 is in state $(N, n)$.

### 2.2 Equilibrium and a Comparison of Information Structures

The Nash equilibria of the one-shot games $B_1$ and $B_2$ are both $(S, S)$. The game becomes interesting with the addition of the dynamic component where intertemporal incentives may support more effort. A player might exert effort even when they are not the beneficiary if they expect this will induce effort from their partner in future periods when they do stand to benefit.

\(^3\)It does not matter if the players see the realization of the current beneficiary or public signal first. For concreteness, suppose the beneficiary realization is first.

\(^4\)This can be shown to be a special case of Blackwell’s criterion for informativeness as considered in Kloosterman 2015a.
Before getting into the specifics of the intertemporal incentives, note that effort is driven by behavior in states \((N,b)\) and \((N,n)\). There are no intertemporal incentives to consider in game \(B\) as effort is myopically and dynamically optimal if and only if the other player (who is in state \((N,b)\) or \((N,n)\)) is exerting effort. Therefore, the analysis here, and also the analysis in the results of the experiment, focuses mostly on behavior in these two states.

The main treatments of the experiment were designed to test Theorem 2 of Kloosterman 2015a. That theorem considers the cutoff discount factor required for the largest feasible payoff to be attainable in a subgame perfect equilibrium. In the asymmetric partnership game, this is an equilibrium in which \((E,E)\) is the outcome in every period. Due to its prevalence throughout, this situation is called full effort hereafter.

Just as in many infinitely repeated games, such as the infinitely repeated prisoner’s dilemma, the cutoff discount factor is determined by the grim trigger strategy where any deviation to shirk is followed by shirk forever after. Unlike infinitely repeated games where this is a single state and therefore a single incentive constraint for grim trigger, there are two different states, states \((N,b)\) and \((N,n)\), where effort needs to be incentivized. The main insight of the theorem is that the state that determines the cutoff for full effort is the state \((N,n)\), because the incentive constraint in this state implies the incentive constraints in state \((N,b)\). Intuitively, fewer future benefits are likely in \((N,n)\) so more patience is required to incentivize effort in this state. Formally, the (normalized) incentive constraints for states \((N,b)\) and \((N,n)\) that must both be satisfied to support full effort are

\[
(N,b) : \quad (\delta (1 - \delta)(1 - \epsilon) + 1/2\delta^2)k \geq c
\]

\[
(N,n) : \quad (\delta (1 - \delta)\epsilon + 1/2\delta^2)k \geq c
\]

The left hand side of these constraints is the expected total benefits (times \(k\)) over the course of the infinite horizon; no benefit today, a benefit with probability \(1 - \epsilon\) or \(\epsilon\) tomorrow, and

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\(^5\)That theorem considers only symmetric games, but the analysis and intuition here are identical even though there is asymmetry, because the equilibrium considered is symmetric.
with probability 1/2 in all periods after that. This must be greater than paying the cost $c$ every period.

As $\epsilon < 1/2$, the constraint for state $(N, n)$ implies the constraint for state $(N, b)$ so they are both satisfied if and only if the latter constraint is satisfied. By solving the latter constraint at equality, a cutoff discount factor is determined for which full effort is possible in equilibrium iff the discount factor is at least as large as this cutoff.

Note that if $\epsilon$ decreases, the expected total benefit in state $(N, n)$ decreases, so the cutoff will increase. This is the key insight of the theorem. The worst state becomes even worse if signals become more informative, so players must be more patient to support full effort. Hence, for every pair of parameters $\epsilon' > \epsilon$ there exists some discount factors where full effort is only possible with the noisier parameter $\epsilon'$. The following proposition summarizes the result from Kloosterman 2015a in the context of the asymmetric partnership game.

**Proposition 1.** For every pair of parameters $\epsilon' > \epsilon$, there exists $\delta$ such that full effort is possible as a subgame perfect equilibrium only with the less informative signals parametrized by $\epsilon'$.

This section concludes with a discussion of the merits of the asymmetric partnership game for a laboratory test. First, the game is one in which the role of information is pronounced. It is fairly salient that who receives the benefit in the future is of utmost importance for deciding whether effort is worth the cost or not, so getting information about the beneficiary in the next period is easily interpretable to subjects. Second, since the two games present vastly different outcomes for a given player after effort exertion, there is much to be gained from knowing more about the future. Third, the game maintains much of the strategic incentives of the infinitely repeated prisoner’s dilemma that has been extensively studied in the laboratory; there is an efficient action that is not myopically optimal and also a coordination aspect to attaining it because the efficient action requires both players to choose effort. To the best of the author’s knowledge, this is the first experimental test of this game. But since it is closely related to the prisoner’s dilemma, it thus also serves as a robustness check within the literature on cooperation.
in infinite horizon games.

2.3 Basin of Attraction

The literature on infinitely repeated games, and particularly the infinitely repeated prisoner’s dilemma, has shown that a discount factor above the cutoff for cooperative outcomes is necessary, but not sufficient, for cooperation. Dal Bó and Fréchette 2011 introduce a basin of attraction in the infinitely repeated prisoner’s dilemma to explain this finding. The idea is that some people will always defect (also an equilibrium strategy), and this strategic uncertainty makes grim trigger and other similar conditionally cooperative strategies not as attractive as equilibrium reasoning predicts. Therefore, cooperation only prevails if the payoff to cooperation or the discount factor are much larger than equilibrium requires.

As the asymmetric partnership game is a similar cooperation game, the same ideas could easily carry over. While there is a cutoff discount factor determined by state \((N,n)\) that is necessary for full effort to be an equilibrium, it may be that higher benefits, lower costs, and/or higher discount factors are required to actually get effort in the laboratory.

To be more concrete, consider the simplifying assumption from Dal Bó and Fréchette 2011 that everyone in the population plays grim trigger or always shirks. Consider a player who is trying to decide which of these two strategies to choose. Suppose this player believes their partner plays grim trigger with probability \(q\) and always shirks with probability \(1 - q\). The expected payoffs for playing grim trigger, conditional on the period 0 states \((N,b)\) and \((N,n)\) are

\[
(N,b) : \quad q((\delta(1 - \delta)(1 - \epsilon) + 1/2\delta^2)k - c) + (1 - q)(1 - \delta)(-c) \\
(N,n) : \quad q((\delta(1 - \delta)\epsilon + 1/2\delta^2)k - c) + (1 - q)(1 - \delta)(-c)
\]

The expected payoff to always shirking is 0 regardless of the state. So by setting each of the

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6Blonski, Ockenfels and Spagnolo 2011 and Blonski and Spagnolo 2014 investigate related ideas.
7See Dal Bó and Fréchette 2014 for a thorough discussion of this concept and why it explains behavior in the infinitely repeated prisoner’s dilemma.
above expressions equal to 0, a cutoff $q$ is determined for which grim trigger is a best response for any player who believes their partner plays grim trigger with at least probability $q$.\footnote{The cutoff will only be defined if the inequality is satisfied for $q = 1$ (i.e. effort is a best response if one’s partner plays grim trigger for sure).}

The basin of attraction (for shirking) is the measure of beliefs for which always shirking is an optimal strategy. So if beliefs about the probability that one’s partner is playing grim trigger are distributed according to some distribution $F$ in the population, the basin of attraction for shirking is $F(q)$ where $q$ is the cutoff for the period 0 state.

The argument of Dal Bó and Fréchette 2011 and 2014 is that the more beliefs that support grim trigger, the more likely grim trigger is to be played. If the distribution $F$ is the same for all states, this means that the smaller the cutoff $q$, the more that effort will be exerted. Interestingly, unlike for the equilibrium discussion in the previous section, effort provision depends on both states $(N,b)$ and $(N,n)$. It is easy to see how. The cutoff is inversely related to the expected future benefits. The more expected benefits, the smaller the cutoff, because more benefits compensate for a smaller chance of meeting a partner who plays grim trigger. So if signals become more informative, state $(N,n)$ becomes worse (just as for equilibrium) but state $(N,b)$ becomes better (a state that doesn’t matter for equilibrium). The following proposition summarizes.

**Proposition 2.** For every pair of parameters $\epsilon' > \epsilon$, the basin of attraction for shirking is smallest in state $(N,b)$ with the more informative signals $\epsilon$, second-smallest in state $(N,b)$ with the less informative signals $\epsilon'$, third-smallest in state $(N,n)$ with the less informative signals $\epsilon'$, and largest in state $(N,n)$ with less informative signals $\epsilon$. 

The proposition says that the best and worst cases for effort are when signals are more informative. Intuitively, the good $b$ signal is better when signals are more informative, while the bad $n$ signal is worse. This means it is unclear whether there will be more effort with less informative or more informative signals. In fact, the results of the experiment will show that it is possible for there to be only significant effort in the best case, state $(N,b)$ with noise $\epsilon$, and therefore more overall effort when signals are more informative.
There is one strong assumption here which is actually quite interesting, because it is implicitly made in infinitely repeated games where it does not matter, but it does matter in Markov games. This assumption is that the distribution $F$ is the same for both states. This assumption is not unreasonable for states $(N,b)$ and $(N,n)$, and so Proposition 2 is okay, but it will turn out to be problematic for $(B,b)$ and $(B,n)$. This point will be elaborated on when the results of the experiment are presented.

3 Experimental Design

3.1 Treatments

There were four treatments coming from two treatment variables, each of which took on two values (a $2 \times 2$ design). The two treatment variables were the noise parameter $\epsilon$, which took on the values $\epsilon = .1$ and $\epsilon = .4$, and the benefit $k$, which took on the values $k = 4$ and $k = 8$. For all treatments, the cost was $c = 1$ and the discount factor was $\delta = 2/3$.

The actual payoffs seen by subjects were an affine transformation of the normalized game presented so far to assure all payoffs were positive.\(^9\) The payoff matrices presented to subjects for benefit $k = 4$ were

\[
\begin{array}{cc}
\text{Game } B_1 & \text{Game } B_2 \\
\hline
E & S \\
39, 7 & 7, 15 \\
15, 7 & 15, 15 \\
\end{array}
\]

\[
\begin{array}{cc}
E & S \\
7, 39 & 7, 15 \\
15, 7 & 15, 15 \\
\end{array}
\]

The payoff matrices for $k = 8$ were

\[
\begin{array}{cc}
\text{Game } B_1 & \text{Game } B_2 \\
\hline
E & S \\
71, 7 & 7, 15 \\
15, 7 & 15, 15 \\
\end{array}
\]

\[
\begin{array}{cc}
E & S \\
7, 71 & 7, 15 \\
15, 7 & 15, 15 \\
\end{array}
\]

\(^9\)An affine transformation does not affect any incentives. The transformation is simply to mitigate framing effects.\]
Table 2 summarizes the four treatments. For ease of reference, treatments with $\epsilon = .1$ are named M (for more informative signals) and treatments with $\epsilon = .4$ are named L (for less informative signals). For treatments where $k = 8$, HB (for high benefit) is added.

The last column of Table 2 states whether full effort is possible in an equilibrium or not. This calculation comes from the incentive constraint for state $(N,n)$ developed in Section 2.2. The parameters were chosen so that Proposition 1 has bite for Treatments M and L. Full effort is possible in Treatment L, but not in Treatment M, so the main comparison of information structures is between these two treatments. However, as noted in Section 2.3 for experiments on the infinitely repeated prisoner’s dilemma, the theoretical cutoff for full effort may not be enough to actually get effort. Treatments MHB and LHB, where full effort is theoretically possible and also much better than shirking, introduces a situation where effort seems more likely.

### 3.2 Procedures

The experiment consisted of 12 sessions with a total of 254 subjects (16-24 subjects per session) from the undergraduate population at New York University run at the Center for Experimental Social Science at NYU. The 12 sessions were divided into 3 sessions of each of the 4 treatments. No subjects participated in more than one session.

In each session, subjects played the asymmetric partnership game for their prescribed treatment 30 times. Hereafter, each of these plays will be called a match. Following the most standard procedure in the literature, the infinite horizon was implemented using random termination with a continuation probability of 2/3.

For the first 10 matches, subjects played the asymmetric partnership game in its standard configuration. For the last 20 matches, subjects played the game with a version of the one-step ahead strategy method introduced in Vespa 2014. Each period, subjects were asked to make a choice for all four possible states before the true state was revealed to them and then the computer implemented their choice corresponding to the true state.\(^{10}\) As all four states occur

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\(^{10}\)This method was introduced by Vespa 2014, but is a little different here because players choose a conditional choice for choices of nature rather than choices of other players.
with positive probability, incentives exist to truthfully report choices for all four states.

The computer pre-randomized three sets of realizations for the random variables; match lengths, beneficiaries, $\epsilon = .1$ signals, and $\epsilon = .4$ signals. The same match lengths and beneficiaries were used in one session of each of the four treatments, but of course different signals are required for treatments with different noise levels. Some summary statistics for the sets are given in Table 3.\footnote{The minimum match length is 1 for all three sets.}

Subjects received feedback after each period. They were told their choice, their opponent’s choice, their own payoff, and their own cumulative payoff for the match. They had this information on their screen for previous periods of their current match and had buttons that allowed them to see this information for any previous matches as well. If it was the last 20 matches, they also learned the true state for the period they just completed.

The experiment was neutrally framed and was programmed and run in z-tree (Fischbacher 2007). Instructions for Treatment M are in the appendix. Subjects earned points in each period of each match which were converted to dollars at the rate of 1.2 cents per point. They also received 10 dollars for participating. Average earnings were $33.10.

3.3 Hypotheses

The first three hypotheses consider just Treatments M and L, because, as noted above, these are the treatments where there is a theoretical difference in the comparison of information structures. The main question is to address this difference, a test of the first hypothesis.

**Hypothesis 1.** More effort will be exerted in Treatment L than in Treatment M.

Abstracting from the comparison of different levels of informativeness, there is a more fundamental question that should be investigated. In this environment, where signals have no effects on payoffs, and in fact no direct effects for the current game whatsoever, do the signals affect behavior at all?
To investigate this question, an analysis of state-contingent effort is useful. Consider Treatment M first. The worst state for obtaining future benefits is state \((N,n)\) and therefore less effort is predicted in this state than in state \((N,b)\). This also means that there should be less effort in state \((B,b)\) than in state \((B,n)\), because players in \((B,b)\) are partnered with players in \((N,n)\) and players in \((B,n)\) are partnered with players in \((N,b)\). For Treatment L, effort is possible in every state so it is predicted that the state should not matter.

**Hypothesis 2.** *More effort will be exerted in state \((N,b)\) than in state \((N,n)\) and in state \((B,n)\) than in state \((B,b)\) for Treatment M. There will be no difference in the frequency of effort across states for Treatment L.*

The asymmetric partnership game is only interesting if subjects use intertemporal incentives to support effort. While punishments can vary across a number of strategies that employ intertemporal incentives, one characteristic of all such strategies is that there should be more effort in later periods when both players exert effort in the current period. The third hypothesis creates a test of this intertemporal behavior.

**Hypothesis 3.** *The outcome \((E,E)\) will be more likely in periods following an \((E,E)\) outcome than in periods following any other outcome.*

The final hypothesis considers behavior in Treatments MHB and LHB. Even though the high benefit treatments are motivated as a way to increase effort, full effort is possible in both of these treatments as well as in Treatment L, so the hypothesis is that behavior will be the same for these three treatments.

**Hypothesis 4.** *Behavior in Treatments L, MHB, and LHB will be the same.*

\(^{12}\)It is also possible to compare across games (e.g. compare effort in states \((B,b)\) and \((N,b)\)), but the focus here is on comparisons between the two signals for each fixed game \(B\) or \(N\).
4 Results

Table 4 presents the effort rates (proportion of choices that were effort) for period 0 choices. The first column considers all period 0 choices (total effort), whereas the last four columns disaggregate choices by the period 0 state (state-contingent effort).

Figure 1 illustrates the impact of experience by disaggregating the total effort rates from the 30 matches into six bins; matches 1-5, matches 6-10, matches 11-15, matches 16-20, matches 21-25, and matches 26-30.

The results section proceeds with three subsections. First, each of the four hypotheses is tested. Second, the results are explained within the framework of the basin of attraction. Third, strategies, rather than just effort rates, are examined.

4.1 Hypothesis Tests

The four hypotheses are addressed in order, restating each before the analysis.

Hypothesis 1. More effort will be exerted in Treatment L than in Treatment M.

For the first hypothesis, consider total effort for Treatments M and L. Contrary to the prediction, there is more effort in Treatment M than in Treatment L (.48 > .25 with $p < .1$). While the difference is only moderately significant, there is almost twice as much effort in Treatment M so the magnitude of the difference is quite large. Furthermore, as seen in Figure 1, the difference grows over the course of the experiment as effort stays fairly constant in Treatment M, but falls in Treatment L.

The impact of information on effort goes in the opposite direction of the prediction. That prediction was based on full effort in Treatment L, and the results clearly refute it. There is actually almost no effort in Treatment L. The reason for why will be investigated in the section on the basin of attraction, but for now, Result 1 summarizes the finding.

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13 This abstracts from the effects of outcomes of earlier periods which will be investigated shortly.

14 Except where noted, standard errors are calculated for all comparisons with probit regressions on a dummy variable for one of the two cases with clustering at the session level.
Result 1. There is more effort in Treatment M than in Treatment L.

Hypothesis 2. More effort will be exerted in state \((N,b)\) than in state \((N,n)\) and in state \((B,n)\) than in state \((B,b)\) for Treatment M. There will be no difference in the frequency of effort across states for Treatment L.

For the second hypothesis, consider state-contingent effort for Treatments M and L from Table 4. For both treatments, there is more effort in state \((N,b)\) than in state \((N,n)\) (.48 > .33 and .21 > .16 with \(p < .01\) for both). There is also more effort in state \((B,n)\) than in state \((B,b)\) (.60 > .50 and .33 > .30 with \(p < .01\) for both.).

Even though there are significant differences in Treatment L, support for the hypothesis is fairly strong as the differences are three times larger in Treatment M than in Treatment L. For game \(N\), the difference in effort rates is \(.48 - .33 = .15\) in Treatment M, whereas it is only \(.21 - .16 = .05\) in Treatment L (.15 > .5 with \(p < .01\)). For game \(B\), the difference in effort rates is \(.60 - .50 = .10\) in Treatment M, whereas it is only \(.33 - .30 = .03\) in Treatment L (.10 > .03 with \(p < .01\)).

The results suggest that subjects are using the signals as predicted, particularly when they are more informative. Specifically, for game \(N\), some subjects in Treatment M seem to understand that the public signal \(b\) is a signal of a good future, and that exerting effort after \(b\) is the way to take advantage of this good future. The result for game \(B\) is particularly striking and shows complex strategic behavior in the following sense. There is the potential for more benefits to accrue in state \((B,b)\) than in \((B,n)\), and yet subjects still exert more effort in the latter state, because they realize that their opponent’s effort rates are not equal after the two different signals. Result 2 summarizes.

Result 2. For both Treatments M and L there is more effort in state \((N,b)\) than in state \((N,n)\) and more effort in state \((B,n)\) than in state \((B,b)\), but the differences are much larger in Treatment M than in Treatment L.

\(^{15}\)Some very small differences are statistically significant here. This is due to these comparisons being within sessions rather than between sessions so clustering actually increases testing power.

\(^{16}\)This is a probit difference-in-difference comparison with standard errors clustered at the session level.
**Hypothesis 3.** The outcome \((E, E)\) will be more likely in periods following an \((E, E)\) outcome than in periods following any other outcome.

To analyze the third hypothesis, Table 5 presents the proportion of outcomes that are \((E, E)\) in all periods greater than period 0 conditional on the period 0 outcome.\(^{17}\) For example, the .64 in the first row and column reflects that 64% of outcomes are \((E, E)\) in periods greater than 0 when the period 0 outcome is \((E, E)\) in Treatment M.

There are many more \((E, E)\) outcomes after \((E, E)\) in period 0 than after any other period 0 outcome for both Treatments M and L (.64 > .14, .64 > .02, .65 > .10, and .65 > .02 with \(p < .01\) for all). The important result from Table 5 is that essentially the only way for benefits to accrue in later periods is for both subjects to choose effort in period 0. Table 4 suggests that some subjects exert effort while others shirk in period 0. For those that exert effort, the result here implies that they do so conditionally, they continue to exert effort only if their opponent exerts effort as well. That is, to the extent that conditional effort is common knowledge, intertemporal incentives are used to support effort. Result 3 summarizes.

**Result 3.** There is much more mutual effort in periods greater than 0 if there is mutual effort in period 0. In fact, there is almost no mutual effort in periods greater than 0 unless there is mutual effort in period 0.

**Hypothesis 4.** Behavior in Treatments L, MHB, and LHB will be the same.

To analyze the fourth hypothesis consider total effort from Table 4 first. Clearly, there is more effort in both Treatments MHB and LHB than in Treatment L (.76 > .25 and .68 > .25 with \(p < .01\) for both). There is not significantly more effort in Treatment LHB than MHB.

The same results hold for state-contingent effort as well. There is more effort state-by-state in Treatments MHB and LHB than Treatment L, but effort in Treatments MHB and LHB are statistically indistinguishable.

Now, consider the differences in effort between the signals as was considered in the analysis\(^{17}\) Similar results hold for baseline periods other than 0, but the most data is available for period 0 so it is presented here.
of Hypothesis 2. The difference in effort between states \((N, b)\) and \((N, n)\) is .05, .08, and .06 for Treatments L, MHB, and LHB respectively and only the two most extreme cases are significantly different (.08 > .05 with \(p < .05\)). The difference in effort between states \((B, n)\) and \((B, b)\) is .03, 0, and .02 for Treatments L, MHB, and LHB respectively and none of these are significantly different from each other.

Finally, the results of Table 5 also suggests the hypothesis holds for behavior conditional on the period 0 outcome. There is more effort after \((E, E)\) in period 0 than after any other outcome (.77 > .22, .77 > .02, .79 > .16, and .79 > .02 with \(p < .01\) for all). Just as for Treatments M and L, there is essentially only benefits accrued in later periods if the period 0 outcome is \((E, E)\). There also are slightly more mutual effort outcomes in Treatment MHB and LHB than in Treatment L after period 0 outcomes other than \((S, S)\), but the effects of such differences on payoffs are negligible. Result 4 summarizes.

**Result 4.** There is about the same amount of effort in Treatments MHB and LHB and this is more than Treatment L. However, the effects of signals and the period 0 outcome \((E, E)\) are the same for all three treatments.

### 4.2 Basin of Attraction

Why is there so little effort in Treatment L? The basin of attraction can explain this finding. Table 6 presents the cutoff beliefs \(q\) that were introduced in Section 2.4 for the parameters in the experiment.\(^{18}\) Recall that \(q\) is the lowest probability one must assign to their partner playing grim trigger in order for effort to be a best response, and therefore lower \(q\)’s may lead to more effort.

Recall that effort is driven by behavior in game \(N\) so consider state \((N, b)\) in Treatment M, and states \((N, b)\) and \((N, n)\) in Treatment L first. The cutoffs are .33, .44, and .58 respectively. In support of the argument for the basin of attraction, effort is ranked from most to least in this

\(^{18}\)While only the cutoffs in \(N\) were given there, the cutoffs for \(B\) follow similarly. Also, there is no cutoff for state \((N, n)\) in Treatment M since effort is never a best response.
order (.48 > .21 > .16 with \( p = .054 \) and \( p < .01 \) respectively).

Effort stayed fairly constant in Treatment M whereas it fell over the course of the experiment in Treatment L. The basin of attraction can be used to explain this evolution if it is assumed that subjects' beliefs about the probability of their partner exerting effort is shaped by the actual probability of their partner exerting effort in the first few matches of the experiment. For concreteness, the first 5 matches are considered in the analysis here. Partner’s effort rates for the three states considered so far are .61, .52, and .48 respectively. Compared to the cutoffs .33, .44, and .58, partner’s effort is well above the cutoff in state \((N, b)\) in Treatment M and near the cutoff for both states \((N, b)\) and \((N, n)\) in Treatment L. Also, Table 5 suggests that the true cutoffs are larger than the simplified cutoffs reported here, so a fall in effort in Treatment L seems reasonable.\(^{19}\)

The glaring deficiency in the theory of the basin of attraction is the effort rate of .33 in state \((N, n)\) in Treatment M. One argument for why the deficiency is not too problematic is that this rate is not significantly different than the effort rate in either state \((N, b)\) or \((N, n)\) in Treatment L \((.33 \neq .21 \text{ and } .33 \neq .16 \text{ with } p > .1)\). Also, partner’s effort is .68 for the first 5 matches in this case which is more than for the other cases discussed above (particularly the cases for Treatment L). Still, there might be a behavioral explanation behind the perception of signals that might be at work here as well. While purely speculative, one possibility that would lead to more effort in Treatment M is that subjects feel more secure when they know the future better, and are more willing to take a riskier option, in this case effort, when they feel secure.

Even though the basin of attraction argument may be not perfect for state \((N, n)\) in Treatment M, it also explains a number of other results and therefore provides a nice general description of behavior in this game. First, there is more effort in game \(B\) than in game \(N\) in all treatments (the only non-significant difference among states within each treatment is between states \((B, b)\) and \((N, b)\) in Treatment M). This is predicted by the basin of attraction as, for each row, the cutoffs are lower in the first two columns of Table 6 than the last two columns.

\(^{19}\)The calculation of \(q\) assumes that if both players exert effort, then they will exert effort in all future periods. Table 5 shows that they only get effort in about 2/3 of periods, so the true cutoff for when effort is best is actually larger than \(q\).
Second, as was the motivation for high benefit treatments, there was more effort in Treatments MHB and LHB than Treatments M and L. Again this is predicted by the basin of attraction as, for each column, the cutoffs are lower in the last two rows of Table 6 than the first two rows.

Third, although slight in magnitude, there is significantly more effort in state \((N,n)\) than \((N,b)\) in Treatment L (and in Treatments MHB and LHB too). This is also predicted by the basin of attraction. Of course, there is also more effort in state \((B,n)\) than state \((B,b)\) in Treatment L (and all treatments in fact) which is opposite to the prediction the cutoffs make. This brings up an important point alluded to at the end of Section 2.3. Partner’s effort rates for the first 5 matches in these two states are .30 and .17 respectively. So even though more beliefs support effort in state \((B,b)\), the distribution of beliefs \((F\) from Section 2.3) is probably not the same, and, as there is almost twice as much partner effort in state \((B,n)\), the basin of attraction argument is consistent with more effort in state \((B,n)\).

The last case makes an important point about comparing behavior where initial distributions of beliefs \(F\) may be very different. As another starker example, note that the cutoff in state \((B,n)\) in Treatment L is .17 and in state \((N,n)\) in Treatment LHB is .18 and yet behavior is very different in these two states. This does not mean the basin of attraction is a bad theory. Partner’s effort rates in the first 5 matches are .30 and .75 respectively so the distribution of beliefs is probably very different between the two states. It therefore makes sense that effort is exerted only in the latter case.

4.3 Strategies

It would be nice to identify the entire strategies used by subjects, but this is a difficult task, because choices are only made for the actual history of play while strategies condition on all possible histories. There are a very large number of histories in this relatively simple game, even for periods right at the beginning of a match. For example, in period 1 the actual history consists of one of four possible period 0 states and one of four possible period 0 outcomes. Adding in the 4 possible period 1 states, there are 64 different histories preceding the period 1 choice of
players. This number grows exponentially for later periods.

So instead of identifying entire strategies, this analysis investigates behavior conditioned only on the outcome of the previous period. Though not perfect, it shall be seen that such an approach yields a number of interesting insights into behavior, many of which are only possible in the Markov games framework.

As in the example, this method of analysis still leaves 64 possibilities in principle. However, exploiting the data from the one-step ahead strategy method, the choices for all four current states are available so there are only the 16 different previous period outcome and state combinations to consider. While this narrows down the number of situations from 64 to 16, it also increases the number of actions from 2, effort or shirk, to 16, effort or shirk in each of the four states. Fortunately, 7 of these contingent-actions account for 98% of responses.\(^{20}\)

The analysis restricts behavior to the last 20 matches, where the one-step strategy method is used, and Treatment M, where behavior is most varied (there is mostly shirking in Treatment L and mostly effort in Treatments MHB and LHB). Table 7 reports the frequency with which each of the 7 aforementioned contingent-actions was chosen. The first choice in each contingent-action is the choice for state \((B,b)\), the second for state \((B,n)\), the third for state \((N,b)\), and the fourth for state \((N,n)\). For example, \((E,E,E,S)\) means the subject chose to exert effort as long as the state was not \((N,n)\).

Figures 2-5 provide the transition probabilities among the 7 contingent-actions conditional on the 16 possible previous period outcome and state combinations.\(^{21}\) For example, in the top cell of Figure 2 there is an arrow that goes from \textit{EESS} to \textit{EEEE} with the proportion .43 on top. This means that a subject who chose the contingent-action \((E,E,S,S)\) last period, where the state in the last period was \((B,b)\) and the outcome was \((E,E)\), chose \((E,E,E,E)\) 43% of the time in the current period. The probabilities do not add up to one hundred, because (for clarity although admittedly ad hoc) only transitions that account for at least 10% and at least 4

\(^{20}\)No other action accounts for more than .7% of choices.

\(^{21}\)The outcome has the biggest effect so the figures are divided and analyzed along this line. The outcome \((E,S)\) is the case where the subject exerted effort and the outcome \((S,E)\) is the case where their partner exerted effort. In other words, all subjects are treated as player 1.
data are included in the figures. In many cases, there are no arrows leaving certain circles, either because the contingent-action from last period is inconsistent with the that period’s outcome or because there is not enough data to draw a conclusion.

After (E, E): Figure 2

There are three types of behaviors after the outcome (E, E) in the previous period that are interesting to analyze. First, many subjects continue with the same contingent-action. This seems reasonable as the outcome of the project was a success.

Perhaps the more interesting behaviors are those not possible in infinitely repeated games. The second type of behavior is that many subjects move to a contingent-action with effort in more states. This suggests that subjects may be hesitant at first and would like to confirm that they face a cooperative partner before completely committing to cooperation themselves. The Markov game provides an environment in which this is possible, because there are multiple states, so subjects can choose to exert effort in just some of them initially.

Third, there are two transitions to less effort which having an interesting interpretation as well. After the state (N, b), some switches occur from (E, E, E, S) to (E, E, S, S) and after the state (N, n), some switches occur from (E, E, E, E) to (E, E, E, S). These transitions indicate that the subject still wants to be cooperative (and still exerts some effort), but did not get the benefit last period and is unwilling to exert effort a second period in a row in the same state and not get the benefit again.

After (E, S): Figure 3

There are again three main types of behaviors after the outcome (E, S) in the previous period. First, many subjects switch to (S, S, S, S) which is consistent with switching to a standard punishment such as grim trigger.

Second, many subjects switched to contingent-actions with less effort, but not all the way to (S, S, S, S). Rather than punishing their partner in every state, the punishment is relegated to the
state in which the shirk occurred (and in a few cases to other bad states as well). Again, this finding is unique to Markov games, where the possibility of limiting a punishment to only some states is introduced.

Third, as for after \((E,E)\), many subjects continued with the same contingent-action. This is harder to understand here, but suggests that subjects are possible lenient, expecting reciprocal effort, or trying to teach cooperative behavior.

**After \((S,E)\): Figure 4**

There are two types of behaviors after the outcome \((E,S)\) in the previous period. Before explaining these, it should be noted that there are almost no instances of grim trigger where subject switch to \((S,S,S,S)\) (the only exception being from \((E,E,S,S)\) after state \((N,b)\)).

The first type of behavior is that again many stay with the same contingent-action. The motives here may be similar to those for after \((E,S)\).

Second, perhaps most surprisingly, many subjects switch to contingent-actions with more effort exertion. In all cases except for the switches from \((E,E,S,S)\) to \((E,E,E,E)\) after state \((N,b)\), the subjects are exerting more effort only in states where they get their benefit. This suggests subjects think their partner will continue to exert effort rather than that they feel guilty about failing to give their partner a benefit.

It should be stressed that behavior after \((S,E)\) is a little difficult reconcile. As can be seen in the results for after the outcome \((E,S)\) and in Table 5, there is little hope of returning to a cooperative relationship and yet subjects seem to continue to exert effort anyways.

**After \((S,S)\): Figure 5**

The outcome \((S,S)\) is the situation where both subjects act noncooperatively. Many subjects switch to \((S,S,S,S)\) here which makes sense given both players shirked. Still, there is much inertia to stay with the same contingent-action.
This section concludes with two remarks. First, one aspect of behavior that shows up in all four figures is that subjects repeat their contingent-actions very often. This behavior is consistent with Markov strategies, strategies that condition on the state but not past actions. Given the importance that is often tied to Markov strategies in other contexts, a little more investigation is worthwhile. Ignoring the first few periods of the match, where many reasons can explain the same contingent-action being played in each period, by period 3 the proportion of choices where the same contingent-action was played three times is .45. This is fairly large and suggests that Markov strategies may be prevalent in the data. However, throwing out those cases where the same contingent-action played was (S, S, S, S) (always a myopic best response) and the cases where the past outcome has always been (E, E) (cases that are consistent with strategies like grim trigger and Markov strategies), the proportion drops to about .2. There does seem to be some subjects who are playing Markov strategies though the majority are not.

Second, Dal Bó and Fréchette 2011 infer entire strategies in the infinitely repeated prisoner’s dilemma, but this process would be difficult in this environment. While it would be possible to infer entire common repeated game strategies, such as grim trigger and always shirk, it would be difficult to capture some of the intricate behavioral aspects, such as effort in only some states and the effect of the state in the previous period, that have been detailed here. As less is known about these behaviors that can occur only in Markov games, the approach taken here seems reasonable in this environment.

5 Conclusion

This paper investigates public information in Markov games with a laboratory experiment on the asymmetric partnership game. The results show that effort is not chosen nearly as much as is theoretically possible in the treatment with less informative signals which leads to little support for the theoretical comparative static. However, the subjects do use the signals to support intertemporal incentives in the way that is theoretically predicted, although just not to
the full extent possible.

The explanation offered for more effort in the treatment with more informative signals is based on strategic uncertainty. Effort exertion when a player cannot receive the benefit requires the player to both expect to have the potential to accrue benefits in future periods, but also to actually receive these future benefits. When players are uncertain about the strategy of the their partner, the probability of the latter decreases and this means that it is not only the worst state that matters, the theoretical reason for less informative signals to increase payoffs, but also the best state and this state is better when signals are more informative.

While the evidence supports this explanation, other explanations are possible and probably exist though maybe on a much smaller scale. Another explanation that is also rooted in strategic uncertainty is that some players are nasty and exert effort only when they can get the benefit (the \((E, E, S, S)\) contingent-action noted in the results) and other players may want to screen them out before committing to exert effort. Screening is easier with more informative signals for the situation where a player does not receive the benefit in the current period but expects to receive the benefit in the next period, because the player knows that it is very likely that they will get the chance to screen out nasty players in the next period. “Behavioral” responses to signals also may contribute to the result. As mentioned briefly above, for instance, subjects may feel more secure when they know the future better and are therefore more willing to take the riskier action of effort.

These conclusions suggest many future directions for research. Within the asymmetric partnership game, many other interesting questions could be addressed. One particularly obvious potential treatment variable is the discount factor. Also, it would be very interesting to investigate the behavioral explanation noted above further with a new experiment designed with this explanation in mind.
## Tables and Figures

### Table 1: Pooled States

<table>
<thead>
<tr>
<th>Pooled State</th>
<th>Player 1 State</th>
<th>Player 2 State</th>
</tr>
</thead>
<tbody>
<tr>
<td>$(B, b)$</td>
<td>$(B_1, b_1)$</td>
<td>$(B_2, b_2)$</td>
</tr>
<tr>
<td>$(B, n)$</td>
<td>$(B_1, b_2)$</td>
<td>$(B_2, b_1)$</td>
</tr>
<tr>
<td>$(N, b)$</td>
<td>$(B_2, b_1)$</td>
<td>$(B_1, b_2)$</td>
</tr>
<tr>
<td>$(N, n)$</td>
<td>$(B_2, b_2)$</td>
<td>$(B_1, b_1)$</td>
</tr>
<tr>
<td>Treatment Name</td>
<td>$\epsilon$</td>
<td>$k$</td>
</tr>
<tr>
<td>----------------</td>
<td>----------</td>
<td>-----</td>
</tr>
<tr>
<td>M</td>
<td>.1</td>
<td>4</td>
</tr>
<tr>
<td>L</td>
<td>.4</td>
<td>4</td>
</tr>
<tr>
<td>MHB</td>
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</tr>
<tr>
<td>LHB</td>
<td>.4</td>
<td>8</td>
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</table>
Table 3: Randomization Statistics

<table>
<thead>
<tr>
<th>Set</th>
<th>Average Match Length</th>
<th>Longest Match Length</th>
<th>% of games that were $B_1$</th>
<th>% of $\epsilon = .1$ signals that were correct</th>
<th>% of $\epsilon = .4$ signals that were correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.07</td>
<td>13</td>
<td>55%</td>
<td>90%</td>
<td>79%</td>
</tr>
<tr>
<td>2</td>
<td>3.40</td>
<td>11</td>
<td>45%</td>
<td>92%</td>
<td>64%</td>
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<tr>
<td>3</td>
<td>3.20</td>
<td>10</td>
<td>48%</td>
<td>86%</td>
<td>61%</td>
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</table>
Table 4: Effort Rates for Period 0

<table>
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<tr>
<th>Treatment</th>
<th>Period 0 State</th>
<th>All</th>
<th>(B, b)</th>
<th>(B, n)</th>
<th>(N, b)</th>
<th>(N, n)</th>
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</thead>
<tbody>
<tr>
<td>M</td>
<td></td>
<td>.48</td>
<td>.50</td>
<td>.60</td>
<td>.48</td>
<td>.33</td>
</tr>
<tr>
<td>L</td>
<td></td>
<td>.25</td>
<td>.30</td>
<td>.33</td>
<td>.21</td>
<td>.16</td>
</tr>
<tr>
<td>MHB</td>
<td></td>
<td>.76</td>
<td>.89</td>
<td>.89</td>
<td>.67</td>
<td>.59</td>
</tr>
<tr>
<td>LHB</td>
<td></td>
<td>.68</td>
<td>.79</td>
<td>.81</td>
<td>.60</td>
<td>.54</td>
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Figure 1: Total Effort Across Matches
Table 5: \((E, E)\) Outcomes

<table>
<thead>
<tr>
<th>Treatment</th>
<th>((E, E))</th>
<th>((E, S)) or ((S, E))</th>
<th>((S, S))</th>
</tr>
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<tr>
<td>M</td>
<td>.64</td>
<td>.14</td>
<td>.02</td>
</tr>
<tr>
<td>L</td>
<td>.65</td>
<td>.10</td>
<td>.02</td>
</tr>
<tr>
<td>MHB</td>
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<td>.22</td>
<td>.02</td>
</tr>
<tr>
<td>LHB</td>
<td>.79</td>
<td>.16</td>
<td>.02</td>
</tr>
<tr>
<td>Treatment</td>
<td>$(B, b)$</td>
<td>$(B, n)$</td>
<td>$(N, b)$</td>
</tr>
<tr>
<td>-----------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>M</td>
<td>.14</td>
<td>.20</td>
<td>.33</td>
</tr>
<tr>
<td>L</td>
<td>.16</td>
<td>.17</td>
<td>.44</td>
</tr>
<tr>
<td>MHB</td>
<td>.06</td>
<td>.08</td>
<td>.12</td>
</tr>
<tr>
<td>LHB</td>
<td>.07</td>
<td>.07</td>
<td>.15</td>
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Table 7: Contingent-Actions for Treatment M

<table>
<thead>
<tr>
<th>Action</th>
<th>(E, E, E)</th>
<th>(E, E, S)</th>
<th>(E, E, S)</th>
<th>(S, E, E)</th>
<th>(E, S, S, S)</th>
<th>(S, E, S)</th>
<th>(S, S, S, S)</th>
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</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>.26</td>
<td>.04</td>
<td>.08</td>
<td>.07</td>
<td>.03</td>
<td>.04</td>
<td>.48</td>
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</table>
Figure 2: After $(E, E)$ in the Previous Period
Figure 3: After \((E, S)\) in the Previous Period
Figure 4: After \((S, E)\) in the Previous Period
Figure 5: After $(S, S)$ in the Previous Period
References


Instructions

Welcome. This is an experiment in decision making. Various research foundations and institutions have provided funding for this experiment and you will have the opportunity to make a considerable amount of money which will be paid to you at the end. Make sure you pay close attention to the instructions because the choices you make will influence the amount of money you will take home with you today. Please ask questions if any instructions are unclear.

The Choice Problems

For the choices in this experiment you will be paired with another participant in the room, whom we will call your partner. You and your partner make choices that affect your own and each other’s payoffs. We will call each of these choices a Choice Problem. There are two different Choice Problems in this experiment which we will call Choice Problem X and Choice Problem Y.

Both Choice Problems consist of both you and your partner simultaneously choosing between two options, which we label A and B. If you choose A you get 7 points and if you choose B you get 15 points. Your partner also gets 7 points if they choose A and 15 points if they choose B. Additionally, if you and your partner both choose A, there is an extra payoff of 32 points (so 39 points in total) that goes to either you or your partner. This is the way in which Choice Problem X and Choice Problem Y differ. In one of them you get the extra payoff of 32, while in the other your partner gets the extra payoff (At the beginning of the experiment you will be told if you get the extra payoff in Choice Problem X or Choice Problem Y and this will remain true for the entire experiment).

Each Choice Problem can be represented in a box as follows. The first row and column are just labels for the choices A and B. Row 2 corresponds to you choosing A while Row 3 corresponds to you choosing B. Similarly, Column 2 corresponds to your partner choosing A while Column 3 corresponds to your partner choosing B. The cell at each intersection shows the points you and
your partner receive for the possible choices. Your payoff is listed first, followed by your partner’s payoff after the comma. For example, if you choose A while your partner chooses B, then you get 7 points and your partner gets 15 points which is represented as 7, 15 in the intersection of Row 2 and Column 3.

If you receive the extra payoff in Choice Problem X, then the Choice Problems are represented as follows.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
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<tr>
<td>A</td>
<td>39, 7</td>
<td>7, 15</td>
</tr>
<tr>
<td>B</td>
<td>15, 7</td>
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Choice Problem Y:

<table>
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<th>B</th>
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</tr>
<tr>
<td>B</td>
<td>15, 7</td>
<td>15, 15</td>
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</table>

Alternatively, if you receive the extra payoff in Choice Problem Y, then the Choice Problems are represented as follows.

Choice Problem X:

<table>
<thead>
<tr>
<th></th>
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<th>B</th>
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<tr>
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<tr>
<td>B</td>
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<td>15, 15</td>
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</table>

Choice Problem Y:

<table>
<thead>
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<th>B</th>
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<tr>
<td>A</td>
<td>39, 7</td>
<td>7, 15</td>
</tr>
<tr>
<td>B</td>
<td>15, 7</td>
<td>15, 15</td>
</tr>
</tbody>
</table>
First 10 Matches

The experiment consists of 30 Matches. At the beginning of each Match you will be randomly paired with another participant from the room (one who gets the extra payoff in the opposite Choice Problem as you) and engage in a number of Rounds with this participant as your partner.

Each of the first 10 Matches proceeds as follows. For each Round, the computer will randomly determine whether you and your partner will engage in Choice Problem X or Choice Problem Y for that Round. The computer is programmed to select each one with 1/2 chance. That is, in every Round, the two Choice Problems are equally likely.

Above, we said that you engage in a number of Rounds in each Match. The exact number varies from Match to Match, and is also randomly determined by the computer. Every Match has at least one Round. After Round 1, the computer will randomly determine whether the Match will continue to Round 2 or end. The computer is programmed to select to continue with 2/3 chance and to end with the remaining 1/3 chance. In fact, this is true not just after Round 1 but after every Round. Note that this means, in every Round, the Match is twice as likely to continue as it is to end.

As each Match progresses, you will be told which Choice Problem the computer has determined for the current Round before you choose A or B in that Round, but the computer does not reveal which Choice Problems it has determined for any future Rounds. However, a signal will be generated and shown to you and your partner, also before you choose A or B for the current Round, that helps you predict what the Choice Problem will be in the next Round. The signal takes on two values, which we will call x and y. If the true Choice Problem in the next Round is Choice Problem X, then the signal x will be generated with 9/10 chance and the signal y will be generated with 1/10 chance. Alternatively, if the true Choice Problem in the next Round is Choice Problem Y, then the signal y will be generated with 9/10 chance and the signal x will be generated with 1/10 chance. That is, the signal x indicates that the Choice Problem in the next Round is 90% likely to be X and 10% likely to be Y while the signal y indicates that the
Choice Problem in the next Round is 90% likely to be Y and 10% likely to be X.

It is worthwhile to stress that only one signal is generated and shown to both you and your partner so you always observe the same signal as your partner. Also, the signal is only informative about the Choice Problem in the Round directly following the current one (and since the number of Rounds is randomly determined you may not reach this Round).

To conclude this section, recall that the distinguishing characteristic of a Match is that you have the same partner for every Round of the Match. You get a new partner every time a new Match starts.

**Your Screen**

Below is a screen shot of what your screen will look like before you make a choice. Note that the Match and Round are indicated in the upper left corner while the Choice Problem in which you get the extra payoff is in the upper right corner. In the middle at the top, you see the Choice Problem and signal for the current Round. Below this you see the box, from above, representing this Choice Problem. You make your choice by clicking anywhere in one of the two rows in this box. The row will turn red once you have selected it. You can switch back and forth as long as you like by clicking the two rows. Once you are ready to submit your choice for good, click the red Confirm button at the bottom.

You can also see the outcomes (Round, Choice Problem, Signal, Your Choice, Partner’s Choice, and Your Payoff) from all past Choice Problems. On the left side of your screen, the previous Rounds of the current Match are displayed. Nothing is displayed in the picture because it is Round 1 but it will fill in as the Match continues. On the right side of your screen you can click on the numbered box to see the outcomes from the Match corresponding to the number in the box (you can click these boxes as much as you like with no effect on your payoff). In the picture, only the box for Match 1 shows, because the picture is in Match 2, but as the experiment progresses more boxes will appear. The last row of each display presents cumulative payoffs. In
other words, this row sums up the column for your payoff over the course of the Match you are considering.

A second screen will show up after each Round as well. It will tell you the outcome for that Round, both in words and in illustration by filling in the column corresponding to your partner’s choice, and whether the Match will continue or end. Also, if the Match is ending, one final screen will recap the outcomes for the entire Match.

**Last 20 Matches**

Nothing substantial changes for the last 20 Matches except that we have you make four choices instead of just one in each Round. Instead of telling you the current Choice Problem and signal at the top of the screen, we ask you to make a choice for all four Choice Problem and signal combinations. You will see four boxes, one for each of these combinations, and you select a row in each of the four boxes just as in the first 10 Matches.
After you have confirmed your four choices, we will then reveal the true Choice Problem and signal for that Round and implement the choice that you specified for this combination as well as the choice that your partner specified. You will only see your partner’s choice (and your partner will only see your choice) for this combination.

Note that each of the four choices is identical to the equivalent choice from the first 10 Matches where you knew the true Choice Problem and signal. Also, all four combinations are always possible (even though the signal from the previous Round suggests they may not be equally likely). Therefore, even though you will ultimately only get points for one of your four choices, if you want to maximize your payoff you should treat each of the four combinations as you did in the first 10 Matches when that combination had been revealed to you. The reason that we have designed the last 20 Matches of the experiment like this is simply to get more data from you. We are not trying to change the decision problem.

Payoffs

We will add up all of your points over the course of the experiment. Points will be converted into dollars at the rate of 1.2 cents per point (In other words, for every 250 points you earn, you get 3 dollars) though we will round up your final payoff to the nearest ten cents. In addition to earnings in the experiment you will get 10 dollars just for participating.