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Coordination in games with incomplete information: experimental results

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Abstract: We use experiments to study coordination in games with incomplete information and ask whether an informed player can use cheap talk strategically. Two players decide whether to enter a market where stage game payoffs either form a prisoner's dilemma or a stag-hunt. One player knows which stage game is played while the other knows only the associated probabilities. When players engage in a prisoner's dilemma each player prefers unilateral entry. When payoffs form a stag-hunt game, the outcome where neither enters Pareto dominates the outcome where both enter. We ask whether cheap talk aids coordination on the Pareto dominant outcome and whether the informed player can use cheap talk to engineer her preferred outcome. Consistent with previous literature, the benefit of cheap talk depends on the relationship between payoffs and risks. We find that cheap talk benefits informed players only when payoff risks are low .

Keywords: cheap talk, coordination, experiments, incomplete information, risk dominance, payoff domiance
JEL classification: C72, C92, D82

1.0 Introduction

There is a sizable experimental literature on coordination in 2x2 games, but few have examined uncertainty over the game form.[1] An important part of the broader coordination literature examines the relationship between payoffs and risk generally, and the credibility of messages more specifically whenever communication is allowed between players.

In the experiments we discuss there is uncertainty over payoffs and subjects in some treatments can engage in cheap talk. The games we consider have different risk and credibility properties, and we are able to tie our results to the existing literature which considers these differences in the context of perfect information. In addition to considering subjects' ability to coordinate we have another motivation which differs from existing literature. Specifically, we consider whether a better informed player is able to use cheap talk to her individual advantage.

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[1] Exceptions include a handful of studies such as Cabrales, Nagel and Armenter (2007) based on Carlsson and van Dammes' (1993) theory of global games.

The experimental economics literature has shown that the effectiveness of communication in simple coordination games can be diminished by factors including: (i) asymmetry of preferences, (ii) the order of messages and actions; (iii) relative payoff differences between Pareto ranked equilibria, and (iv) message credibility.[2] To summarize some of the findings, Cooper et al. (1989) show the benefits of one-way communication over two-way communication in battle-of-the-sexes games. Charness (2000) demonstrates that coordination is improved if messages are sent prior to actions being taken as opposed to agents explicitly deciding on actions and then sending their message.[3] Several papers address the risk and payoff properties of games including: Straub (1995), Clark et al. (2001), Schmidt et al. (2003) and Dubois et al. (2009). A persistent finding is that players are very responsive to changes in the riskiness of payoffs (all else equal). Battalio et al. (2001) show that players coordinate more often the more costly it is to fail to coordinate. Clark et al. (2001) show inconclusive results testing Aumann's (1990) suggestion (discussed below) that the credibility of subjects' messages is important for cheap talk to improve coordination on socially optimal outcomes.

This paper contributes to previous research by looking at the effects of cheap talk when there is uncertainty over payoffs in 2x2 coordination games. One of our results is that uncertainty accentuates previous findings. For instance, we illustrate the robustness of cheap talk as a coordination device for games with low risk and high message credibility. Also, in our experiments, the better informed player only benefits from cheap talk when payoff risks are low.

In section 2 we overview some of the literature on credibility and risk in 2x2 coordination games and in section 3 we describe our experimental design. Section 4 discusses the theoretical predictions and section 5 discusses the results. In section 6 we offer our conclusions.

2.0 Credibility and risk in 2x2 coordination games

If cheap talk is an effective coordination device, it should move agents toward Pareto dominant Nash equilibria (Farrell, 1988). Yet, Aumann (1990) provided a counter example showing that cheap talk is not credible if one agent has strict preferences over the other's action. For example, suppose two players (*i* and *j*) are engaged in the coordination game in table 1, and player *i* can send a cheap talk message before actions are taken. Equilibrium (*B, B*) Pareto-dominates outcome (*A, A*) since the former gives higher payoffs to both players; however, player

[2] Devetag and Ortmann (2007) is a good review of coordination in games with Pareto ranked equilibria. They include relevant literature using 2x2 games as well as order-statistic games.

[3] Charness (2000) tests the assertion by Farrell (1988) that the order of messages and actions affects the credibility of the message.

i prefers player *j* to choose action *B* independent of her own intended action. Aumann (1990) argued this lack of what he called "self-enforcement" rendered cheap talk irrelevant because player *j* should see that player *i* should always say she intends to play action B even if (for whatever reason) she intends to play A. If messages convey no information about the sender's intention, cheap talk may as well be ignored.

Combining analyses from Farrell (1987, 1988) and Aumann (1990) credible messages have two properties. First, self-commitment: the sender should have an incentive to choose the action corresponding to her message if her message is believed. This is the case in the example above because if *j* believes *i* will choose B, *j* will choose B, and therefore, so will *i*. If the sender's message is furthermore *self-signaling* she has an incentive to send that message only when she wants the other player to best-respond. This property is lacking in the table 1 since *i* has an incentive to send message B regardless of her own intended action.[4]

It is a behavioral question whether absence of the self-signaling property is enough to make the sender perceive a message as non-credible. Clark et al. (2001) demonstrate Aumann's suggestion that cheap talk is not very effective at coordinating actions when players *do have* strict preferences over the other player's action; however, simply changing the payoffs to eliminate that strict preference did not help subjects coordinate on the Pareto dominant outcome: "… in this Game many subjects appear to use communication to secure the Pareto dominated outcome," (Clark et al., 2001, p. 508).

The experimental economics literature consistently shows the importance of risk in equilibrium selection. Consider again the example in Table 1. The row player would surely like to trust the column player to choose B, but there is some 'risk' he will instead choose A leaving her with 0 payoff (maybe there is not common knowledge of rationality or maybe the column player will simply make a mistake, etc.). In the absence of communication players gravitate to the (A,A) equilibrium. Harsanyi and Selten (1988) refer to outcomes such as (A,A) as 'risk dominant'. Formally, if x_{ij} is row player's payoff when row chooses action i and column chooses action j (and if column players payoffs are similarly defined using y_{ij}), then, equilibrium (A,A) risk dominates (B,B) if $(x_{AA} - x_{BA})(y_{AA} - y_{AB}) > (x_{BB} - x_{AB})(y_{BB}-y_{BA})$ or equivalently $\frac{(x_{AA}-x_{BA})}{(x_{BB}-x_{AB})} > \frac{(y_{BB}-y_{BA})}{(y_{AA}-y_{AB})}$. In figure 1 (A,A) is the risk dominant outcome since $\frac{2-0}{4-3} > \frac{4-3}{2-0}$.[5]

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[4] See Baliga and Morris (2002) for a theoretical discussion of self-signaling in incomplete information games with strategic complementarities and positive spillovers.

[5] Harsanyi and Selten (1988, p. 76 and 82-84).

While (A,A) is risk dominant in table 1, (B,B) is Pareto or payoff dominant since both players receive a higher payoff than in any other equilbrium. There is no single rule allowing one to say when risk dominance selects the equilibrium and when payoff dominance should. I will briefly summarize some of the findings.

Straub (1995) is an early example of experimental research specific to this question. He uses eight 2x2 games attempting to tease apart the relative importance of the two dominance measures. Five of these games were coordination games of the form in table 1, but the location of the risk dominant outcome varied. The other three games were battle of the sexes. In three out of five coordination games, players most often achieved the risk dominant outcome, but the payoff dominant outcome occurred most often in the other two. In one of these the mixed strategy equilibrium was risk dominant. In the other, game 8, Straub tried to exaggerate payoff dominance while minimizing risks to probes more deeply into the relationship.[6] In this game subjects played payoff dominant strategies most often. In game 8 Straub tested informally what Dubois et al (2009) later attempted to formalize.

Dubois et al. (2009) take the risk concept a bit further defining the 'relative riskiness' (RR) of payoffs. In a symmetric game such as figure 1, RR is defined as: $\frac{|x_{AB}-x_{AA}|}{x_{BB}-x_{BA}}$ where $x_{AB} \neq x_{AA}$. If relative riskiness matters to players, an RR close to 0 favors the risk dominant outcome; risk becomes similar between the two outcomes as RR approaches 1. In figure 1, RR = $\frac{1}{4}$. In Straub's game 8, RR was $\frac{4}{7}$, slightly greater than $\frac{1}{2}$. Dubois et al. try to disentangle the impacts of relative riskiness and the optimization premium of Battalio et al. (2001). Battalio et al. define the optimization premium (OP) as "the difference between the payoff of the best response to an opponent's strategy and the inferior response." Suppose the row player in table 1 expects the column player to choose strategy B with probability q. Then the expected payoff to the row player from choosing strategy B over A can written $\pi(B,q) - \pi(A,q) = \delta(q - q^*)$ where q^* is the probability of choosing B in the mixed strategy equilibrium.[7] Battalio et al. studied 3 games with optimization premia of 15, 25 and 50; they find more best response behavior and more risk dominant outcomes as the OP is increased. Their results illustrate that the magnitude of payoff dominance matters, but risk is constant in their study. Holding the OP constant, Dubois et al. find more risk dominant choices when the RR is lower. However, when RR was held constant, increasing the OP did not affect the frequency of risk dominant choices. This result is perfectly

[6] The payoffs were (A,A) = (30,30), (A,B) = (70,10), (B,A) = (10,70) and (B,B) = (80,80).

[7] In figure 1, the OP (δ) is 3.

consistent with results from Schmidt et al. (2003) who, using their own data and first round observations from similar studies, find that unilateral changes in risk parameters significantly influence behavior while unilateral changes in the payoff parameter do not. A contrasting result is found by Rankin et al. (2000), however, who present subjects with 75 sequences of SH games with variations in payoffs that change the payoff and risk dominant outcomes. They conclude that the pattern of play that emerges favors payoff dominant outcomes.

3.0 Experimental Design

The experiment is a 2 × 2 design described in tables 2a and 3. Experimental instructions for the cheap talk treatments are given in the appendix. We study two games; game 1 randomizes between PD payoffs and SH_1 while game 2 randomizes between PD payoffs and SH_2. Players each had two strategies: "In" and "Out". To describe the different payoffs or states we used the terminology "high demand" and "low demand" strictly for convenience. High demand refers to the PD state where players have a dominant strategy to play In. Low demand refers to the SH state which has two pure strategy equilibria: (i) both play In and (ii) both play Out. One player (player A) knows the state with certainty while the other (player B) knows there is a 70% chance the true state is either PD or SH.[8] For each of the games we varied the communication allowed between players. In the no-communication treatments subjects simultaneously made choices each period without any means to signal intentions; in the cheap talk treatments player A sent a non-binding message to player B indicating her intended action that period, and then players simultaneously made choices.

Subjects were matched with the same partner for 16 rounds and changed player types every 4 rounds.[9] Thus, all subjects experienced 8 rounds as player A and 8 as player B. Subjects participated in only one treatment, so our results are out of sample. Player A received a message at the beginning of each round that demand for the round was either high or low. Player B received a message that demand was either high or low with 70% probability. For example, if

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[8] Rubinstein (1989) considers an electronic mail game with two possible states of nature. One player knows the true state and can attempt to communicate it to the other player by sending an electronic 'blip' in one state and nothing in the other state. Rubinstein's purpose is to show how lack of common knowledge (even if players have "almost common knowledge") affects outcomes.

[9] A random matching protocol provides a better test of theory if one accepts that each matching resembles a one-shot game. Players learn about the game over rounds with different players but do not theoretically have an incentive to build a reputation. However, Schmidt et al. (2003) show that even with random matching, subjects' behavior is affected by observed histories. Since we are primarily interested in the effects of cheap talk across treatments that only differ in the stage game payoffs, any incentives to build a reputation should be the same across these treatments. When we compare treatments where the variable is whether or not cheap talk is allowed, our result will likely overstate the benefits of cheap talk compared to a design that uses random matching.

player B received the message: "There is a 70% chance that Demand this period is Low," then there was a 70% chance Player A received the message: "Demand this period is Low" and a 30% chance Player A received the message "Demand this period is High".[10] At the end of each round players received feedback on their own decision, the other player's decision, actual demand for that period (high or low), and their own payoff (knowing the other's action, a player could infer the others' payoff). A player's own payoff for each round was maintained in a history table.

The normal forms for the PD, SH_1 and SH_2 states are shown in table 2a. SH_1 and SH_2 have different strategic properties. To see this, consider the games from the perspective of player A and assume both players know which payoffs are relevant. Both players prefer (Out, Out) to (In, In), but in SH_1 player A prefers player B to play Out no matter what she herself intends to do. Thus, message "Out" conveys no information. In SH_2, player A only wants B to play Out if she intends to do the same. While both SH_1 and SH_2 satisfy the self-commitment criterion discussed in the introduction, messages in SH_1 are not self-signaling.[11] In addition, (Out,Out) is risk dominant in SH_2 so, while the uncertainty involved in the games adds complication, the lower risk of coordinating on the payoff dominant outcome in SH_2 means we expect to observe it more often in game 2 than in game 1 even without communication.

4.0 Equilibria

4.1 Without communication

In this section we discuss the equilibrium outcomes of the (one-shot) games.[12] Since our design is a partner design, we must take this repeated interaction into affect as well. We examine this interaction empirically in section 5.3 using panel data analysis.

Let $p \in [0.3, 0.7] \equiv$ the probability nature chooses demand is high,

$x \equiv$ the probability A chooses action In,

$y \equiv$ the probability B chooses action In,

$m \equiv$ the message A sends to B.

[10] Player A's message is the true one, but player B's message is operationally determined first. If B's message was 'There is a 70% chance Demand this period is Low', z-tree drew a random number between 0 and 1 from a uniform distribution. If the number was < 0.3, player A received the message "Demand this period is High", and players faced a PD game. If the random number was ≥ 0.3, player A received the message "Demand this period is Low", and players faced a SH game.

[11] Duffy and Feltovich (2002) provide a good description of the self-committing and self-signaling properties of PD and SH games.

[12] This description of the equilibria follows Fudenberg and Tirole (1991).

If player B receives the signal “There is a 70% chance demand this period is low,” then p = the probability nature chooses high demand is 0.3. A high signal for player B means she is told “there is a 70% chance demand this period is high”. For player A a high signal means she is told “demand this period is high”. Low signals are similarly defined.

Player A has a dominant strategy to play In when demand is high. We can thus use the reduced normal form of the payoffs shown in table 2b to compute the Bayesian Nash Equilibria of the game.[13] Player A’s strategy consists of her choice for each signal. So, (In, Out) means play In if demand is high and Out if demand is low. Strategies that have player A choosing Out when demand is high have been eliminated. The only equilibrium when p = 0.7 is (In,In,In). When p = 0.3 both (In,In,In) and (In,Out,Out) are equilibria.

There is also a mixed strategy equilibrium which we can calculate letting y = the probability player B chooses In and letting x = the probability player A chooses (In,In). Player A is indifferent between her strategies (In,In) and (In,Out) when:

$$2y+[6p+e(1-p)](1-y)=2py+[6p+4(1-p)](1-y). \qquad (1)$$

From this we determine player A prefers strategy (In,In) for $y > \frac{4-e}{6-e}$ and strategy (In,Out) for $y < \frac{4-e}{6-e}$. Player A’s mixed strategy is independent of p, the signal player B receives.

Player B’s indifference probability is determined as follows:

$$2x+[2p+e(1-p)](1-x)=4(1-p)(1-x) \qquad (2)$$

For $x > \frac{(4-e)-p(6-e)}{(6-e)-p(6-e)}$ player B prefers to play In, and for $x < \frac{(4-e)-p(6-e)}{(6-e)-p(6-e)}$ she prefers Out.

The two games we study differ in the value of e as shown in table 2a. In game 1 e = 3 and in game 2 e = 1. With these values, the indifference probabilities in the mixed strategy BNE are as follows: (i) for game 1, $x=\frac{1/3-p}{1-p}$ and $y=\frac{1}{3}$; (ii) for game 2 $x=\frac{3/5-p}{1-p}$, and $y=\frac{3}{5}$. For any $p \geq 0$, play of Out is more likely when e = 1.

[13] We thank an associate editor for suggesting this simplification.

While there are many variations which could be tested in alternative treatments, we have chosen p = 0.3 and 0.7. With these values, we introduce a non-trivial amount of uncertainty while giving uninformed players better than 50-50 odds of knowing demand.

Proposition 1: When p = 0.7 (In,In) is the most observed outcome.
When p = 0.7 player B has received the signal that there is a 70% chance demand is high. In this case (In,In,In) is the only pure strategy equilibrium, and using equation (2) we conclude there are no positive values of x for which B is indifferent between strategies. For both game 1 and game 2 player B always prefers to play In when she receives a high signal.

Proposition 2: (Out,Out) is more likely in game 2 than in game 1.
For the SH stage games (In,In) is risk dominant in SH_1 and (Out,Out) is risk dominant in SH_2.[14] Using the reduced form of the games in table 2b, (In,Out,Out) is payoff dominant in both games, but (In,Out,Out) is risk dominant only in game 2.

Table 4 shows players' payoffs using table 2b when p = 0.3, and table 5 shows players' expected payoffs in each game following different strategies. For example, (In,Out,1/3) means player A chooses In when demand is High and Out when demand is Low while player B chooses In with probability 1/3. Player A prefers (In,Out,Out) to both players mixing, but player B is virtually indifferent between playing Out and mixing following a low signal. If B decides to mix she will affect player A's payoff without affecting her own. As long as player A chooses (In,Out), B's payoff is almost invariant to her own action in game 1. Based on expected payoffs we expect Player B to choose Out following a low signal in either game, but we may observe her mixing in game 1.

4.2 Effects of communication

Out messages are not self-signaling in game 1, and while message Out *is* self-signaling for the SH stage game in game 2, it *is not* self-signaling for the reduced form of the game (table 4). In a one shot game messages should not affect outcomes in game 1 or game 2 since player A

[14] Using Harsanyi and Selten's (1988) definition, (In,In) is risk dominant in SH_1 since $\frac{2-0}{4-3} > \frac{4-3}{2-0}$. In SH_2 $\frac{2-0}{4-1} < \frac{4-1}{2-0}$ making (Out,Out) risk dominant. Using Dubois et al.'s (2009) definition SH_1 and SH_2 have the same relative riskiness (1/4); using Batallio et al.'s (2001) definition SH_2 has an optimization premium of 5 while SH_1 has an optimization premium of 3. Dubois et al.'s measure chooses the risk dominant outcome in each SH game since RR is closer to 0 than to 1, and Batallio et al. would predict more risk dominant outcomes in SH_2.

would always want player B to choose Out. However, since we use a partner design subjects may try to build reputations even though there is a finite, known time horizon and explicit punishment is not part of the game. We look for evidence of reputation building in the econometric results in section 5.3. Using an evolutionary analysis, Blume et al. (1998) predict convergence to a separating equilibrium when players are repeatedly matched to play divergent interest games with two allowable messages.[15] Our games are better described as having partially divergent interests, and we do not have a corresponding prediction for this case[16] Our predictions are summarized by propositions 3 and 4 below.

Proposition 3: when $p = 0.7$, player B will choose In and A's message will be ignored.
This follows from proposition 1.

Proposition 4: Player A can do no better than send m = Out (and subsequently play Out) when she knows demand is low. This follows from the expected payoffs in table 5. If message have an effect at all it will be to add assurance in game 2.

5.0 Results

The experiments were programmed in Z-tree (Fischbacher, 2007) and conducted at Appalachian State University. 150 subjects earned US$16 on average for sessions lasting approximately 1 hour 10 minutes. The breakdown of subjects to treatment is shown in table 3. In sections 5.1 and 5.2 we provide a descriptive analysis of the data and perform nonparametric analysis to address coordination and informational advantages.[17] We focus on three questions: first, to what extent is cheap talk effective at coordinating actions on the socially preferred outcome? Second, is cheap talk more effective in game 2 where the socially preferred outcome is risk dominant (and messages are self-enforcing in the SH stage game)? Third, what are the relative payoffs between players? In section 5.3 we control for group interaction between partners using panel regression
analysis.

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[15] Hypothesis 3, p. 1326. Their experimental results show support for the hypothesis but are inconclusive.

[16] Blume and Arnold (2004) develop a learning model for coordination in partial interest games. The application of learning models to these types of games is a direction for further research.

[17] Unless otherwise indicated we use a Mann-Whitney test when 2 samples are being compared, and a Wilcoxon sign-rank test is used within samples. Our significance level is 5%.

5.1 No Communication

Tables 6 and 7 show overall choices and outcomes across the four treatments. According to proposition 1 there should be few choices of Out when a player's signal is high, but we instead see a surprising number of Out choices in this case. In game 1 this result is more extreme without cheap talk; it is more extreme in game 2 with cheap talk. More B players choose Out following a high signal than do A players while more A players choose Out following a low signal. While this high proportion of Out choices is unexpected we cannot rule out that subjects are trying to nudge the other player to choose Out independent of their signal. This explanation would be in line with Clark and Sefton (2001) who find that subjects matched repeatedly with the same partner are more likely to coordinate on efficient outcomes (even in the first period) than when subjects play one shot games.[18]

According to proposition 2 we should observe players choosing Out more in game 2 than in game 1, but this is only true when they can engage in cheap talk. Without cheap talk there are more Out choices in *game 1* following a high signal; following a low signal the proportion of Out choices is statistically the same between games.

We use information on individual choices in the last 4 periods to determine if subjects appear to settle on either a pure or mixed strategy at the end of the game.[19] We claim above, for example, that we expect B players to choose Out following a low signal in game 2 and to either choose Out or use a mixed strategy in game 1. This expectation is based on the expected payoff calculations in Table 5. We report the results following low signals first for B and then for A players. In game 1, only 4 of 18 subjects played Out in the final periods of the game when there was no communication while 7 mixed between In and Out (the remaining 7 subjects choose only In). With cheap talk the picture is similar in game 1: five out of eighteen subjects played Out only, and 9 mixed between In and Out. In is only in game 2 with cheap talk that subjects appear to truly follow a pure strategy. Seventeen out of 21 subjects played Out only while 4 mixed between In and Out. Without cheap talk in game 2 the results are similar to game 1; four out of seventeen subjects played Out only while 7 mixed between In and Out. B players appear to settle on a pure strategy following low signals only in game 2 and only with cheap talk.

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[18] In their experiments subjects coordinated on the efficient outcome 60% of the time in the first round of repeated coordination games versus 30% of the time in the first sequence of one-shot pairings. They attribute this to subjects signaling their willingness to play the efficient strategy.

[19] B players' signals are determined before A players' signals, as described in footnote 9. B players did not receive a low signal in period 16, so these results for B players are for periods 13-15.

Player A subjects were more likely than B players to choose a pure strategy following low signals. In game 1 , 9/18 played Out only without cheap talk and three mixed. With cheap talk 10/19 played Out only while five mixed. In game 2, 6/21 played Out only without cheap talk and 10 mixed. With cheap talk 19/21 played Out only while 2 mixed. The average final period choices for both A and B players are shown in figure 1.

5.2 Communication

According to proposition 3 player B should ignore A's messages when p = 0.7. Using Table 8 player the proportion of In and Out messages player B receives is similar in game 1 when p = 0.7; using a Mann-Whitney test we cannot reject that B players choose Out equally often following each message. It does appear they are ignoring the signal in this case. In game 2 Player B receives an Out message 92% of the time when her signal is high and responds by playing out 79% of the time. From this we cannot say she is ignoring A's message.[20] Our econometric results in the next section show the interaction of A's message with her truthfulness affects B's willingness to choose Out.

We find evidence supporting proposition 4 for game 2 only: figure 2 shows player A sends message Out 61% overall in game 1 and 90% overall in game 2. Following a low signal the percentages are 75 for game 1 and 91 for game 2. After a low signal A players choose Out 66% of the time in game 1 and 96% of the time in game 2. In game 2 A players are close to a pure strategy with both messages and choices when their signal is low. We cannot say the same about game 1.

We see from table 7 that, in game 1, cheap talk does not significantly increase either cooperation (on equilibrium outcomes) or coordination (on the payoff dominant outcome). However, the story for game 2 is quite different. (Out, Out) occurs significantly more often with cheap talk while (In, In) occurs significantly less often. Cheap talk significantly increases coordination on the payoff dominant outcome from 35 to 85% when p = 0.3 and from 6 to 68% when p = 0.7. Thus, for game 2 cheap talk increases coordination, specifically, cooperative coordination.[21]

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[20] Playing Out following message In appears irrational. This happens in our data, but infrequently overall, and we cannot rule out that players are trying to send a signal when they behave this way. Other studies have found this occurrence with similar frequency. In Duffy and Feltovich (2002) approximately 15% of the time subjects cooperated after sending a defect message in a PD game (see their footnote 24). They attribute this to noise. Clark and Sefton (2001) note the incentive to 'signal' other players in repeated games. We believe some of this behavior is noise in our data, but particularly in game 2, we believe subjects are signaling.

[21] Cheap talk decreases disequilibrium outcomes in game 2 and (slightly) increases them in game 1.

In the SH_2 state messages are self-enforcing, and this could explain the increased cooperation in low demand states, however, messages are not self enforcing in the overall game described in table 2b. Therefore, we suggest that cooperation is increased in game 2 relative to game 1 because (In,Out,Out) in risk dominant in game 2.

Using table 7 we do not find evidence that player A is able to use cheap talk strategically. In general Player A might benefit (i) simply from the uncertainty B faces, (ii) using cheap talk strategically when demand is high, (iii) using cheap talk to coordinate. If A can use cheap talk strategically we should observe more (In,Out) outcomes when demand is high and more (Out,Out) outcomes when demand is low relative to treatments without cheap talk. Table 7 is broken down by player B's signal, but the picture is similar when broken down by A's signal: cheap talk does not increase play of (In,Out) when demand is high or (Out, Out) when demand is low. When demand is high, A players do not obtain their preferred outcome more often with communication in either game. In game 2, (Out,Out) does occur more with cheap talk, but this is true when demand is high as well as when demand is low. Combining this result with A's messages shown in figure 2 we conclude A players are using cheap talk in game 2 to (successfully) coordinate on the socially preferred outcome, even when demand is high. In section 5.3 we ask if A's informational advance translates into higher profits for her either absolutely or relative to player B.

5.3 Group interactions

In this section we check the robustness of our descriptive analysis using panel data regressions to control for repeated interaction between players. We apply logit models to look at each player's choices separately and at group outcomes. Tables 9-11 show the variables included in the models and the results. Table 12 and 13 compares players' profits. These models are estimated using population averaged Generalized Estimating Equations. Harrison (2007) summarizes the interpretation of coefficients from this model:

> "In many practical settings the population-averaged estimates will be identical to those obtained with a subject-specific estimation procedure, such as random effects specification. However, the interpretation of the coefficients is very different. Consider the effect of a dummy variable for the house money treatment on the probability of making a positive contribution. A subject specific estimate would be interpreted as the effect of a change in the treatment on the subject, holding all other characteristics constant. The population-averaged estimate would instead be interpreted as the effect on an average subject in one treatment compared to the average subject in the other

treatment. In fact, for many inferential purposes that is what one is interested in, but the differences must be kept in mind" (p. 434-435).

The data is coded as follows:

- Treat is a dummy variable coded as 1 for cheap talk treatments when making comparisons within game 1 or game 2. When the two games are being compared game 2 is coded as 1. Out choices (and lagged choices a_{it-1} and b_{it-1}) are coded as 1 and In choices as 0. A positive value on a lagged choice would indicate a player being more willing to play Out this period if the other played Out last period.[22]
- Signals (s_A and s_B) are coded 1 for high and 0 for Low. We expect a negative sign on this variable.
- Message, is coded as 0 for In and 1 for Out.
- Truth is a dummy variable = 1 if A's message was truthful in the previous period. We cannot predict the sign of this variable alone, but when we interact truth and message (tmessage) we expect a positive sign. A positive sign means (m_t = Out | $truth_{t-1}$ = 1) increases the chance B will play Out this period. A negative value could either imply (m_t = In | $truth_{t-1}$ = 1) or (m_t = In,Out | $truth_{t-1}$ = 0). Either of these cases would increase the chance B played In.
- Outcome is a dummy variable equal to 1 if the outcome is (Out,Out) and equal to 0 for the other 3 possible outcomes.
- Profdif is the difference between A and B's profit.

Using tables 9 and 10 we can look for the effect of cheap talk on players' choices. Models 3 and 4 in table 9 show that the treatment variable (cheap talk) has a significant effect on player A's choice only in game 2. Using models 3 and 4 in table 10 we arrive at the same conclusion for player B. This is consistent with the results in section 5.1. Players' signals are always significant and negative meaning a high signal decreases the probability a player chooses Out. The lagged choice of the other player always has a positive sign, indicating that player *j* choosing Out in the previous period increases the probability player *i* will choose Out in the current period. The fact that a_{t-1} is significant for Player B in model 2 and not in models 1a and 1b is in line with Duffy and Feltovich (2002); i.e., subjects use observation when cheap talk is not available.

Model 1 in tables 9 and 10 compares the cheap talk treatments between games 1 and 2. The treatment variable is positive and significant in both tables meaning both players choose Out

[22] We have also interacted this variable with the current signal instead. It was not significant at the 5% level.

more often in game 2 with cheap talk than in game 1. For player A, sending message Out increases the chance she plays Out. For player B the interaction term between truth and message is positive and significant in table 10 meaning that B players are more likely to play Out in the current period if they received message Out and player A was truthful in the previous period.

If cheap talk alone aids coordination on the payoff dominate outcome, it should be significant in both games 1 and 2. If the riskiness of payoffs and/or the credibility of messages matter, then cheap talk should be more effective at aiding coordination in game 2 than in game 1. The results shown in table 11 are consistent with the nonparametric results above.[23] Looking at the treatment variable in models 3 and 4, we conclude cheap talk improves coordination on the (Out, Out) equilibrium in game 2 but not in game 1, so cheap talk alone is not enough. (Out, Out) occurs more in game 2 than in game 1 when talk is possible (model 1), but there is no difference between treatments when there is no communication (model 2). Thus, risk dominance and payoffs that satisfy self-enforcement are not enough. Our design does not allow us, unfortunately, to determine if subjects coordinate in game 2 with cheap talk because (Out,Out) is risk dominant in the reduced form of the game, so that cheap talk adds assurance, or because messages are self-enforcing in the SH state (even though messages are not self-enforcing in the reduced form). As Clark et al. (2001) found, changing the payoffs so that messages become self-enforcing is not enough to improve coordination on the Pareto dominant outcome. We conclude that cheap talk is adding assurance in game 2 and helping players coordinate on the risk dominant (and also Payoff dominant) outcome.

Finally, we ask if player A makes relatively higher profit than B in game 1 and game 2 and whether player A's absolute profits are higher with cheap talk. These results are in table 12. Player A's signal is positive and significant meaning she does individually better when demand is high (models 1b and 2b) and better relative to player B when demand is high (models 1a and 2a). In models 1a and 2a, however, the treatment variable is negative meaning she does worse than player B in both games when cheap talk is used. Individually, she does better with cheap talk than without in game 2 (model 2b), but worse with cheap talk in game 1 (model 2a). Consistent with the results in section 5.2 we do not find evidence that Player A was able to use cheap talk strategically. She seems to use cheap talk more to coordinate and does worse than

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[23] s_A and s_B are correlated, but both are included to capture the fact that both affect the outcome. We test the extent of multicollinearity by checking the magnitude of the correlation coefficients. These are .5638, .2242, .3426, and .4372 in T0-T3, and are considered acceptable. Also including both variables does not change the sign or significance of the variables compared to just including one. The size of the individual coefficients are somewhat lower, and the p-value on s_B is slightly higher in models 1, 2 and 3.

player B because B plays Out less often than A following Out messages (except in game 2 with low demand, as seen in table 8).

Table 13 shows the relative payoffs of both players on average as a function of actual demand. Player A does relatively better than B when demand is high and relatively worse when demand is low, and cheap talk only benefits player A in game 2. We conclude that A benefits from cheap talk in game 2, but that B's uncertainty works to A's advantage in game 1. We might conjecture that an informed player can gain strategically the more risky the payoffs player face, but more experiments are needed to say this with confidence.

6.0 Conclusions

We use laboratory experiments to study the role of cheap talk when one player (player B) is uncertain whether payoffs form a prisoner's dilemma (PD) or a stag hunt game (SH). We study two games where, in each game, subjects faced either PD (high demand) or SH payoffs (low demand). The two games differ by the risk properties of the SH game.

We ask three general questions (i) to what extent is cheap talk effective at coordinating actions on the socially preferred outcome? (ii), is cheap talk more effective when the socially preferred outcome is risk dominant (and messages are self-enforcing in the SH stage game)? (iii) Can better informed players use their knowledge advantageously? In answering (i) and (ii) message credibility and risk matter, although with our design we cannot really say which of these matters more. In game 2 the payoff dominant outcome in the low demand state is also risk dominant, and messages are self-enforcing as described by Aumann (1990); in the reduced form of game 2 the payoff dominant outcome remains risk dominant, but messages are no longer credible. Nevertheless, cheap talk increases the percentage of payoff dominant outcomes in both the PD and SH stage games. Even with PD payoffs there are incentives to play efficiently in order to maintain trust. In game 1, the payoff inferior outcome is risk dominant in both the low demand stage and in the reduced form of the game. Here, cheap talk does not significantly increase payoff dominant outcomes.

In game 2, player A benefits by using cheap talk to coordinate; this benefits player B as well. In game 1, player A is unable to use cheap talk to her advantage (either by coordinating with B or by taking advantage of her). Instead, player A appears to benefit from B's uncertainty. This benefit is in the form of higher payoffs for A without cheap talk and higher relative payoffs when demand is high.

Previous experimental studies have shown that cheap talk can improve coordination between players when there are multiple equilibria, and have shown the robustness of risk dominant outcomes. We have added imperfect information and shown that risk dominant outcomes are similarly persistent in our design, particularly when players engage in cheap talk.

This research suggests various avenues for future research. We intentionally chose a partner design for this experiment; future research should consider a stranger design as a test of 'one-shot' behavior. The partner design could be expanded to include a dynamic analysis of trust and reciprocal behavior between subjects, and to test learning models. The effects of asymmetry between players could be further explored by manipulating the probability of signal accuracy. Finally, there is more to do to explore the relative importance of message credibility and risk dominance in coordination games generally and in partial common interest games specifically.

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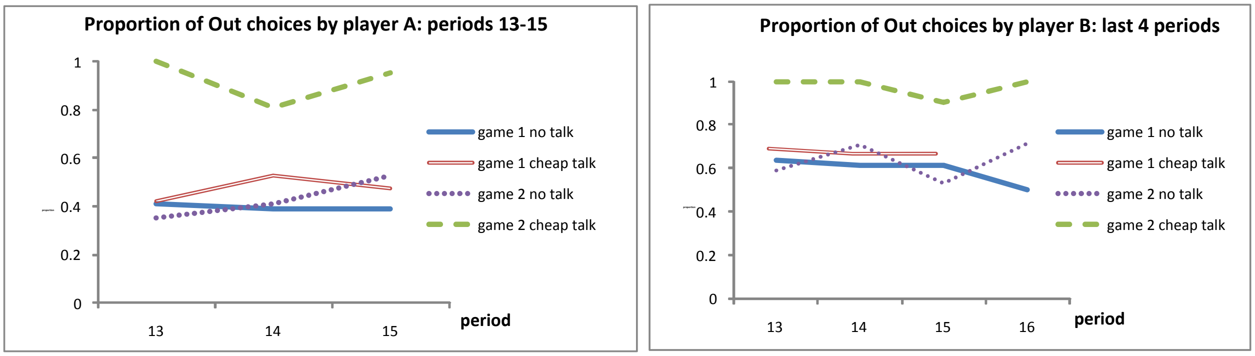

Figure 1: Choices by types with low signals: last periods of play

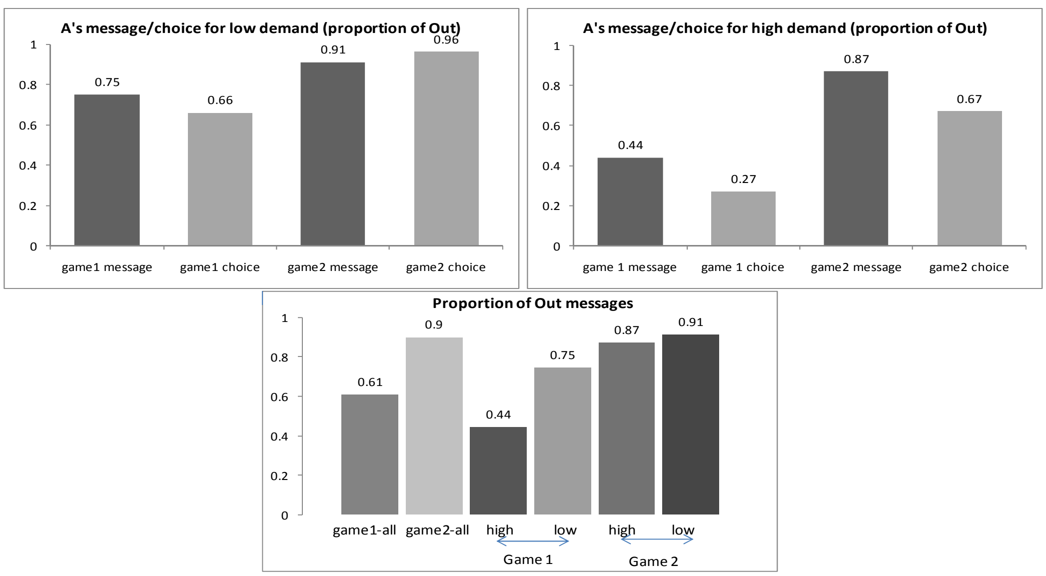

Figure 2: player A's message and choice by treatment and actual demand state

	A	B
A	2,2	3,0
B	0,3	4,4

Table 1: payoffs from Aumann, 1990

		Player B	
		In	Out
Player A	In	2,2	6,0
	Out	0,6	4,4

PD payoffs

		Player B	
		In	Out
Player A	In	2,2	3,0
	Out	0,3	4,4

SH_1 payoffs

		Player B	
		In	Out
Player A	In	2,2	1,0
	Out	0,1	4,4

SH_2 payoffs

Table 2a: State payoffs

		In	Out
Player A	In, In	2,2	6p +e(1-p),0
	In, Out	2p, 2p + e(1-p)	6p + 4(1-p), 4(1-p)

Table 2b: The reduced normal form, where e = 3 in game 1 and e = 1 in game 2

	No Talk	Cheap Talk
Game 1	36 subjects (18 groups)	38 subjects (19 groups)
Game 2	34 subjects (17 groups)	42 subjects (21 groups)

Table 3: Treatments

Game 1: p = .3 and e = 3

	In	Out
In, In	2, 2	3.9, 0
In, Out	0.6, 2.7	4.6, 2.8

Game 2: p= .3 and e = 1

	In	**Out**
In, In	2, 2	2.5, 0
In, Out	0.6, 1.3	4.6, 2.8

Table 4: Expected payoffs with p = 0.3 and e = 1,3 using Table 2b

Game 1 with p = .3		
(In, .05, 1/3)	expected payoff to A:	3.26
	expected payoff to B:	2.67
(In,Out,Out)	expected payoff to A:	4.6
	expected payoff to B:	2.8
(In,Out,1/3)	expected payoff to A:	3.27
	expected payoff to B:	2.77
Game 2 with p = .3		
(In, .43, .6)	expected payoff to A:	2.2
	expected payoff to B:	1.56
with (In,Out,Out)	expected payoff to A:	4.6
	expected payoff to B:	2.8
with (In,Out,.6)	expected payoff to A:	2.2
	expected payoff to B:	1.9

Table 5: Expected payoffs with p = 0.3 and selected strategies.

	No Talk		Cheap Talk	
	Game 1	Game 2	Game 1	Game 2
High Signal				
Player A	31	12	27	67
Player B	43	18	29	75
Low Signal				
Player A	66	69	66	96
Player B	57	60	49	93

Table 6: Percentage of Out choices based on each player's signal. A's signal is the actual demand state; B's signal is *p*.

p = 0.7

Game 1	*In/In*	*Out/Out*	*In/Out*	*Out/In*
no talk	42.07	24.83	18.62	14.48
cheap talk	44.08	16.45	12.5	26.97
Game 2				
no talk	50	5.88	11.76	32.35
cheap talk	10.12	67.86	7.14	14.88
p = 0.3				
Game 1	*In/In*	*Out/Out*	*In/Out*	*Out/In*
no talk	25.87	41.96	14.69	17.48
cheap talk	30.26	31.58	17.11	21.05
Game 2				
no talk	19.85	35.29	25	19.85
cheap talk	3.57	85.12	7.74	3.57

Table 7: Actual Outcomes (%).

Game 1	Message	*% of messages*	% of *Out* choices for A	% of *Out* choices for B
p = 0.7	Out	*53*	55	33
	In	*47*	31	25
p = 0.3	Out	*68*	64	56
	In	*32*	27	33
Game 2	message	*% of messages*	% of Out choices for A	% of Out choices for B
p = 0.7	Out	*92*	87	79
	In	*8*	36	29
p = 0.3	Out	*89*	93	99
	In	*11*	53	47

Table 8: % of Out choices conditional on player A's message and player B's signal.

	Model 1 Cheap talk (game 1 vs 2)	Model 2 No talk (game 1 vs 2)	Model 3 Game 1	Model 4 Game 2
Treat	.3007 (.000)	-.0447 (.645)	-.0012 (.989)	.4550 (.000)
s_A	-.3586 (.000)	-.4460 (.000)	-.3721 (.000)	-.4950 (.000)
b_{it-1}	.1045 (.065)	.0267 (.577)	.0554 (.200)	.0680 (.236)
Message	.2960 (.000)			

Table 9: y_{it} = achoice. GEE population averaged logit model with robust standard errors clustering on groups, marginal effects. p –values in parentheses.

	Model 1a Cheap talk (game 1 vs 2)	Model 1b Cheap talk (game 1 vs 2)	Model 2 No talk (game 1 vs 2)	Model 3 Game 1	Model 4 Game 2
Treat	.4035 (.000)	.4104 (.000)	-.1178 (.075)	-.1025 (.183)	.5137 (.000)
s_B	-.2473 (.000)	-.2389 (.000)	-.2635 (.000)	-.1612 (.003)	-.3651 (.000)
a_{it-1}	.0255 (.672)	.0595 (.319)	.1177 (.010)	.1070 (.020)	.0677 (.167)
Message	.0352 (.708)	.2770 (.000)			
Truth	-.1470 (.156)				
Tmessage	.3589 (.002)				

Table 10 y_{it} = bchoice. GEE population averaged Logit model with robust standard errors clustering on groups, marginal effects. p –values in parentheses.

	Model 1 Cheap talk treatments	Model 2 No talk treatments	Model 3 Game 1	Model 4 Game 2
Treat	.5636 (.000)	-.0154 (.855)	-.0860 (.326)	.6217 (.000)
s_A	-.2495 (.000)	-.1805 (.000)	-.1555 (.000)	-.3534 (.000)
s_B	-.1804 (.001)	-.1418 (.001)	-.1012 (.024)	-.2313 (.000)
Message	-.3670 (.000)			

Table 11. y_{it} = outcome. GEE population averaged Logit model with robust standard error clustering on groups, marginal effects. p – values in parentheses.

	Model 1a Game 1 y_{it} = profdif	Model 1b Game 1 y_{it} = profit	Model 2a Game 2 y_{it} = profdif	Model 2b Game 2 y_{it} = profit
Treat	-.3395 (.054)	-.3782 (.054)	-.2443 (.049)	1.296 (.000)
s_A	1.146 (.000)	.6928 (.000)	.8408 (.000)	.6152 (.000)
Constant	-.3535 (.001)	2.489 (.000)	.0179 (.849)	2.054 (.000)

Table 12. Profit for player A and profit differences between A and B. GEE population averaged OLS model with robust standard errors clustering on groups. p –values in parentheses.

High Demand	π_A	π_B	π_A - π_B
Game 1 no talk	3.1	2.37	0.73
Game 1 cheap talk	2.89	2.38	0.51
Game 2 no talk	3.11	1.81	1.3
Game 2 cheap talk	3.55	3.24	0.31
Low Demand	π_A	π_B	π_A - π_B
Game 1 no talk	2.57	2.86	-0.29
Game 1 cheap talk	2.04	2.78	-0.74
Game 2 no talk	1.77	2.04	-0.27
Game 2 cheap talk	3.58	3.64	-0.06

Table 13: Average period profits (π) by treatment and actual demand (s).

Appendix: Experimental Instructions:

Sample instructions for the cheap talk experiments. The no-talk instructions do not include the information about sending messages.

EXPCT
Experiment Instructions

This is an experiment in the economics of decision making. Your earnings in the experiment will depend on your own choices and the choices of subject(s) you are paired with. You will receive $5 for participating in addition to any earning you make during the experiment. Now that the experiment has begun talking is not permitted.

****

There are 16 rounds in this experiment. You are matched with one other person in this room. You are matched with the same person for all 16 rounds of the experiment. One of you will be assigned the role of Player A and the other will be Player B. Your role will change every 4 rounds. That is, if you begin as player A, you will be player A for rounds 1-4, player B for rounds 5-8, player A for round 9-12 and player B for rounds 13-16. Likewise, if you begin as player B, you will change roles every 4 rounds.

In this experiment you and the other player must each decide whether or not to enter a market. You have two choices: In or Out. Your profit is determined by your choice as well as the decision of the other player. You will have to make your choice *without knowing* what the other player has decided to do. There is also an element of chance.

Your payoffs depend on demand conditions in the market you are deciding to enter. Demand for your product may be High or Low. There are two possibilities: (i) there is a 70% chance demand is high or (ii) there is a 30% chance demand is high.

At the beginning of each round Player A will be told for certain if demand is high or low. Player B will only be told the likelihood that demand is high or low.
If you have the role of Player A you can send a message to Player B stating what choice you plan to make each round. This message is one-word: in or out. These messages are not required to be true messages. For example, Player A may send the message "out" (indicating she does not plan to enter the market), but then choose "in" instead. Player B will read A's message and then both players will make their choices. Note: Player B must draw his or her own conclusion about Player A's message.

How are your earnings determined? On the next page are 2 sample payoff tables.

How do we read the tables? If demand is high, the top table is true; if demand is low the bottom table is true. In the tables Player A's choices are in rows and B's choices are in columns. A's payoffs are shown first and B's are shown second.

High Demand

		Player B	
Player A		**In**	**Out**
	In	A's Profit: W B's Profit: w	A's Profit: X B's Profit: x
	Out	A's Profit: Y B's Profit: y	A's Profit: Z B's Profit: z

Low Demand

		Player B	
Player A		**In**	**Out**
	In	A's Profit: L B's Profit: l	A's Profit: M B's Profit: m
	Out	A's Profit: N B's Profit: n	A's Profit: O B's Profit: o

Suppose demand is high and both players enter the market (both choose In) Player A receives W and Player B receives w (this is the box on the top left). If neither player enters the market (both choose Out), Player A receives Z and Player B receives z (this is the box on the bottom right). If Player A chooses In and B is chooses Out, then A receives X and Player B receives x. If A chooses out and B chooses In, A receives Y and B receives y.

If demand is low, the payoffs for the players are shown in the second table. We read the table the same as before, but the numbers are different. For example, this time if A plays In and B plays Out, A receives M and B receives m.

B players must decide whether to play In or Out without knowing for certain which table represents the true payoffs. A players know which table is true, but they don't know what choice B players will make.

How will you be paid?
The program will calculate your earnings (in points) for the 16 rounds of the experiment. At the end of the experiment we will divide your points by 4 to get your earnings in dollars. You will also receive a $5 participation fee.

Before starting the actual experiment we will have a number of practice rounds to be sure you understand how payoffs are calculated. You must complete the practice rounds before beginning the experiment. There are no actual earnings for practice rounds.

After the practice rounds you will receive a separate sheet with the payoff tables that will be used in the experiment.

(D) Payoff tables subjects received after the practice rounds.

I begin as Player ________

High Demand

		Player B	
Player A		**In**	**Out**
	In	A's Profit: 2 B's Profit: 2	A's Profit: 6 B's Profit: 0
	Out	A's Profit: 0 B's Profit: 6	A's Profit: 4 B's Profit: 4

Low Demand

		Player B	
Player A		**In**	**Out**
	In	A's Profit: 2 B's Profit: 2	A's Profit: 1 B's Profit: 0
	Out	A's Profit: 0 B's Profit: 1	A's Profit: 4 B's Profit: 4

Timing of each round:
1. Player A is told if demand is high or low, and Player B is told the likelihood demand is high or low;
2. Player A sends a message to Player B (in or out);
3. Player B reads the message;
4. Both players make choices;
5. Earnings for the period are shown.

Tips:
1. All typing should be lower case.
2. If there is an OK or Continue button on the screen, click on it as soon as you are ready to proceed.
3. Please do not click on the numbers in the payoff tables.

Recall:
Your role changes every 4 periods. If you begin as player A, you will be player A for four periods, player B for 4 periods, etc. If you begin as player B, you will be player B for 4 periods, player A for 4 periods, etc. There are 16 periods.