RAND Journal of Economics
Vol. 20, No. 4, Winter 1989

Communication in the battle of the sexes game: some experimental results

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We report experimental results on the role of preplay communication in a one-shot, symmetric battle of the sexes game. We conducted games in which there was no communication, and we studied the effects of three different communication structures: one-way communication with one round of messages and two-way communication with one round as well as three rounds of messages. With these messages, each player could indicate which action he planned to take. Communication significantly increased the frequency of equilibrium play. One-way communication was most effective in resolving the coordination problem. While there was more conflict with two-way communication, one round of communication helped to overcome some of the coordination problems, and three rounds of communication performed even better.

1. Introduction

■ There are two leading interpretations of a Nash equilibrium in games with complete information. According to one, agents make strategic decisions which are best responses to the conjectured actions of others. In equilibrium, these conjectures are correct. In this process, the objectives of all players are common knowledge, and hence, agents are able to deduce each other's best responses (Pearce, 1984). An alternative interpretation is that a Nash equilibrium is the outcome of nonbinding preplay communication leading to the selection of a self-enforcing agreement (Farrell and Maskin, 1987). This form of communication is

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We thank Joseph Farrell for valuable discussions on this topic, Maxim Engers and two anonymous referees for several helpful comments on an earlier version of this paper, and Robert Pearson for his programming assistance. Partial support for all four authors was provided by NSF Grant SES-8808201. Partial support for Cooper was provided by NSF Grant SES-8605302 and a NSF grant to the Hoover Institution for the National Fellows Program. Partial support for DeJong was provided by Price Waterhouse, and partial support for Forsythe was provided by NSF Grants IST-8610360 and SES-8607771. Financial support from the University of Iowa, the Hoover Institution, and the Social Sciences and Humanities Research Council of Canada is also gratefully acknowledged.

known as "cheap talk"; messages are assumed to be costless, nonbinding, and payoff irrelevant.

In games with a unique Nash equilibrium, these two interpretations lead to the same prediction: each player should have no difficulty conjecturing his opponents' actual moves. In games with multiple Nash equilibria, however, agents may have difficulty conjecturing the behavior of others unless one of the equilibria is focal. Thus, for example, when each of the players prefers a different equilibrium *ex ante,* they may have difficulty coordinating their behavior to achieve any equilibrium *ex post.* For such games, cheap talk might serve an important coordinating function by resolving the uncertainties about opponents' play.

In this article, we focus on the role of preplay communication in avoiding the problem of *ex post* disequilibrium. This is quite naturally addressed in an experimental setting. We examine a symmetric battle of the sexes game in which there are two pure-strategy asymmetric equilibria and one symmetric mixed-strategy solution.

This is a famous old game (Rapoport, 1966), which is interesting for at least two reasons. First, it lies at the core of certain theoretical models in industrial organization. Farrell (1987) and Dixit and Shapiro (1986) used it to study firms' decisions to enter a naturally monopolistic industry. They argued that the logical outcome absent communication is the symmetric mixed-strategy equilibrium. However, this solution is problematic in that, *ex post,* players may not be at any equilibrium.[1] The game appears again in models of product standardization. (See, for example, Farrell and Saloner (1985)) in which both firms would benefit from standardizing technologies, but each prefers to select the technology in which it is the most advanced.

Second, Farrell (1987) has proposed a theory of the role of cheap talk in this game. He constructed an equilibrium for a two-stage game in which cheap talk preceded play in a battle of the sexes game; this reduced the frequency of *ex post* disequilibrium. His equilibrium provides a useful theoretical benchmark for evaluating our experimental results.

Section 2 provides a theoretical discussion of communication in the battle of the sexes game, which summarizes and extends Farrell's equilibrium. Section 3 describes our experimental design. We examined three different communication structures: no communication, one-way communication, and two-way communication. Our main finding, reported in Section 4, is that cheap talk can reduce the significant coordination problems arising in the battle of the sexes game without communication. One-way communication, in which the sender of the message simply chooses his preferred equilibrium and the receiver best responds, is the most effective way to resolve the problem. With two-way communication, there was more conflict than with one-way, since players had to coordinate their messages. Still, two-way communication helped to overcome some coordination problems.

Farrell (1987) presented a model in which the performance of two-way communication is improved if players have additional rounds in which to communicate. We examine this possibility in Section 5 by presenting the results from games in which players had the opportunity to send three rounds of messages before choosing their payoff-relevant strategies. While we found that the additional rounds of communication significantly reduced the number of coordination failures relative to the earlier two-way games, significantly more failures continued to occur than in the one-way games. Overall, our results provide qualitative support for the equilibrium outlined by Farrell (1987).

2. Communication and coordination

■ To understand the potential implications of introducing communication into the battle of the sexes (BOS), consider the symmetric BOS game in Figure 1, where $x > y > 0$.

[1] Although each player uses his equilibrium mixed-strategy *ex ante,* an *ex post* disequilibrium results whenever the players' actual chosen actions do not constitute a pure-strategy equilibrium.

Figure 1

		Column Player	
		$C1$	$C2$
Row Player	$R1$	(0, 0)	(y, x)
	$R2$	(x, y)	(0, 0)

This game has two pure-strategy equilibria, $(R2, C1)$ and $(R1, C2)$, and a symmetric mixed-strategy equilibrium in which strategy $i = 1, 2$ is played with probability p_i where $p_1 = y/(x+y)$ and $p_2 = x/(x+y)$. The expected payoff to each player in this equilibrium is $xy/(x+y)$.[2]

Without communication, the symmetry of the mixed-strategy equilibrium makes it a natural outcome of this game; it also implies that there is a positive probability of *ex post* disequilibrium of $(x^2 + y^2)/(x+y)^2$. In this case, communication might avoid this coordination problem.

The effect of adding a communication stage to the beginning of a game depends upon the communication technology available to the players. Two key elements seem particularly important. The message space from which players are permitted to select their messages must be clearly specified. Are players permitted uncontrolled conversation for an extended period of time, or are they restricted to making announcements regarding their intended play and/or suggestions for the play of others? Experiments on repeated prisoner's dilemma games have revealed that uncontrolled communication leads players to resort to threats and name-calling in an effort to induce cooperation. (See Dawes (1980).) Such behavior could be interpreted as an attempt to change the nature of the game by altering the payoffs. Since our interest is in the behavior of players playing the games we put before them, this is undesirable. In the research reported here, communication represents simple messages about prospective actions.

The second element of the communication technology deals with who can communicate with whom and how often. We consider two possibilities. First, let only one player be allowed to send one cheap-talk message, which consists of a nonbinding announcement. With this announcement he can "indicate which action he plans to play." Second, let the players be allowed to send these messages to each other simultaneously, but only once. It should be noted that silence is always an option available to the players. This was not an option in Farrell (1987), therefore our theoretical predictions will be somewhat different from his.[3]

Regardless of the interpretation of silence, one equilibrium in this game is for communication to have no effect whatsoever. If players cannot commit to follow through on announcements and the communication has no effect on payoffs, there will always be a "babbling" equilibrium in which each player picks his announcement randomly and everyone ignores everyone else's announcement, leaving the set of outcomes of the second-stage game unchanged from those possible without communication (Myerson, 1987).

However, work on cheap-talk communication by Farrell (1985, 1987), Myerson (1987), and others, has focused on restricting beliefs in order to support other equilibria in which cheap talk does matter. For example, consider the effects of letting only the row player send a single message to the column player prior to the play of the game in Figure 1. Following Farrell (1985), make the following assumption.

[2] Since this is less than the minimum payoff in either pure-strategy equilibria, a coordination failure arises *ex ante* whenever the mixed-strategy equilibrium occurs.

[3] Farrell (1982) did include the possibility of silence in a game with incomplete information. His interpretation of this message is similar to the "coordination announcement" view, which we explain later in this section.

Assumption 1. If it is optimal for the row player to honor his announcement when the column player believes that the row player will honor it, then the announcement will be believed and honored.

If Assumption 1 accurately describes the beliefs that players hold about the meaning of cheap talk, then in the two-stage game with communication, there will only be one equilibrium. The row player will announce $R2$; the column player will believe this announcement and play $C1$; the row player will then honor this announcement and play $R2$. In this setting, the ability to communicate confers a first-mover advantage on the row player. Relative to the mixed-strategy equilibrium, both players are better off with this type of communication, although the sender clearly gains more than the receiver.

In the one-way communication game, it is difficult to imagine why any player would choose to remain silent (announce 0). Given that Assumption 1 holds, the player who is permitted to communicate can get his preferred equilibrium outcome by announcing 2, so no matter what an announcement of 0 means, announcing 2 will at least weakly dominate announcing 0.

The effects of two-way communication are less clear. Let each row (column) player have a single opportunity to communicate a strategy which consists of either $R0$, $R1$, or $R2$ ($C0$, $C1$ or $C2$) prior to playing the game in Figure 1. We must first specify a role for silence in these games. While silence could simply be viewed as noise, it could also be interpreted as being the same as some other announcement, or it could signal one's intention to ignore his opponent's announcement and play a particular strategy. Instead of examining all of these possibilities in detail, we will focus on one particular interpretation of silence which, as we will see below, best fits the data.

In this interpretation, silence (announcing 0) is assumed to be a coordinating announcement. By announcing 0, a player is stating his intention to take an action which will lead to a pure-strategy equilibrium, given the action announced by his opponent. This generates a mapping of announcements into actions as follows.

Announcements		Actions
$(R0, C1)$	$\rightarrow$	$(R2, C1)$
$(R0, C2)$	$\rightarrow$	$(R1, C2)$
$(R1, C0)$	$\rightarrow$	$(R1, C2)$
$(R2, C0)$	$\rightarrow$	$(R2, C1)$

Thus, if one, but not both players, announces 0, then the announcements constitute a pure-strategy equilibrium for the second-stage game. If both players announce 0, no coordination has been achieved, since the announcements do not constitute a pure-strategy equilibrium for the second-stage game.

Following Farrell (1987), we make the following assumptions.

Assumption 2. If the announcements of both players constitute a pure-strategy equilibrium for the second-stage game, each player will play his announced strategy.

Assumption 3. If the announcements of both players do not constitute a pure-strategy equilibrium in the second-stage game, each player will play his mixed-strategy Nash equilibrium strategy. Denote the expected payoff to each player from this outcome by u.[4]

The payoff matrix to this communication game is given in Figure 2. Since $x > y > u$, there will be four asymmetric pure-strategy equilibria in this communication game, as well

[4] Note that Assumption 2 ensures that it would be subgame perfect not to reopen negotiations even if further communication were possible. However, Assumption 3 would not be consistent with subgame perfection as mutual gains to renegotiation would exist. See our discussion of multiple rounds of two-way communication in Section 5.

Figure 2

		Column Player Announces		
		C0	C1	C2
Row Player Announces	R0	(u, u)	(x, y)	(y, x)
	R1	(y, x)	(u, u)	(y, x)
	R2	(x, y)	(x, y)	(u, u)

as a symmetric mixed-strategy solution. In the mixed-strategy equilibrium, the probability of announcing 0 is

$$q_0 = (y - u)(x - u)/\alpha,$$

the probability of announcing 1 is

$$q_1 = (y - u)^2/\alpha,$$

and the probability of announcing 2 is

$$q_2 = (x - u)^2/\alpha,$$

where $\alpha \equiv (x - u)^2 + (y - u)^2 + (x - u)(y - u)$.

The expected payoff from this mixed-strategy equilibrium is[5]

$$E\pi_1 = y - (y - u)\cdot\left[\frac{(y - u)^2}{(x - u)^2 + (y - u)^2 + (x - u)(y - u)}\right].$$

Compared with the no-communication game, two-way communication reduces the frequency of *ex post* disequilibrium and increases each player's expected payoff.

Using these theoretical results, we address two specific questions related to the role of communication in these games. First, does communication matter? That is, does the play of the game after the addition of preplay communication differ from that in the game with no communication? Second, if communication does make a difference, does it either fully or partially resolve the coordination problem?

Farrell (1987) and our extension here provide answers to these questions. This theory predicts that cheap talk will help resolve the coordination problems inherent in the battle of the sexes game and generates specific predictions concerning the frequency of various messages and the mapping from these messages to actions. Our experiment was designed to test these hypotheses.

3. Experimental design and parameters

■ Players were asked to participate in a complete information, bimatrix game. Each player was designated as either a row or column player and paired with an anonymous opponent. The game was one of complete information, since each player's payoff matrix was common knowledge. The payoffs in the cells of the matrix represented a player's utility if the respective strategies were chosen.

We induced payoffs in terms of utility using the Roth-Malouf (1979) binary lottery procedure. In the matrix game, each player's payoff was given in points which then determined the probability of the player winning a monetary prize. At the end of each game, we conducted a lottery in which "winning" players received a monetary prize specified below and "losing" players received nothing. The probability of winning was computed by dividing

[5] It can be shown that this expected payoff is higher than what players would earn in the symmetric mixed-strategy equilibrium of the game with two-way communication in which silence is not an option.

the points a player earned by 1,000. Since expected utility is invariant with respect to linear transformations, this procedure ensured that when a player maximized his expected utility, he maximized his expected number of points in each game, regardless of his attitude toward risk.[6]

We used this method, instead of enumerating payoffs directly in dollars, because the models we tested require that the payoffs be the von Neumann-Morgenstern utilities of the players and that these payoffs be common knowledge. The binary lottery procedure accomplishes this by making individual "utility" payoffs (i.e., the probability of winning) common knowledge. This would not be possible if individual payoffs in the bimatrix game were given in dollars.[7]

The experiment was conducted using nine cohorts of players, each consisting of eleven different players, recruited from upper-division undergraduate and MBA classes at the University of Iowa. Players were seated at separate computer terminals and given a copy of the instructions for the experiment. Since these instructions were also read aloud, we assume that the information contained in them was common knowledge.

Each player participated in a sequence of one-shot games against different anonymous opponents within his cohort. The pairings of the players were randomly determined prior to the start of each session by the computer. Each player alternated between being a row and a column player. Since each player reported his strategy choices through a computer terminal, no player knew the identity of the player with whom he was currently paired, nor the history of the decisions made by any of the other players in the cohort.

Each cohort participated in two separate sessions.[8] In session 1, all players participated in ten symmetric one-shot dominant strategy games without communication. The instructions and the parameters for the session 1 games are reproduced in Appendix A. During session 1, each player played one game against every other player. Since there was an odd number of players, one sat out each period. Thus, session 1 consisted of eleven periods. Applying the binary lottery procedure to these games, winning players received \$1 and losing players received nothing. The dominant strategy game was conducted to provide players with experience about the experimental procedures.

In session 2, all players participated in twenty one-shot battle of the sexes games. The game was identical to that in Figure 1 with $x = 600$ and $y = 200$. Instructions for these games are reproduced in Appendix A. Each agent played against every other player twice: once as a row player and once as a column player. As in session 1, one player sat out in each period, and each player alternated between being a row and a column player during the periods in which he was participating. Thus, session 2 consisted of twenty-two periods. In these session 2 games, winning players received \$2 and losing players received nothing in the binary lottery.

We varied the type of communication across the cohorts. There were three treatments with three cohorts per treatment. In the no-communication (*NC*) treatment, players were not allowed to send messages prior to play. This provides a baseline for evaluating the implications of communication. In the one-way communication procedure (1*W*), the row player had the option to send or not send the column player a message, and he was told that with this announcement "you may indicate which action you plan to take." After all messages were received, the players simultaneously chose actions. In the two-way com-

[6] See Roth and Malouf (1979) and Berg, Daley, Dickhaut, and O'Brien (1986) for a complete description of this procedure.

[7] As reported in Cooper *et al.* (forthcoming), we have run a number of coordination games using dollars as well as the binary lottery method. The method of payment produced no apparent differences in the outcomes of the games.

[8] Each cohort completed the two sessions in about one to one and one-half hours. Payments ranged from \$6 to \$36.

munication procedure ($2W$), both of the players simultaneously had the option to send or not to send messages to each other. The exchange of messages was then followed by the simultaneous choice of actions.

With $x = 600$ and $y = 200$, the mixed-strategy equilibrium for the game without communication requires that players play strategy 1 with probability .25 and strategy 2 with probability .75. The expected payoff from playing this game, u, is 150. The predicted frequency of "hits" (*ex post* equilibrium outcomes) is .375.

With one-way communication, under the assumptions described above, the player sending the message should announce and play strategy 2, while his rival plays 1, leading to payoffs of 600 for the sender and 200 for the receiver. As players alternate being senders and receivers, each should average 400 points per game. In principle, one-way communication solves the coordination problem; the predicted frequency of hits is 1.00.

With two-way communication, where silence is interpreted as a coordinating announcement, the predicted frequencies of announcement are

$$q_0 = .099, \qquad q_1 = .011, \qquad \text{and} \qquad q_2 = .890.$$

Two-way communication helps, but does not solve the coordination problem. The predicted proportion of hits (*ex post* equilibrium outcomes) goes from .375 without communication to .499 with two-way communication. To test the assumption that 0 is a coordinating announcement, we examined the mapping between announcements of 0 and actions. In particular, when only one player announces 0, that player should choose his best response to the strategy announced by the other player.

4. Results

■ As discussed in the previous section, we began each of the sessions with a dominant strategy game. For that game, the dominant strategy was played 87.7% of the time over the nine cohorts. Thus, as in Cooper *et al.* (forthcoming), it is clear that the dominant strategy was played almost all of the time.

To determine whether we could pool our data for row and column players, we conducted difference-of-proportions tests. Pooling of results for row and column players is appropriate for all but the one-way communication game. In all other games, there were no significant differences between the actions chosen by the row and column players at the 5% level. We also tested for serial dependence in all of these experiments. Using a chi-square test, we looked for serial dependence in actions, announcements, and actions conditional on announcement types. None of these tests produced evidence of dependence significant at the 5% level. Finally, we conducted chi-square tests and found no significant differences of actions across replications of all treatments. For these reasons, we present our results for all experiments pooled over all twenty-two periods and across all three replications, and for all but the one-way communication experiments, pooled across row and column players.

□ **No-communication (NC).** In the absence of communication, there are three equilibria for the battle of the sexes game given in Figure 1. As argued in the previous section, the natural candidate is the symmetric mixed-strategy equilibrium in which, when $x = 600$ and $y = 200$, the probability of playing strategy 2 is .75 and the likelihood of observing equilibrium play is .375.

Table 1 gives the frequency of play of strategy 2 for the entire twenty-two periods (660 individual plays) as well as the frequency of actual "hits" (i.e., the play of equilibrium strategies, *ex post*) for all twenty-two periods (330 pairings). This table pools the results over the three replications and across row and column players.

The observed play of strategy 2 is significantly less than the prediction of .75 from the symmetric mixed-strategy solution. Furthermore, the observed proportion of hits is higher

TABLE 1 **Summary of Results of *NC* Games**

Proportion of Hits	.48
Proportion Play 2	.63

than the predicted level from the symmetric mixed-strategy Nash equilibrium, although it is very close to the fraction of hits we would expect (.47) if players were playing mixed-strategies with a probability of playing strategy 2 of .63. Both proportions are significantly different from their predicted values at levels of significance much less than 1%, using the normal approximation of the binomial distribution. Overall, we see that the play of strategy 2 occurs less often than predicted.

Based on these results from the no-communication games, the existence of potential gains from coordination is clear. In these games, 52% of the play resulted in disequilibrium *ex post,* indicating that both players could have been made better off by coordinating their actions. Our task now is to evaluate the role of communication in overcoming these coordination problems. We begin by reporting the frequency of hits and the frequency of plays of strategy 2 under the three alternative communication structures. Detailed results on these treatments are also presented in the following subsections.

□ **Comparing communication structures.** Table 2 summarizes our results regarding the players' choices of actions across communication structures. Qualitatively, the important implication of the theoretical work on communication is that coordination problems should be reduced by allowing cheap talk. Our results strongly support that prediction.

These proportions of hits indicate that, in each case, communication improves the outcome relative to the *NC* games. One-way communication is particularly effective. Again, using difference-of-proportion tests, we examined the significance of these differences. All pairwise comparisons of hits are significantly different at the 5% level, with the exception of the comparison between *NC* and $2W$, which is significant at the 10% level.

Another means of assessing the relative values of these communication games is to evaluate the expected winnings of participants in each of these three treatments. The figures given in Table 3 represent the product of the actual average number of points earned per game and the expected value of each point in the lottery (i.e., \$2/1,000). These monetary values may better illustrate what is actually at stake in these games.

Thus, the important prediction of the cheap-talk models holds in our experiment: communication aids in coordinating the actions of agents. It is also of interest to investigate the nature of the announcements made in these different treatments and their interpretation by the players. These issues are discussed next.

□ **One-way communication.** One means of overcoming the conflict inherent in the battle of the sexes game is for one, and only one, of the players to announce his strategy. From Section 2, recall that as long as the other player believes this to be credible then the sender's

TABLE 2 **Comparison of Results Across Communication Structures**

	Proportion of Hits	Proportion of Plays of 2
No communication (*NC*)	.48	.63
One-way communication ($1W$)	.95	.52
Two-way communication ($2W$)	.55	.65

TABLE 3 **Expected Payoffs Given Actual Average Points**

No-communication (*NC*)	\$0.39
One-way communication (1*W*)	\$0.76
Two-way communication (2*W*)	\$0.44

best message is that he will play the strategy that supports his preferred Nash equilibrium. The receiver will then best respond. Our results, given in Table 4, provide remarkably strong support for this outcome.

The results are quite striking. We observed equilibrium play 95% of the time. This was mainly achieved by the sender announcing strategy 2 and following through with this play, while the receiver best responded and played 1. This is the equilibrium outlined in Section 2. There are only 16 out of 330 outcomes which are disequilibrium *ex post*. Seven of these occurred when the receiver played strategy 2 following a sender's announcement of strategy 2. One occurred when the sender announced strategy 2 and played strategy 1, and the other eight occurred when the sender chose not to make an announcement, and both players chose strategy 2.

In this game, the sender's silence often led to an *ex post* disequilibrium. Overall, 16 of the 18 times he chose to remain silent, the sender played strategy 2. However, the receiver frequently interpreted silence as the sender's intention to play strategy 1, since he also chose to play strategy 2 in 10 of these 18 instances. Thus, silence, in our admittedly small sample, appears to have been dominated by announcing 2. While choosing not to send a message does happen rarely in the one-way communication game, it is more important in the analysis of two-way communication.

□ **Two-way communication.** The results for this communication structure are given in Table 5. Here, the second statistic (.80) reports the frequency of equilibrium play (i.e., hits) that followed the announcement of that equilibrium. The fourth statistic (.39) gives the frequency of equilibrium play following disequilibrium announcements. We separate equilibrium announcements (1, 2) and (2, 1) from the coordinating 0 announcements of (0, 1), (0, 2), (1, 0), and (2, 0), where one player is silent. The disequilibrium announcements are (0, 0), (1, 1), and (2, 2).

From this table we see that the proportion of times that equilibrium announcements yield equilibrium play is quite high: 80% overall. This is in line with the equilibrium conjectured by Farrell (1987), and with our Assumption 2. Further, equilibrium play following coordinating announcements of 0 occurred at almost an identical frequency: 79%. Thus, based on the frequency of subsequent equilibrium play, coordinating announcements of 0 are no different from equilibrium announcements.

In the event that announcements did not constitute an equilibrium, Farrell argued that the natural outcome was the symmetric Nash equilibrium, in which, for our game, strategy 2 should have been played 75% of the time. These results support that prediction: 71%

TABLE 4 **One-Way Games**

	Results	Prediction
Proportion of Hits	.95	1.00
Proportion of Announcements of 2	.93	1.00
Play of 2 given Announcement of 2	.99	1.00
Proportion of Announcements of 0	.05	0
Play of 2 given Announcement of 0	.89	—

TABLE 5 **Two-Way Games**

		Results	Prediction
Proportion of Hits		.55	.499
Equilibrium play given equilibrium announcements		.80	1.000
Equilibrium play given coordinating 0 announcements		.79	1.000
Equilibrium play given disequilibrium announcements		.39	.375
Play of 2 given disequilibrium announcements		.71	.750
Announcements:	Proportion announcing 0	.27	.099
	Proportion announcing 1	.09	.011
	Proportion announcing 2	.63	.890

is the actual proportion observed, which is not significantly different from 75% at the 5% level of significance. Correspondingly, hits following disequilibrium announcements occurred 39% of the time, which is not significantly different from the 37.5% predicted.

The apparent anomaly here is that the mixed-strategy equilibrium prediction regarding the play of strategy 2 following disequilibrium announcements is not rejected in the $2W$ games, while it is rejected in the *NC* games. One way to explain this result is by considering the possibility that there were altruists in each cohort[9], who saw their payoffs as the *sum* of the payoffs given in each cell in Figure 1.[10] In Appendix B, we consider a game of incomplete information in which a fraction, ρ, of the players are altruists and $1 - \rho$ of the players are egoists. Using the data from the no-communication games, we estimated the fraction of altruists in our subject population by finding the equilibrium which best explains this data and computing the value of ρ associated with that equilibrium. For the *NC* games, $\rho = .37$. We will now use this frequency to evaluate the expected outcomes in games with communication.[11] As we show in Appendix B, if $\rho \in [.25, .50]$, there will be a fully-revealing equilibrium in the game with two-way communication in which altruists announce 0 or 1 and egoists announce 2. The value $\rho = .37$, which was computed in the no-communication game, is within this interval. Since this model predicts that all egoists announce strategy 2, 63% of all players are predicted to announce 2. This is exactly what we observed!

Furthermore, the model predicts that when 37% of the players are altruists, strategy 2 will be played following disequilibrium announcements 71% of the time; this is precisely the observed fraction. The fact that this prediction (.71) is very close to the prediction (.75) from the model without altruists suggests that altruists have little effect on the probability that strategy 2 is played given that disequilibrium announcements are made. When a player announces (0, 0) or (1, 1), he reveals himself to be an altruist and thus will play the altruistic mixed-strategy equilibrium in the subsequent game in which each altruist plays strategy 2 with probability .5. In our $2W$ games, the play of 2 followed the announcement of (0, 0) or (1, 1) 53% of the time as compared with the prediction of 50%. Similarly, the disequilibrium announcement of (2, 2) reveals that the players are egoists and will play the egoistic mixed-strategy equilibrium in the ensuing game. In our experiment, the play of 2 followed the announcement of (2, 2) 74% of the time as compared with the prediction of 75%. There

[9] There is much experimental evidence that suggests that substantial fractions of players in simple games are concerned with fairness. This has been documented in a variety of different games, including the prisoner's dilemma game (Dawes, 1980), games with public goods (Palfrey and Rosenthal, 1985, 1988), bargaining games (Forsythe *et al.*, 1987, 1988), and coordination games (Cooper *et al.*, forthcoming).

[10] This is only one way to model altruistic behavior. Besides maximizing the sum of their point earnings, altruists could also maximize the sum of their dollar earnings. See Cooper *et al.* (1989) and Palfrey and Rosenthal (1987) for discussions of alternative models of altruistic behavior.

[11] The problem with this incomplete information model is that it predicts that we must have a perfectly revealing equilibrium in order for it to explain the observed data. In this equilibrium, all altruists play strategy 1, and all egoists play strategy 2. In our data, there was no player who was always altruistic in this sense. Furthermore, only two of the thirty-three players were always egoistic.

TABLE 6

		Strategy Chosen			
		(1, 1)	(1, 2)	(2, 1)	(2, 2)
Announcement Made	(0, 1)	0	1	10	2
	(0, 2)	8	89	0	17

was very little disequilibrium play between altruists; they were either paired with egoists or, when paired with another altruist, often avoided a disequilibrium announcement by using a coordinating 0 announcement.[12]

The announcement data provides evidence in support of the hypothesis that silence is a coordinating announcement. In Table 6, we present the data on the strategies chosen whenever only one of the players remained silent. For convenience, we give the silent player's announcement first in the announcement row and the silent player's strategy choice first in the strategy column. Of the 114 times one player was silent while the other announced strategy 2, the silent player played strategy 1 in 97 of these instances. Further, there were 13 times that one player announced 1 while the other player was silent; in 12 of these cases, the silent player chose strategy 2. Thus, the silent player's actions seem consistent with the hypothesis that announcing 0 is a coordinating move. Furthermore, the player who received no announcement seems also to have interpreted 0 as a coordinating message. Of the 127 observations in the table, the player who made an announcement chose the announced strategy in 116 of these instances. This indicates that in most cases, he expected the silent player to coordinate to his announcement.

The interpretation of announcing 0 as a coordinating device yields the predicted announcement frequencies of .1, .01, and .89 for announcements of 0, 1, and 2, respectively. These proportions were computed using the theoretical mixed-strategy solution, i.e., $u = 150$. The predicted frequency of announcements of 0 is significantly lower than that which we observed, and the predicted frequency of announcements of 2 is significantly higher than that which we observed. The pattern of announcements however is qualitatively similar to the predictions of the coordinating 0 theory.[13]

5. Multiple rounds of two-way communication

■ When both players send one round of messages simultaneously, there is a chance of confusion that does not arise when only one player communicates. Farrell (1987) demonstrated that fewer coordination failures would occur, *ex post*, if players could send multiple rounds of messages. In this section we briefly consider this possibility by examining an extension of our earlier games with two-way communication; here, each player can send messages to the others simultaneously three times before the second-stage game is played. Thus, players have more than one opportunity to coordinate their actions in the event that one round of communication does not lead to an equilibrium.

To see how multiple rounds of two-way communication can further increase coordination, consider the effects of allowing two rounds, and make the following additional assumptions.

[12] While this incomplete information model fits certain aspects of the data, it has one major shortcoming. In games with two-way communication, players' announcements should reveal their types; yet we observe very few players consistently revealing their types in this way. From the data, there was no player who was always altruistic as this model predicts—no one always announced 0 or 1. There were also few egoists in this sense: only two players always announced strategy 2 in all 20 periods, and only six players announced strategy 2 at least 90 % of the time.

[13] The incomplete information model presented in Appendix B predicts that there will be an equal number of 0s and 1s announced. As can be seen from Table 6, 0s were announced three times as often as 1s.

TABLE 7 Two-Way, Three Round Games

	Results	Prediction
Proportion of Hits	.63	.500
Equilibrium play given equilibrium announcements	.78	1.000
Equilibrium play given disequilibrium announcements	.39	.375
Play of 2 given disequilibrium announcements	.69	.750

Assumption 4. If, in the first round of communication, players' announcements constitute a pure-strategy equilibrium to the (final stage) BOS game, players will follow through on these first-round announcements, and the second round of communication (though perhaps still conducted) is irrelevant.

Assumption 5. If, in the first round, players' announcements do not constitute a pure-strategy equilibrium to the BOS game, players disregard these first-round announcements. The second round of communication is governed by Assumptions 2 and 3.

A second round of communication provides another chance to coordinate. To see its effect on the mixed-strategy equilibrium of the announcement game and on the expected payoffs, one needs simply to reinterpret u in Figure 1 as the valuation of the continuation game (the game with only one round of communication), $E\pi_1$. The probability of announcing $R2$ and $C2$ is higher in the first round when there is a second round to follow than when there is not; but the probability of announcing $R1$ and $C1$ or of remaining silent decreases. Furthermore, the expected payoffs for the game are higher with the added round of communication. A similar argument holds for three rounds of communication.

Thus, with three rounds of two-way communication, the equilibrium frequencies of announcements of 2 increase, expected profits increase, and the predicted frequency of hits increases. However, the gains are relatively small when going from one to three rounds of communication. The equilibrium frequency of announcing 2 goes from .89 with one round to .9993 with two rounds to .9999 with three rounds. The predicted frequency of hits goes from .4987 to .4997 to .500, respectively; expected profits go from 199.45 to 199.99 to 199.99, respectively.

As before, three separate cohorts played the games with three rounds of two-way communication using the exact same design discussed in Section 3. Table 7 provides information on these hypotheses. The second entry gives the proportion of time that an equilibrium was reached if there was ever an equilibrium message sent between a pair. The third is the frequency of hits given that an equilibrium message was never sent. Finally, the last is the proportion of time that strategy 2 was played if no equilibrium announcements were made. As in the previous games, we define disequilibrium announcements as (0, 0), (1, 1), and (2, 2); equilibrium announcements are (2, 1) and (1, 2). Equilibrium announcements led predominantly to equilibrium play. The fraction, 78%, is very close to that observed in the game with one round of two-way communication (80%). The fraction is higher if we focus on equilibrium announcements made in the last round of communication. The proportion of cases in which equilibrium play followed equilibrium announcements in the third round is 86%. When an equilibrium is announced in an early round, there is still the possibility of additional conflict between the players: of the 145 times that an equilibrium announcement was made in either of the first two rounds, equilibrium play was observed only 72% of the time.[14]

[14] This proportion includes cases in which an equilibrium was also announced in the last round.

As with the two-way communication games in which the players could send a single round of messages, disequilibrium announcements led to play consistent with the mixed-strategy equilibrium. The observed frequency of the play of strategy 2, 69%, is not significantly different from the mixed-strategy prediction of 75%, at a 5% significance level. Furthermore, the frequency of hits is 39% which is also not significantly different from the mixed-strategy prediction of 37.5%. Finally, we find that, conditional on the occurrence of disequilibrium announcements, the play in the two-way games was strikingly similar, regardless of the number of rounds of communication: both led to equilibrium play 39% of the time.

6. Conclusions

■ This article summarizes the results from an experiment conducted to understand the way agents play the battle of the sexes game and the effects of adding cheap-talk communication to this game. This game, which features multiple Nash equilibria, is interesting for at least two reasons. First, it is a game with real-world counterparts, such as standardization problems. Second, there exists a well-formulated theory to explain behavior in such settings, including predictions regarding the effects of adding cheap talk.

After extending the theory somewhat to allow agents to decide whether to communicate, we confronted the theory with the results of the experiment. In general, the theory developed by Farrell is quite helpful in explaining the observed play and understanding the effects of communication. We find that communication does matter, even if it is made up exclusively of nonbinding announcements between anonymous opponents; play was significantly altered when communication was permitted, and the average payoffs rose. Allowing one-way communication was the most efficient way of coordinating beliefs and achieving equilibrium. Multiple rounds of two-way communication appear to have been more helpful than single rounds, as predicted.

We do find that the theory predicts "tougher" play than was observed; the actual frequencies of play lie somewhere between those predicted by the theory and those consistent with players adopting cooperative mixed strategies. As mentioned above, this result may not be surprising in light of the large literature on players' tendencies toward cooperation in settings designed to elicit noncooperative behavior.

Appendix A

INSTRUCTIONS FOR SESSION 1

General

■ You are about to participate in an experiment in the economics of decision making. If you follow these instructions carefully and make good decisions, you might earn a considerable amount of money, which will be paid to you in cash at the end of the experiment.

The experiment will consist of a series of separate decision-making periods. Each period consists of two phases. In Phase I you will be paired with another person, and based upon your combined actions, you will be able to earn *points*. In Phase II, you will have the opportunity to earn dollars based upon the points you earned in Phase I. We begin by describing Phase II, so that you understand how the points you earn affect the number of dollars you earn. Then, we describe Phase I in detail, so that you understand how to earn points.

Phase II Instructions

■ At the end of Phase I, you will have earned between 0 and 1,000 points according to the rules we will discuss below. The number of dollars you earn in Phase II will depend partly on the number of points you earned in Phase I and partly on chance. Specifically, we have a box which contains lottery tickets numbered 1 to 1000. In Phase II, a ticket will be randomly drawn from the box. If the number on the ticket IS LESS THAN OR EQUAL TO the number of points you have earned in Phase I, you WIN *$1.00.* If the number on this ticket IS GREATER THAN the number of points you have earned in Phase I, you WIN *$0.00.* For example, if you have 600 points, you will have a 60% chance of winning $1.00. Notice that the more points you have, the larger will be your chance of winning the $1.00 prize.

Phase I Instructions

■ In each decision-making period, you will be paired with another person. One of you will be designated player *B* and the other will be designated player *S*. At the beginning of the period, both player *B* and player *S* must separately and independently select an action. The combined actions of player *B* and player *S* jointly determine the number of points earned by player *B* and the number of points earned by player *S*.

You will alternate from being player *B* to being player *S* from one period to the next. Since there is not an even number of people participating in this experiment, you will occasionally be required to not participate during a particular period. When this is the case, you will receive a message on your terminal which states:

"FOR PERIOD ____, YOU ARE SITTING OUT."

In the periods in which you are participating you will receive a message stating:

"FOR PERIOD ____, YOU ARE A *B* PLAYER."

or

"FOR PERIOD ____, YOU ARE AN *S* PLAYER."

You will be participating in a series of separate sessions during today's experiment. During the current session, you will play against each person once—as either player *B* or player *S*. However, you will not know the identification of the person you are playing against in any period. Similarly, nobody in your decision-making pair will know your identification in any period. Further, you will not be told who these people are either during or after the experiment.

In your folder you will find a set of record sheets. On these sheets you will indicate, based on the message previously received on your terminal, whether you are player *B*, player *S*, or not participating for each period. The points that you earn in each period will be determined by the rules given below.

Specific Instructions for Player *B*

■ In this part of the instructions, we will be referring to specific numbers of points. These numbers are the same as you will be using in the first session of today's experiment.

In those periods in which you are player *B*, you and player *S* must separately and independently decide on actions which will jointly determine the number of points earned by you and the number of points earned by player *S*. As player *B*, you may either choose action *B*1, action *B*2, or action *B*3. Similarly, player *S* may choose action *S*1, action *S*2, or action *S*3. The number of points earned by you is given by the following table for each pair of actions you and player *S* might select:

Number of points earned by player *B*

		S's Action		
		*S*1	*S*2	*S*3
	*B*1	320	440	500
B's Action	*B*2	420	600	660
	*B*3	180	360	420

To read this table, suppose that you chose action *B*2 and player *S* chose action *S*1. You would then earn 420 points. Similarly, suppose that you chose action *B*1 and player *S* chose action *S*3. You would then earn 500 points. In a like manner, you can use this table to determine the number of points you would earn for all other pairs of actions you and player *S* may select. *S* players also earn points depending upon the type of action they select. These are given in the next section of the instructions.

When you select an action, enter the action chosen into the computer via your terminal and record the action chosen on your record sheet. Once both you and player *S* have selected your actions and entered them into the computer via your terminals, the computer will determine the number of points earned by you based on the table given above. The result is then sent to you via your terminal. The message will look like the one below:

PERIOD POINTS ARE ____.

At the end of the period, you are to record your point earnings for Phase I on your record sheet. Make sure you check your earnings in points against the computer's calculations. The computer will also inform you about the action taken by player *S*. Make sure you record this information on your record sheet.

Specific Instructions for Player *S*

■ In those periods in which you are player *S*, you and player *B* must separately and independently decide on actions which will jointly determine the number of points earned by you and the number of points earned by player *B*. As player *S*, you may either choose action *S*1, action *S*2, or action *S*3. The number of points earned by you is given by the following table for each pair of actions you and player *B* might select:

Number of points earned by player *S*

		S's Action		
		*S*1	*S*2	*S*3
	*B*1	320	420	180
B's Action	*B*2	440	600	360
	*B*3	500	660	420

To read this table, suppose that player *B* chose action *B*2 and you chose action *S*1. You would then earn 440 points. Similarly, suppose that player *B* chose action *B*1 and you chose action *S*3. You would then earn 180 points.

When you select an action, enter the action chosen into the computer via your terminal and record the action chosen on your record sheet. Once both you and player *B* have selected your actions and entered them into the computer via your terminals, the computer will determine the number of points earned by you based on the table given above. The result is sent to you via your terminal. The message will look like the one below:

PERIOD POINTS ARE ______.

At the end of the period, you are to record your point earnings for Phase I on your record sheet. Make sure you check your earnings in points against the computer's calculations. The computer will also inform you of the action taken by player *B*. Make sure you record this information on your record sheet.

Phase II Recording Rules

■ After completing your Phase I record sheet for a given decision-making period, you are to use your profit sheet to record the dollars you earn in Phase II. First, record your Phase I point earnings in the row corresponding to the number of the period that is currently being conducted. The person who sat out in this period will then be asked to draw a lottery ticket from the box. Before he/she returns the ticket to the box, the number on the ticket will be announced. You should record the number of the ticket in the second column of your profit sheet. If the number drawn IS LESS THAN OR EQUAL TO the number of points earned in Phase I, circle $1.00 in the next column; otherwise circle $0.00 in that column. Pay careful attention to what you circle. Any erasure will invalidate your earnings for the period. If you do make a mistake and circle the wrong number, call it to the experimenter's attention.

At the end of the session, add up your total profit in dollars and record this sum in row 23 of your profit sheet. All dollars on hand at the end of the session in excess of $2.00 are yours to keep. Subtract this number, which is on row 24, from your total dollars on row 23 and record this difference on row 25. This is the amount of dollars you have earned in this session.

In summary, your earnings in the experiment will be the total of the amounts you win in all Phase II lotteries. The amount of money you earn will depend partly upon luck and partly upon whether you have made good decisions in Phase I. Notice that the more points you earn in Phase I, the more likely you will win in Phase II. Are there any questions?

SAMPLE INFORMATION SHEET

Player *B*

Number of points earned by player *B*

		S's Action		
		*S*1	*S*2	*S*3
	*B*1	320	440	500
B's Action	*B*2	420	600	660
	*B*3	180	360	420

Player S

Number of points earned by player S

		S's Action		
		$S1$	$S2$	$S3$
	$B1$	320	420	180
B's Action	$B2$	440	600	360
	$B3$	500	660	420

INSTRUCTIONS FOR SESSION 2

■ This session of the experiment will again consist of a series of separate decision-making periods. Each period will again consist of two phases. In Phase II you will be able to earn dollars from the points you have earned in Phase I in exactly the same way you did in the first session. In Phase I, you will again be paired with another person and, based upon your combined actions, you will be able to earn points. However, the Phase II in this session differs in the following way:

(1) The value of the lottery prize if you win is *$2.00*. Thus, if the number on the lottery ticket drawn in Phase II is less than or equal to the number of points you earned in Phase I, you win *$2.00*. Otherwise, you win *$0.00*.

The Phase I in this session differs in the following ways:

(1) The number of points which players can earn are given by new tables. These tables are shown on the attached Information Sheet.

(2) You will only have two actions to choose from. If you are player S, you may choose either $S1$ or $S2$. If you are player B, you may choose either $B1$ or $B2$.

(3) You will play against each person twice, once as player B and once as player S.

(4a) *1-Way Communication:* The Phase I portion of each period will consist of two stages. In the first stage, player B may choose to make an announcement to player S. In this announcement, player B may indicate which action he plans to take in the second stage. If player B chooses to make an announcement he will be able to announce either $B1$ or $B2$. After player B has decided whether he wishes to make an announcement and, if so, what the announcement will be, player S will receive that announcement. To be more specific, the first stage of Phase I will proceed in the following way: If you are player B, the computer will ask you;

DO YOU WISH TO MAKE AN ANNOUNCEMENT?

If you enter "No," you will not make an announcement this period. If you enter "Yes," the computer will ask you,

WHAT DO YOU WISH TO ANNOUNCE?

You may enter $B1$ or $B2$. After all B players have decided whether to make an announcement and, if so, what they wish to announce, all S players will receive a message which will tell them whether the player they are paired with made an announcement and, if so, what the B player announced. The second stage of Phase I will proceed exactly as before. The computer will ask you to choose either $B1$ or $B2$ if you are player B or it will ask you to choose $S1$ or $S2$ if you are player S. If you are player B, you are not required to choose the action you announced in the first stage. Recall that the number of points you earn depend only on the choices made by you and the player with whom you are paired.

(4b) *2-W-1-Rd. Communication:* The Phase I portion of each period will consist of two stages. In the first stage you may choose to make an announcement to the player you are paired with. In this announcement, you may indicate which action you plan to take in the second stage. If you choose to make an announcement and you are a B player, you will be able to announce either $B1$ or $B2$. If you choose to make an announcement and you are an S player, you will be able to announce either $S1$ or $S2$. After both players have decided whether they wish to make an announcement and, if so, what their announcement will be, each player will receive the announcement of the player he or she is paired with. To be more specific, the first stage of Phase I will proceed in the following way: The computer will ask you,

DO YOU WISH TO MAKE AN ANNOUNCEMENT?

If you enter "No," you will not make an announcement this period. If you enter "Yes," the computer will ask you,

WHAT DO YOU WISH TO ANNOUNCE?

You may enter $B1$ or $B2$ if you are player B. If you are an S player you may enter $S1$ or $S2$. After all players have decided whether to make an announcement and, if so, what they wish to announce, you will receive a message which will tell you whether the player you are paired with made an announcement and, if so, what he announced. The second stage of Phase I will proceed exactly as before. The computer will ask you to choose either $B1$ or $B2$ if you are player B, or it will ask you to choose $S1$ or $S2$ if you are player S. You are not required to choose the action you announced in the first stage. Recall that the number of points you earn depend only on the choices made by you and the player with whom you are paired.

(4c) *2-W-3-Rd. Communication:* The Phase I portion of each period will consist of two stages. The first stage will consist of three rounds. In each of the three rounds, you may choose to make an announcement to the player you are paired with. In your announcement you may indicate which action you plan to take in the second stage. If you choose to make an announcement and you are a B player, you will be able to announce either $B1$ or $B2$. If you choose to make an announcement and you are an S player, you will be able to announce either $S1$ or $S2$. In each round after both players have decided whether they wish to make an announcement and, if so, what their announcement will be, each player will receive the announcement of the player he or she is paired with. To be more specific, the first stage of Phase I will proceed in the following way: The computer will ask you,

DO YOU WISH TO MAKE AN ANNOUNCEMENT?

If you enter "No," you will not make an announcement this round. If you enter "Yes," the computer will ask you,

WHAT DO YOU WISH TO ANNOUNCE?

You may enter $B1$ or $B2$ if you are player B. If you are an S player you may enter $S1$ or $S2$. After all players have decided whether to make an announcement and, if so, what they wish to announce, you will receive a message which will tell you whether the player you are paired with made an announcement and, if so, what they announced. This ends the first round. The second and third rounds will proceed in exactly the same way as the first round. The second stage of Phase I will proceed exactly as before. The computer will ask you to choose either $B1$ or $B2$ if you are player B or it will ask you to choose $S1$ or $S2$ if you are player S. You are not required to choose the action you announced in the first stage. Recall that the number of points you earn depend only on the choices made by you and the player with whom you are paired.

All dollars you earn in this session of \$0.00 dollars are yours to keep.

Appendix B

■ In this appendix, we present a model in which some fraction of the players are altruists. We examine only a simple form of altruistic behavior by assuming that altruistic players receive a payoff equal to the sum of the payoffs in each cell of Figure 1. Thus, the payoffs for an altruistic row player are

		Column Player	
		$C1$	$C2$
Row Player	$R1$	0	$x+y$
	$R2$	$x+y$	0

The two altruists play a coordination game in which they are indifferent between the two pure-strategy Nash equilibria and are worse off in the mixed-strategy equilibrium where an *ex post* disequilibrium can result.

We assume that a fraction of the players, ρ, are altruists (A), and $(1-\rho)$ are egoists (E).

(i) The No-communication game. Let σ^i be the probability that a type i agent plays strategy 2, $i = A, E$. Further, let $\pi^i(s^i)$ be the payoff if he plays strategy s^i given that his opponent follows some candidate equilibrium strategy. We next partition the unit interval by restricting values of ρ and present an equilibrium for each case.

Case 1. If $\rho \in [0, y/(x+y)]$, then $\sigma^A = 0$ and $\sigma^E = x/[(x+y)(1-\rho)]$.

For this to be an equilibrium, it must be true that

$$\pi^A(2) \leq \pi^A(1) \tag{A1}$$

and

$$\pi^E(2) = \pi^E(1). \tag{A2}$$

(A1) ensures that no altruist has any incentive to defect from the equilibrium and play strategy 2, while (A2) keeps egoists indifferent between playing strategies 1 and 2.

Since $\pi^A(2) = \rho(x+y) + (1-\rho)[(x+y)(1-\sigma^E)]$ and $\pi^A(1) = (1-\rho)\sigma^E(x+y)$, then

$$\pi^A(2) - \pi^A(1) = (x+y)[\rho + (1-\rho)(1-\sigma^E) - (1-\rho)\sigma^E] = (x+y)[1 - 2(1-\rho)\sigma^E] \leq 0$$

if and only if $\sigma^E \geq 1/[2(1-\rho)]$, which holds for the values of σ^E and ρ given above.

Next, consider the egoists payoffs, $\pi^E(1) = (1-\rho)\sigma^E y$ and $\pi^E(2) = \rho x + (1-\rho)(1-\sigma^E)x$. Thus, $\pi^E(2) - \pi^E(1) = x - (1-\rho)\sigma^E(x+y) = 0$ if and only if $\sigma^E = x/[(1-\rho)(x+y)]$ as assumed. Also, $\sigma^E \leq 1$ if and only if $\rho \leq y/(x+y)$.

Case 2. If $\rho \in [y/(x+y), .5]$, then $\sigma^A = 0$ and $\sigma^E = 1$.

For this to be an equilibrium it must be true that

$$\pi^A(2) \leq \pi^A(1) \tag{A3}$$

and

$$\pi^E(2) \geq \pi^E(1). \tag{A4}$$

(A3) ensures that no altruist has any incentive to defect from the equilibrium and play strategy 2, while (A4) keeps egoists from defecting from the equilibrium to play strategy 1.

Since $\pi^A(2) = \rho(x+y)$ and $\pi^A(1) = (1-\rho)(x+y)$, then $\pi^A(2) - \pi^A(1) = (x+y)[\rho - (1-\rho)] \leq 0$ if and only if $\rho \leq .5$.

Next, consider the egoists payoffs, $\pi^E(1) = (1-\rho)y$ and $\pi^E(2) = \rho x$. Thus,

$$\pi^E(2) - \pi^E(1) = \rho x - (1-\rho)y \geq 0$$

if and only if $\rho \geq y/(x+y)$ as assumed.

Case 3. If $\rho \in [.5, 1]$, then $\sigma^A = (2\rho - 1)/2\rho$ and $\sigma^E = 1$.

For this to be an equilibrium it must be true that

$$\pi^A(2) = \pi^A(1) \tag{A5}$$

and

$$\pi^E(2) \geq \pi^E(1). \tag{A6}$$

(A5) ensures that an altruist is indifferent between playing strategies 1 and 2, while (A6) ensures that an egoist does not wish to defect from his equilibrium strategy to play strategy 1.

Since $\pi^A(2) = \rho[(x+y)(1-\sigma^A)]$ and

$\pi^A(1) = \rho\sigma^A(x+y) + (1-\rho)(x+y)$, then $\pi^A(2) - \pi^A(1) = (x+y)[\rho(1-\sigma^A) - \rho\sigma^A - (1-\rho)] = 0$

if and only if $\sigma^A = (2\rho - 1)/2\rho$, which holds for the values of σ^A and ρ given above.

Next, consider the egoists payoffs, $\pi^E(1) = \rho\sigma^A y + (1-\rho)y$ and $\pi^E(2) = \rho(1-\sigma^A)x$. Thus,

$$\pi^E(2) - \pi^E(1) = \rho x - (1-\rho)y - \sigma^A(\rho x + \rho y) \geq 0$$

if and only if $\sigma^A \leq 1 - y/[\rho(x+y)]$. Since $x > y$, this final inequality is satisfied.

To see which of these three cases best fits our data, we calibrated on the frequencies of strategy 2 being played. In this game, the probability that strategy 2 is chosen is given by $\rho\sigma^A + (1-\rho)\sigma^E$. Recall that $x = 600$ and $y = 200$ for each of the three cases. The frequency with which strategy 2 should be played is given as follows:

Case 1. $\rho\sigma^A + (1-\rho)\sigma^E = x/(x+y) = .75$,

Case 2. $\rho\sigma^A + (1-\rho)\sigma^E = (1-\rho)$,

Case 3. $\rho\sigma^A + (1-\rho)\sigma^E = .5$.

In our games with no communication, 63% of the time players chose strategy 2; this implies that we are in case 2, where $\rho = .37$.

(ii) The Two-way, One-round game. Let m^i be the message of agent i that he intends to play strategy m^i, and let $\sigma^i(m^i, m^j)$ be the probability that a type i agent plays strategy 2 given his message, m^i, and his opponent's message, m^j, $i, j = A, E$. Furthermore, let $\pi^i(m^i)$ be the profit of agent i if agent i sends message m^i given that agent j sends a candidate equilibrium message, and that both agents play their equilibrium response functions, $\sigma^i(m^i, m^j)$ and $\sigma^j(m^j, m^i)$. While there are numerous equilibria for this game, we concentrate on one which contains the value $\rho = .37$, which we found in the no-communication game.

If $\rho \in [a, 4y/(5y + x)]$, where $a = \max [4y^2/(3x^2 + xy + 2y^2), 4y^2/(x^2 + xy + 4y^2)]$, the following constitutes a fully-revealing equilibrium: all egoists send the message $m = 2$ and all altruists send the message $m = 0$ with probability .5 and $m = 1$ with probability .5. Then, egoists choose strategy 2 as follows:

$$\sigma^E(1, 2) = \sigma^E(1, 0) = \sigma^E(0, 2) = 0,$$
$$\sigma^E(2, 1) = \sigma^E(0, 1) = \sigma^E(2, 0) = \sigma^E(0, 0) = \sigma^E(1, 1) = 1,$$
$$\sigma^E(2, 2) = x/(x + y).$$

Altruists choose strategy 2 as

$$\sigma^A(1, 2) = \sigma^A(1, 0) = \sigma^A(0, 2) = \sigma^A(2, 2) = 0,$$
$$\sigma^A(2, 1) = \sigma^A(0, 1) = \sigma^A(2, 0) = 1,$$
$$\sigma^A(0, 0) = \sigma^A(1, 1) = .5.$$

Let p^A be the probability that an altruist sends the message $m^A = 1$ and $(1 - p^A)$ be the probability that an altruist sends message $m^A = 0$.

For this to be an equilibrium, we must verify that

$$\pi^E(2) \geq \max [\pi^E(1), \pi^E(0)] \text{ and } \pi^A(2) \leq \pi^A(1) = \pi^A(0).$$

Here, $\pi^E(2) = \rho x + (1 - \rho)xy/(x + y)$, $\pi^E(1) = \rho(1 - p^A)y + \rho p^A x/2 + (1 - \rho)y$, and

$$\pi^E(0) = \rho(1 - p^A)x/2 + \rho p^A x + (1 - \rho)y.$$

Rearranging terms and using $p^A = .5$, it can be shown that

$$\pi^E(2) \geq \pi^E(1) \quad \text{if and only if} \quad \rho \geq 4y^2/(3x^2 + xy + 2y^2) \quad \text{and that}$$
$$\pi^E(2) \geq \pi^E(0) \quad \text{if and only if} \quad \rho \geq 4y^2/(x^2 + xy + 4y^2).$$

For altruists,

$$\pi^A(2) = \rho(1 - p^A)(x + y) + \rho p^A(x + y) + (1 - \rho)[x/(x + y)](x + y),$$
$$\pi^A(1) = \rho(1 - p^A)(x + y) + \rho p^A(x + y)/2 + (1 - \rho)(x + y),$$

and

$$\pi^A(0) = \rho(1 - p^A)(x + y)/2 + \rho p^A(x + y) + (1 - \rho)(x + y).$$

So, $\pi^A(1) = \pi^A(0)$ if and only if $p^A = .5$, and $\pi^A(2) \leq \pi^A(1)$ if and only if $\rho \leq 4y/(5y + x)$.

For our parameters, $y = 200$ and $x = 600$, this is an equilibrium as long as $\rho \in [.25, .5]$. Furthermore, the probability that strategy 2 is played given that there are disequilibrium announcements of (0, 0), (1, 1), or (2, 2) is $(3 - 6\rho + 4\rho^2)/(4 - 8\rho + 6\rho^2)$. Recall that the implied value of ρ from the no-communication games is .37. With two-way communication, the probability that strategy 2 is played given disequilibrium announcements is .71 if $\rho = .37$.

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