A Survey on Mitigating Coordination Failure

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1 Introduction

This paper surveys several papers that examine solutions for mitigating coordination failures in coordination games. Coordination games have two or more Nash Equilibria with associated levels of efficiency. Coordination failures occur when games either finish at a Pareto-dominated equilibrium or at ex post disequilibrium. Solutions examined in this survey are one-way communication, two-way communication, outside options, and arbiters. These solutions are examined in a variety of contexts including games of varying amounts of players, games with varying amounts of risk, and games with varying payoff structures. While no solution proves to solve coordination failures completely, this survey finds evidence that coordination failures can largely be mitigated in certain contexts.

2 Cooper, DeJong, Forsyth, and Ross 1994

In Cooper, DeJong, Forsyth, and Ross' (CDFR) 1994 paper, they investigate possible solutions for mitigating two types of coordination failures that were previously demonstrated in their 1989 paper. The first of the coordination failures involves—assuming an equilibrium outcome will always be realized—a player unilaterally playing a strategy that leads to a Pareto-dominated Nash Equilibrium. The second coordination failure involves ex post disequilibrium when no pure strategy equilibrium is attained.

Two solutions for reducing coordination failures are proposed: costless, nonbinding preplay communication and an outside option. Preplay communication is an attempt to focus players' beliefs on a Pareto dominant equilibrium by allowing them to signal their intentions before they play their actual strategy. Both one-way communication and two-way communication are considered in this paper. Additionally, CDFR also examine whether an outside option—the choice of taking a payoff rather than continuing in the game—may coordinate play through the logic of forward induction.

To test these ideas, CDFR run a number of treatments on a battle of the sexes (BOS) game and a basic coordination game. The payouts for both of these games can be seen in Table 1. In the coordination game, the Pareto-dominant equilibrium is a play of (2, 2). Any other outcome is considered a coordination failure, and plays of (1, 2) and (2, 1) result in disequilibrium resulting from strategic uncertainty. The Nash Equilibria in the BOS game differ in the fact that they are not Pareto-rankable. The Nash Equilibrium outcome of (2,1) is preferred by the row player, and the outcome of (1, 2) is preferred by the column player. It is also important to note that this game also has a mixed strategy equilibrium; however, the weaker of the two pure strategy equilibria for each player, yielding 200 to the respective player, is still preferred to the expected payoff of 150 resulting from the mixed strategy equilibrium. Despite the fact that the Nash Equilibria are Pareto-rankable in the coordination game but not the BOS game, in both games there is a clear incentive to coordinate and avoid ex post disequilibrium.

In offering a reasonable outside option to the row player in certain treatments, the authors suggested that the column player should be able to use forward induction to reason what row intends to play. For example, in the coordination game, if the row player rejects an initial outside option of 900, the column player should be able to reason that row intends to play for a better payoff. In other words, there is no rational reason for a player to play 1, securing a guaranteed payoff of 800, after they have rejected a guaranteed payoff of 900. Generally speaking, the rejection of any outside option between the Pareto-dominant equilibrium payoff and the Pareto-dominated equilibrium payoff should signal to the column player that row intends to play for the Pareto-dominant equilibrium. Outside options below the Pareto-dominated equilibrium payoff should always be rejected because playing 1 would always earn more, and outside options above the Pareto-dominant equilibrium payoff should always be accepted because playing 1 or 2 could never earn a better payoff. Similar logic can be applied to the BOS game.

With one-way communication, the authors suggest, as per Farrell's argument (1987), that it is optimal for the sender of the message to play accordingly with his message if he expects the receiver to believe the message. With two-way, simultaneous communication, Farrell suggests that announcements that constitute a pure strategy Nash Equilibrium outcome should be played honestly, and that announcements that do not constitute a pure strategy equilibrium should be ignored.

Table 1

Coordination Game and BOS Game, respectively

		Column Player 1	Column Player 2
Row Player	1	800, 800	800, 0
	2	0, 800	1000, 1000

		Column Player 1	Column Player 2
Row Player	1	0, 0	200, 600
	2	600, 200	0, 0

Ten treatments were run in the experiment:

1. Simple coordination game (CG)
2. Coordination game with an outside option paying (900, 900) (CG-900)
3. Coordination game with an outside option paying (700, 700) (CG-700)
4. Coordination game with one-way communication (CG-1W)
5. Coordination game with two-way communication (CG-2W)
6. Simple BOS game (BOS)
7. BOS game with an outside option paying (300, 300) (BOS-300)
8. BOS game with an outside option paying (100, 100) (BOS-100)
9. BOS game with one-way communication (BOS-1W)
10. BOS game with two-way communicaiton (BOS-2W)

Results from CG demonstrated the severity of the coordination problem in a simple coordination game. 97% of games settled on the Pareto-dominated equilibrium in the last 11 rounds, and the rest ended up in disequilibrium.

In striking contrast, CG-900, which offered a relevant outside option to the row player, led to 77% of subgame play at the Pareto-dominant equilibrium while decreasing play at the Pareto-dominated equilibrium to 2% in subgames. The results of this treatment are well aligned with forward induction.[1]

CG-700 was included as a treatment to test for a focal point effect since forward induction could not be applied to this irrational outside option. Again, it is irrational because a player could play 1 and secure a guaranteed payoff greater than 700. This focal point effect was not expected to play a big role in this game, and the results are in accordance. 82% of periods settled with play at the Pareto-inferior equilibrium, and none settled at the Pareto-superior equilibrium.

Both forms of communication showed an improvement in play at the Pareto-dominant equilibrium. While not having as significant an impact as a relevant outside option, play at the Pareto-dominant equilibrium was increased to 53%. Play at disequilibrium was, however, also increased from 3% in the base game to 31%.

[1] The prevalence of players taking the outside option, while still part of a subgame perfect equilibrium, is contrary to the predictions of forward induction.

The results of this game also do not align well with Farrell's theory. Though row announces strategy 2 87% of the time, he only follows through on the announcement 80% of the time. Additionally, while demonstrating an understanding of the announcement, column only responds to the announcement of 2 with 2 75% of the time. This rate is low enough to make a play of 1 by a signaler whom had announced 2 a relevant strategy. Announcements of 1, however, settled on play at (1, 1) in all but 1 of 21 games with announcements of 1. The results from this game demonstrated that announcements of 2 were not frequent enough for communication to be fully effective, and that players often do not play according to the theory put forth by Farrell.

Two-way communication showed the greatest increase of play at the Pareto-dominant equilibrium. Following announcements of 2 by both players in every single one of the last 11 rounds, players converged at the Pareto-superior equilibrium 90% of the time. Adding another direction of communication clearly demonstrated an increased confidence from players in this game. Players demonstrated that they could be confident in playing their announced strategy, with players deviating from their announcement of 2 only 9% of the time. The results of this game clearly demonstrated that two-way communication is the best of the proposed strategies for mitigating coordination failures in this coordination game.

Like CG, the base BOS game demonstrated significant coordination failures with disequilibrium play in 59% of the final 11 periods. Also in a similar fashion, a very significant increase in equilibrium play resulted when offering a relevant outside option in BOS-300. In demonstrating a clear understanding of the message, the row player played 2 98% of the time after rejecting the outside option, and column played 1 92% of the time. This resulted in equilibrium play 90% of the time.

Unlike in CG-700, BOS-100, which also offered an irrational outside option, demonstrated what the authors believe to be evidence of a focal point effect. The outside option was rejected in all but 3 cases, yet play at (2, 1) shot up to 63% of the time from 19% in the base game. With such strong evidence of a focal point effect, the authors conclude that the success of BOS-300 may be largely due to a focal point effect rather than forward induction.

In contrast to CG-1W and CG-2W, one-way communication was far more successful at coordinating an equilibrium than two-way communication. One way communication led to equilibrium play at (2, 1) 96% of the time. These successes followed announcements of 2 95% of the time and, as per Farrell's theory, play of 2 following an announcement of 2 98% of the time. Likely due to the asymmetry of payoffs, two-way communication did not fare so well. Coordination at equilibrium was only attained 58% of the time. While, in accordance with Farrell's theory, players followed through on announcements of (1, 2) or (2, 1) in all but one case, 43% of announcements were (2, 2) with 47 of 71 of these games ending in disequilibrium. This demonstrates the issue that arises with two-way communication and asymmetric payoffs. Different preferences led to more non-equilibrium announcements. These announcements, as Farrell suggests, are useless and should be ignored.

The authors conclude that communication and outside options cannot not fully resolve all coordination problems. In BOS games, both strategies involve risk and variably ranked equilibriums. In accordance with the results from this experiment, a focal point seems to be most important in settling on an equilibrium in these games. The clearest focal point proved to be when only one player stated their intended strategy. This did not allow for conflicting, useless announcements. The simple coordination game presented in this paper differs in that both players have a common goal of reaching the Pareto-dominant equilibrium. This paper finds that two-way coordination is the most effective way to overcome risk-dominance and settle on the Pareto-dominant equilibrium. With announcements of 2 from both players, both players have informally agreed upon the payout dominant equilibrium and should not have any reason to deviate.

3 Clark, Kay, and Sefton 2001

While recognizing the effectiveness of costless, preplay communication in coordination games, as demonstrated in the previous paper, Clark, Kay, and Sefton (CKS) questioned how sensitive the results were to the payoff structure. Their research question was based on Aumann's conjecture (1990) that the effectiveness of communication should depend heavily on the payoff structure of the game. Aumann's conjecture asserts that communication cannot be useful in a coordination game if one player has a strict preference over his opponent's strategy. For example, if row player, regardless of whether he plays 1 or 2, will always earn more money if column player plays 2, then row player has a strict preference for column to play 2. In this situation, Aumann argues that communication is useless because if row's announcement of 2 should increase the chances of column playing 2, then row should always announce 2. Column should then disregard the message because row should announce 2 regardless of his actual intentions. It is importantly noted that Aumann's conjecture does not apply to the coordination game discussed in the previous paper because of the safe option offered to players (playing 1) and the fact that players do not have a strict preference over their opponent's strategy choice. CKS rather focus on why communication in coordination games may not always work in the intuitive manner that is suggested by Farrell (1987) and Cooper et al. (1992).

Table 2

Games 1, 2, and 4 payoffs, respectively

		Column Player 1	Column Player 2
Row Player	1	$800, 800$	$800, 0$
	2	$0, 800$	$1000, 1000$

		Column Player 1	Column Player 2
Row Player	1	$700, 700$	$900, 0$
	2	$0, 900$	$1000, 1000$

		Column Player 1	Column Player 2
Row Player	1	$900, 900$	$700, 0$
	2	$0, 700$	$1000, 1000$

The test their theories, CKS use three games. First, they use the same coordination game from CDFR (Game 1) to reproduce results from the previous paper. Second, they use a game from Farrell and Rabin (1996) which gives each player a strict preference over their opponent's strategy (Game 2). Farrell and Rabin mention Aumann's conjecture that the messages are not self-signaling and are therefore useless, but claim that cheap talk will still help mitigate coordination failures in this game. Running experiments on this game was meant to produce experimental evidence on the two proposed theories. Finally, they use a third game (Game 3) which gives row player a preference for column to play 1 if they play 1, and a preference for column to play 2 if they play 2. The same preferences apply to column as well. This game was used to study the effects of communication when players had an incentive to represent themselves truthfully. The payoffs for these three games can be seen in Table 2.

As expected, the play in games 1 and 2 both converge to play at the risk-dominant strategy without communication in 10 rounds of repeated play. With communication, game 1 once again shows a big improvement in coordination. Game 2 also shows an improvement, however the effect is dramatically less pronounced with only 30-40% of games coordinating at the payoff-dominant equilibrium in the final rounds versus around 80-90% in the final rounds of game 1. Strikingly, announcements for both games were nearly the same with announcements of (2, 2) being predominant. In both games, announcements of (2, 2) climb from about 66% in round one to a plateau at about 88% in rounds 4 through 10. This demonstrates a marked difference in the effectiveness of communication in these two games. While 96% of players followed through by playing 2 after a (2, 2) announcement in game 1, less than half played 2 after a (2, 2) announcement in game 2. This demonstrates the ineffectiveness of the non self-signaling messages. In game 1, there is little reason to believe that an opponent will not follow their announcement after a (2, 2) announcement. The results of game 2 demonstrate that opponents are left with much doubt and uncertainty about the truthfulness of their opponent's announcements.

The results from game 3 without communication are, as expected, in line with games 1 and 2. CKS expected that the incentive to be truthful would lead players to announce 2 often and follow through on it to play at the payoff-dominant equilibrium. While the results do show that players recognized the incentive to be honest and were honest, the announcements of (2, 2) went down dramatically and announcements of (1, 1) increased. It turns out that players just used communication to coordinate on the safer option in this instance. Though this result is interesting, it is important to note how teribly this game was designed (as the authors themselves even point out). The payoff structure offers only a difference between 900 and 1000 between the payoff-inferior and payoff-superior equilibria. Additionally, there is significant risk involved in playing 2 in this game. Thus, the risk of losing 900 in order to gain 100 more seems to be too great for players to attempt to coordinate on (2, 2). The authors theorize that the result may have been very different with a lower payoff-inferior equilibrium.

CKS conclude that Nash Equilibria are self-enforcing in game 1, but not game 2. In game 1, players have an incentive to coordinate on 2, and thus an incentive to both announce and play 2. In game 2, however, players always have an incentive to announce 2 regardless of their intentions, so the messages are not self-signaling and therefore ineffective as per Aumann's conjecture. The results from game 3 show that communication is indeed sufficient for self-enforcing nash equilibria, however, communication is not an effective tool for avoiding coordination failures. Again, however, the authors point out the flaw of having such a high payoff-inferior equiibrium and suggest further research on similar games with a lower payoff-inferior equilibrium. Finally, it is also important to note that Farrell's suggestion that communication would still help in game 2 is not entirely incorrect. There was indeed an improvement in coordination at the payoff-dominant equilibrium, however, the improvement was markedly less. The results thus reveal an uncertainty by players to believe the non self-signaling messages.

Table 3

Stag Hunt Games and Prisoner's Dilemma (on bottom right) payoffs

		Column Player 1	Column Player 2
Row Player	1	$70, 70$	$80, 50$
	2	$50, 80$	$90, 90$

		Column Player 1	Column Player 2
Row Player	1	$70, 70$	$80, 10$
	2	$10, 80$	$90, 90$

		Column Player 1	Column Player 2
Row Player	1	$70, 70$	$80, 0$
	2	$0, 80$	$90, 90$

		Column Player 1	Column Player 2
Row Player	1	$70, 70$	$120, 10$
	2	$10, 120$	$90, 90$

4 Charness 2000

Charness did further research on Aumann's conjecture regarding self-signaling messages. Farrell suggested that, although Aumann's conjecture held weight, it was still likely that non self-signaling messages would help mitigate coordination failures. This proved to be true in Clark et al., however, the messages were all chosen before their respective actions which may not be realistic in real world economic situations. While Farrell denied Aumann's conjecture that non self-signaling would be useless in solving coordination problems, he agreed that Aumann's argument was compelling if the messages were chosen after a strategy had already been played. This is because the self-interest motive from the signaling player may be more salient to the receiving player. As this theory was not tested in Clark et al., Charness sought to gather experimental evidence on the issue.

In the experiment, Charness used three stag hunt style games and one prisoner's dilemma (PD) game (see payoffs in Table 3). Because risk-dominant equilibria are typically realized in these sorts of games without communication, a variety of stag hunt games were used to test susceptibility to risk-dominance. For each of the stag hunt games there was a no signal (NS) treatment, a signal followed by an action (SA) treatment, and an action followed by a signal (AS) treatment. The prisoner's dilemma treatment was used as a control to see if players only signaled 2 because they felt contractually bound by their signals. Each treatment was performed across six groups playing 10 rounds with randomly matched partners each round.

The results of the SA treatment once again demonstrated the effectiveness of communication in mitigating coordination failures. 2 was signaled in 95% of games and those games ended at the Pareto-dominant equilibrium 94% of the time. This brought the likelihood of efficiency to 89.5% of the time. Among the receivers, 83% of receivers found the 2 messages credible and 92% of receivers found the 2 signals credible at least 75% of the time. The NS treatment, as expected, did not fare as well with only about 25-34% of outcomes at the Pareto-dominant equilibrium in the early rounds and only around 10% in the final rounds.

The PD treatment showed that players did not in fact feel contractually obligated to follow through on their signals. Although 2 signals were sent 79% of the time, this led to only 12% of play at (2, 2). Signalers followed through on their 2 signals on 12% of the time, and receivers played 2 conditional on a 2 only 10% of the time. These results demonstrated that players were willing to break from their signals when it could be advantageous for them to do so.

Finally, results from the AS treatment were very mixed among the six different groups. Two groups converged to nearly all play at (2, 2), two group converged to nearly all play at (1, 1), and the other two groups saw mixed play throughout the 10 periods. Signals of 2 were cast 82% of the time, but play of 2 conditional on a signal of 2 ranged from .07% of the time in one group to 100% in another. Overall, plays at the efficient (2, 2) start at about 55% and drop to about 40%. While there was statistical differences between the AS and SA treatments, the AS results could not be statistically distinguished from the NS results.

There are several takeaways from the results produced in this experiment. First, signals were once again proven to improve efficiency. Second, the PD results showed that players' honesty is susceptible to the payoff structure and that players did not at all feel bounded by their messages. Players instead showed an effort to lie in order to make gains off of their opponents. Third, and most importantly, the results proved that the ordering of the messages has a huge effect on the outcomes. While Clark et al. concluded that signaling helped even when the messages were not self-signaling, Charness concluded no statistical differences between treatments without signals and the treatments with actions preceding signals. He suggests that this may be caused by more saliency being placed on self-interest in this situation.

To conclude, Farrell's comment on Aumann's conjecture turned out to be spot on. The ordering of messages is clearly relevant for non self-signaling messages. Though the results for the AS treatment were not great, one way communication was once again shown to mitigate coordination failures in certain contexts.

Table 4

Games A, B, and C payoffs, respectively

		Column Player		
		1	2	3
Row Player	1	$5,5$	$0,0$	$0,0$
	2	$0,0$	$5,5$	$0,0$
	3	$0,0$	$0,0$	$5,5$

		Column Player		
		1	2	2
Row Player	1	$9,9$	$0,0$	$0,0$
	2	$0,0$	$5,5$	$0,0$
	2	$0,0$	$0,0$	$1,1$

		Column Player		
		1	2	3
Row Player	1	$7,3$	$0,0$	$0,0$
	2	$0,0$	$5,5$	$0,0$
	3	$0,0$	$0,0$	$3,7$

5 Van Huyck, Gillette, and Battalio 1990

Van Huyck, Gillette, and Battalio (VGB) examined a sort of 0-way communication involving an arbiter in attempting to mitigate coordination failures. Unlike in the previous experiments surveyed, it was not the players doing the communication, but rather the arbiter. Before playing their strategies, the two players would receive a nonbinding assignment of play from the arbiter. The idea behind this is that the arbiter should be able to influence the outcome of the game by setting a focal point on a certain equilibrium. VBG denote assignments by the arbiter that result in the actual outcome as credible assignments.

The major research question of VGB was to examine the credibility of assignments with various payoff structures. All three games, which can be seen in Table 4, contain three strategies for each player and three strict equilibrium points. This means that on coordination, neither player could do better by playing a different strategy. In game A, players receive a payoff of 5 each as long as they coordinate on (1, 1), (2, 2), or (3, 3). There is no incentive to coordinate on one strategy or the other, and the arbiters assignment should thus provide a focal point for players to coordinate on.

Game B still provide symmetric payoffs, however, a hierarchy of payoff dominance is introduced. In this game, it is advantageous for players to coordinate on (1, 1) which rewards them each with a payoff of 9 versus a payoff of 5 or 1 for coordinating at (2, 2,) or (3, 3), respectively. While an arbiters assignment of (3, 3) should be credibly followed by players, VBG sought to examine whether players would consider payoff dominated assignments of (2, 2) or (3, 3) to be credible and follow through on them.

Game C again removes payoff dominance in any of the equilibria, but introduces asymmetry to the payoffs of outcomes (1, 1) and (3, 3). Only (2, 2) in this game provides a symmetric and efficient payoff to both players. Thus, an assignment of (2, 2) should be taken as a credible assignment, but an assignment of (1, 1) or (3, 3) may not be credible to one or both players despite being a strict equilibrium.

The results from testing game A were as expected. Without an arbiter, only 40% of games ended in equilibrium and the coordinated outcomes were spread across the three equilibria. Adding an arbiter increased coordination to 98% with 100% of those coordinations resulting from a credible assignment. With such a vast improvement, it is clear that the arbiter effectively focused players on a single equilibrium and mitigated nearly all coordination failures.

Payoff dominance proved to play a huge roll in the results of game B. Without an arbiter, 94% of games played at the payoff dominant equilibrium (1, 1) and no other equilibria were realized. Adding an arbiter, as expected, brought this percentage up even higher to 98% with an assignment of (1, 1). Assignments of (2, 2) and (3, 3), however, were not taken as very credible assignments by the players. Only 25% of games played at (2, 2) and 17% of games played at (3, 3) after their respective announcements. Additionally, in 99% of cases where players defected from their payoff dominated assignment, the players defected to play at the payoff dominant strategy. The results from this treatment demonstrate the strong effect of payoff dominance in discrediting the arbiters assignment.

In game C, 70% of games land on the equal payoff equilibrium (2, 2) without an arbiter. Only two games coordinated at the asymmetric outcome of (1, 1), and none coordinated at (3, 3). With an arbiter, assignment to (3, 3), which is preferred by the column player, was only credible in 16% of games. Of those defecting, row players defected to the equal payoff outcome 57 of 58 times, and column players defected to the payoff equal outcome 49 of 49 times. Results from with and without the arbiter both show that symmetry is powerful in predicting actions by players. Additionally, the results show that the introduction of an arbiter introduces conflict between selection principles for the players. Players were split nearly half and half between finding the arbiters announcement of (3, 3) credible and not credible. Thus, half of these people were drawn by symmetry, and half were drawn to the focal point set forth by the arbiter. In the end, only half of the pairs playing this game were able to coordinate on a strict equilibrium that earned them payouts.

VGB also questioned whether expectations of the arbiters announcements also affected their decisions to defect from the assignments. In all treatments, subjects were notified up front of the sequence of assignments for each round. This was to show to the players that the assignments were not dependent on their previous actions. By running several other treatments, they indeed showed that they could manipulate the credibility of the arbiter by toying with the order of announcements. For example, in a treatments involving game C, assignments of (3, 3) were found credible by pairs only 16% of the time. With alternating announcements {3, 1, 3, 1, 3, 1,...}, however, announcements were credible to 83% of pairs in round 7 (versus 27% credibility with announcements {3, 3, 3, 3, 3, 3,...}). Thus, players knowing that they could earn equal payoffs by playing with the announcements was convincing enough for them not to defect.

To conclude, VBG find that the credibility of announcements depends on the strategic details of each game. While in game A the announcements can be taken as credible, payoff dominance in game B discredits the announcements. Additionally, asymmetry in game C split the credibility among players in half and introduced many coordination failures as a result. In examining defections in game B and C, the defections were strategically sound nearly all of the time. In game B, players nearly always defected to the payoff dominant equilibrium, and in game C players almost always defected to the equal payoff equilibrium. This shows that players were able to use the arbiter to their advantage when they could and were able to use other inductive and deductive reasoning when the arbiter was not helpful.

6 Blume and Ortmann 2007

Though the games discussed so far have dealt with only two players, there are a variety of coordination games susceptible to coordination failures that may involve many more players. Citing the previous successes with communication in Cooper et al. (1994), Van Huyck et al. (1990), and some of the papers surveyed here, Blume and Ortmann sought to study the usefulness of communication in coordination games with more than two players.

Specifically, Blume and Ortmann study two games: a minimum effort game and a median effort game. In a minimum effort game, everyone simultaneously submits their minimum effort, as can be seen in the payoff table in Table 5, players are paid according to the minimum effort with higher payoffs when you are closer to the minimum effort. Payoffs are higher for everyone the higher the minimum effort value is. Thus, it is beneficial for everyone to play a higher effort unless they suspect

Table 5

Minimum and Median Game payoffs

Median Value

Player's Choice		7	6	5	4	3	2	1
	7	**1.30**	1.15	0.90	0.55	0.10	-0.45	-1.10
	6	1.25	**1.20**	1.05	0.80	0.45	-0.00	-0.55
	5	1.10	1.15	**1.10**	0.95	0.70	0.35	-0.10
Player's Choice	4	0.85	1.00	1.05	**1.00**	0.85	0.60	0.25
	3	0.50	0.75	0.90	0.95	**0.90**	0.75	0.50
	2	0.05	0.40	0.65	0.80	0.85	**0.80**	0.65
	1	-0.50	-0.05	0.30	0.55	0.70	0.75	**0.70**

Minimum Value

		7	6	5	4	3	2	1
	7	**1.30**	1.10	0.90	0.70	0.50	0.30	0.10
	6	—	**1.20**	1.00	0.80	0.60	0.40	0.20
	5	—	—	**1.10**	0.90	0.70	0.50	0.30
Player's Choice	4	—	—	—	**1.00**	0.80	0.60	0.40
	3	—	—	—	—	**0.90**	0.70	0.50
	2	—	—	—	—	—	**0.80**	0.60
	1	—	—	—	—	—	—	**0.70**

someone else will play a lower effort. Playing a 7 when the low is 1 will earn a meager payout as compared to playing a 1 or 2 as well. Due to the risks involved in playing a high number when the minimum is low, players typically converge to playing 1, an inefficient Nash Equilibrium, in this game.

In a median game, you receive the largest payout by playing an effort that is equivalent to the median of all efforts. The payoff optimal outcome is, again, everyone playing an effort of 7. Like in the minimum game, payoffs decrease as the median decreases, and your payoff decreases the farther from the median you are. The payoff structure for this game can be seen in Table 5.

Similar to the basic coordination game (payoffs in Table 1), the pure strategy equilibria in both the minimum and median games are Pareto-rankable. The Pareto-dominant equilibrium is at the top left of each payoff table, and the strictly Pareto-dominated equilibrium is at the bottom right. All other pure strategy equilibria are on the diagonal in between and are emboldened.

For the experiment, both the baseline and communication treatments involved nine subjects each playing over eight periods. In the communication treatments, non binding, costless announcements were selected by each participant and then displayed before the action stage.

Though communication has typically helped in coordination games, Blume and Ortmann point out several challenges posed to the effectiveness of communication in coordination games with more than two players. First, communication has shown to be successful where the announcement constitutes a Nash Equilibrium. This was often easy to achieve with just two players, but with nine players, there is far more room for one or more players to veer from a Nash Equilibrium that most other players had settled on. As Farrell (1987) suggested, announcements that did not constitute an equilibrium should be ignored. Thus, would the larger group size lead to less announcements of Nash Equilibria and would these messages be ignored by players?

This also brings into play the credibility of announcements. For example, imagine all players announce 7 in the minimum game and one person announces 3. If the 3 player finds all of the 7 announcements to be credible, then they should play 7. However, if a 7 player finds the 3 announcement credible, then they should play 3. This would then ruin the credibility of that 7 player to other 7 players, and so on. In all, determining the credibility of announcements was a big question to be examined in the experiment.

Furthermore, there is a fair amount of risk dominance in play for both of these games that may overshadow the effectiveness of communication. While communication was expected to help alleviate some of the risk, strategic uncertainty could certainly lead some players to abandon their announcements for a safer alternative. Though strategic uncertainty poses a problem to players in both the median and minimum games, it plays a much bigger role on the minimum game. In the minimum game, it only takes one player to lower the minimum effort for everyone. The median game, however, typically requires a change in play by multiple players to affect the median.

Finally, Aumann's conjecture regarding self-signaling messages applied to these games as well. While messages can be seen as self-signaling in the median game, they can not in the minimum game. Players in the minimum game weakly prefer that all other players play higher strategies. Thus, a person intent on playing 4 would have no issue signaling a message of 7. Doing this in the median game would only potentially set the median at 7 while you have played a 4.

Results from the baseline treatments were as expected. In the median game, the median strategy was 5 in the first round with 60% of players playing a strategy between 4 and 6 and 29.2% playing at the Pareto-dominant equilibrium. This demonstrates a substantive coordination failure without communication. In the minimum game, while 80% of participants in four separate sessions chose to play at the Pareto-dominant equilibrium, in three of four sessions at least one player played at the worst Pareto-ranked equilibrium. As expected, the distributions of strategies quickly plunged to the lower, inefficient Pareto-ranked strategies.

With communication, the results showed that first round choices in the median game improved with 54.2% choosing to play at the Pareto-dominant equilibrium. There was no improvement, however, in the first round choices of the minimum game. In all, communication proved to increase the overall payoffs in both games, but Blume and Ortmann point out that communication did not lead to fully efficient play in either games. They suggest that this is likely due to the limitations of communication discussed previously. Namely, communication clearly did not remove all strategic risk involved in playing at the Pareto-dominant equilibrium.

It is also interesting to note that not all minimum games converged to the efficient outcome. In two of the eight sessions with communication, one converged to the worst Pareto-ranked outcome, and one converged in the middle. Despite this, the results showed a much better improvement in efficient play for the minimum game than the median game. The authors suggest that the overall improvement in efficient play was due to the signals removing enough strategic uncertainty for the players to focus on the more efficient strategies. They also suggest that the less pronounced improvement in the median game may have been due to players using the signals to secure a median rather than using the signals to secure the Pareto-dominant outcome.

Regarding the credibility of messages, players that announced their intention to play the Pareto-dominant outcome followed through on their message 81% of the time in the median game and 86.2% in the minimum game. Thus, in both games, a majority of the messages were not only efficient, but truthful. This shows that players, for the most part, believed their messages and others to be self-committing and to have credibility.

Blume and Ortmann conclude that communication can indeed help solve issues of coordination failure in coordination games with more than two players. Communication showed to reduce strategic uncertainty and helped move players towards equilibria with higher Pareto rankings. Because the players were largely truthful with their signaling and playing, the messages seem to be credible and help focus play at more efficient outcomes before convergence to a safe but inefficient outcome.

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