Coordination with A Prominent Group Member in Minimum Effort Games*

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Abstract

We examine in the laboratory whether a prominent group member can help groups overcome their coordination difficulties in a repeated minimum effort game. Subjects are paired in groups of 6 and play multiple rounds of the minimum effort game with fixed matching. In one treatment, groups have access only to ex-post monitoring. In the other, individuals can also observe in real-time the choices of one prominent member, who in turn can observe the choices of all group members.

We find that groups with a prominent member behave closer the Nash equilibrium. We also find that groups with a prominent member do not obtain, on average, better outcomes compared with the groups in the control treatment. We offer evidence that this happens because of information uncertainty about how other players interpret the actions of the prominent member.

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1 Introduction

Numerous economic and social activities are characterized by strong complementarities between individual's optimal choices. Workers on an assembly line should exert high effort only if their co-workers do so. In athletic teams a player's effort is wasted if another team member slacks off. Storming beaches only makes sense if all other soldiers also do it. Observing social norms is often a best response if others observe them as well. These strategic situations can be formalized as a *weakest link* game, also known as the *minimum effort* game. A player's payoff increases with the minimum level of effort chosen by the group and decreases with her own effort. This payoff structure leads to multiple, Pareto-ranked Nash equilibria. The fundamental questions in this kind of strategic interactions are whether individuals can coordinate to a Nash equilibrium and if so, whether they choose a favorable equilibrium. A large body of laboratory experiments has found that it is very difficult to achieve tacit coordination. Players' actions rarely constitute a Nash equilibrium; when they do, players typically fail to select the equilibrium that gives them the largest possible payoff. The coordination failure appears to be caused by strategic uncertainty: players are uncertaint about other player's actions and about other players' beliefs to which they best respond.

In this paper we examine in the laboratory whether groups with a prominent member are able to overcome the typical coordination failure. Situations in which a group member's actions are observed by her peers and might affect their behavior are common outside the laboratory. For example, individuals might take a cue on how hard to work or how much effort to put in the game from their managers or their team captains. Similarly, in social interactions one might be influenced by the actions of social role models such as the elderly, celebrities, or political leaders. Chwe (2001) provides numerous examples of political rituals: public actions of leaders intended to drive the behavior of the political body. Observing the actions of a prominent group member may alleviate other players' strategic uncertainty. The public nature of the prominent member's actions could turn them into a focal point (Shelling (1960), Mehta et al. (1994)) to which group members can naturally coordinate. The prominent member might also choose his actions to induce the group members to coordinate to a better outcome. This creates information uncertainty: group members may not know how other players interpret the prominent member's actions. If the information uncertainty is severe enough it may undo the positive benefits of reducing strategic uncertainty, leading to more coordination failure.

In our experiment subjects play a pure coordination game 10 times, with fixed matching. In each round, they have 60 seconds to choose a number between 1 to 7, representing their level of effort.[1] They can change their choice of effort upwards and downwards during a given round. Their choice in the last second of the round determines their payoff for that round; their overall payoff is the sum of round payoffs. The group output is the minimum effort level chosen by the players in a group. The players' payoff increases with the group output and decreases with their own choice of effort. At the end of each round, subjects learn everyone else's choices, the minimum choice, and their own payoff. In one treatment individuals have no real time information about other group members' choices. This treatment replicates several tacit coordination experiments with complete ex-post monitoring, and it serves as the baseline. In another treatment, individuals in each group observe in real time the choices of one prominent member of the group, who in turn can observe in real time everyone's choices. In this treatment, the group member's information flows form a star network, so we call this treatment Star and we refer to the baseline as the Null treatment.

Our first set of results suggests that a prominent group member induces play that is closer to one of the Nash equilibria. Individuals are more likely to best respond to other group members' choices in the Star treatment and their choices of effort are more likely to constitute a Nash equilibrium. As a consequence, individuals waste significantly less effort when they can observe one prominent member. In the Null treatment individuals choose levels of effort that are on average 1.45 larger than the group's minimum choice. Individuals in groups with a prominent member choose levels of effort that are on average only 0.79 larger than the equilibrium choice, an improvemnt of 45%. Both prominent members, who have real-time information on all other group member's choices, and the regular group members, who can only observe the prominent member's choices, are

[1] Although we are using a team production context in presenting the game and discussing the results, the game was presented context-free to subjects.

able to better respond to others' choices of effort. A complementary result is that groups in Star are able to achieve the same group output with statistically significant lower total effort than the groups in the baseline treatment.

We also find that on average groups in the Star treatment do not choose to coordinate on Pareto superior equilibria compared to groups without a prominent member. Their group output is slightly lower, although the difference between treatments is not economically or statistically significant. Using our preferred measure, how groups performed in the second half of the experiment, groups in the baseline treatment obtain an output of 4.2, compared to 4.15 in the Star treatment. In the first half of the experiment, while subjects learn how to play the game, groups in the baseline treatment actually outperform groups with a prominent member, although this difference is not statistically significant either. A few groups in the Null treatment manage to coordinate to the equilibrium yielding the largest payoff relatively quickly, but the rest generally fail to coordinate, and when they do, they choose the low rewards equilibrium. In contrast, groups in the Star treatment are less likely to coordinate to the highest output equilibrium at the beginning of the experiment, but on average they improve considerably throughout the experiment.

We thus find that real time, common knowledge information on a group member's behavior does indeed seem to reduce strategic uncertainty. The players are less likely to deviate from the best response given by other players' actions, even when they can observe only one such player, as long as that player's actions are common knowledge. Why can't then groups in Star coordinate to better outcomes than the groups in the baseline treatment? We conjecture that the severity of information uncertainty is responsible for the latter set of results. While the other players have *common knowledge* about the prominent member's actions, they lack a *common understanding* of what she is attempting to accomplish.The prominent member may act as a monitor, as in the shirking theory of the firm of Alchian and Demsetz (1972), merely providing other players with information about the current optimal choice. The prominent member may also attempt to lead by example, as in Hermalin (1998), showing the other group members what they should do in order to obtain better outcomes. The players are uncertain about how to interpret the prominent member's actions and about how other players interpret them. We provide some support for this explanation. We find that the largest improvement towards equilibrium play among groups in Star treatment takes place when the prominent member chooses a low effort level. In these situations, the information uncertainty is minimized because the best response for all other players is to choose low effort levels as well, independent of what other players believe.

Deck and Nikiforakis (2012) have also recently examined the role real time information plays in coordination games. They find that when all group members have real time information about everyone else's choices, players manage to coordinate extremely well. They then test whether some intermediary amount of real time information can also induce coordination. When players are connected in a circle network, each player having real time information only about his two neighbors, players do not obtain better outcomes than when they have no real time information. In our Star treatment, players still lack complete information about everyone else's choices, but they have some common knowledge information. We find that common knowledge of the prominent member's actions reduces strategic uncertainty but it is not sufficient to overcome the inherent information uncertainty players have about these actions.

1.1 Literature Review

Our main contribution is to the experimental literature interested broadly in how people coordinate in the absence of direct communication, and more narrowly in the role of information about others' actions in overcoming coordination failure. Huyck et al. (1990) and Cooper et al. (1990) have shown that tacit coordination is very difficult to achieve. Coordination failure is sometimes alleviated by giving players more information. Berninghaus and Ehrhart (2001) and Brandts and Cooper (2006) find that in repeated games with fixed matching giving subjects complete information about past play increases coordination. However, Devetag (2005) finds that such ex-post monitoring leads to no improvements in coordination.

We are also contributing to a literature interested in the role cheap talk plays in economic behavior, in particular in achieving equilibrium play and in equilibrium selection. One can interpret the numbers chosen by the subjects in the Star treatment before the last second as messages to the players who can observe them. The subjects can change their number at any time during the round, so their choices can be seen as cheap talk messages. Blume and Ortmann (2007) show that such communication can improve coordination in a game with multiple Pareto-ranked Nash equilibria. We find that such cheap talk messages have a limited role for coordination, equilibrium play typically unraveling in the last seconds of a round.

A strain of the experimental literature has been interested in examining how some players' previous actions affect subsequent coordination. Cason et al. (2012) show that successful coordination in a median effort game improves coordination in a minimum effort game. Weber (2006) examines whether efficient coordination can be achieved by adding more more players to a small group of players that has previously coordinated. The older group members in that experiment are akin to the prominent members here: their previous choices are made public to the newer group members, which leads to successful coordination. In contrast to these experiments, the prominent member in our setup does not commit to a given action before the others choose theirs.

Our paper also contributes to a growing literature interested in determining the extent to which individuals can lead others. A few papers examine specifically the role of leaders in overcoming coordination failures. Weber et al. (2001) allow some subjects to give an inspirational speech before playing various coordination games and find that subjects incorrectly attribute coordination success or failure to the qualities of the leaders. In a working paper Cartwright et al. (2009) examine whether endogenously emerging leaders solve coordination problems. In their experiment leaders can help solving coordination problems, but too many leaders emerge. Brandts et al. (2007) examine whether subjects with a lower cost of choosing the payoff dominant equilibrium action emerge as leaders. They find that variation in costs leads to better initial coordination, but that the leaders are the types with the most common costs. Leading by example was also examined in a different contest by Guth et al. (2007). They find that allowing one group member to contribute to a public good before others leads to larger contributions.

The rest of the paper is structured as follows. In the next section we present the experiment design. The results are presented in Section 3, and the findings are discussed in Section 4. The last section concludes.

2 Experiment Design

2.1 Stage Game

The stage game is a pure coordination game played among a group of 6 players. The game was presented to the subjects free of context, but we use the context of joint-production while presenting the game and the experimental results. Each player is a worker in a firm whose production function exhibits strong complementarities. Each player chooses an effort level between 1 and 7. Player i's stage payoff depends on own effort and the effort of other players in the group, according to the formula: $0.6 + 0.25 \cdot \min(e_i, e_{-i}) - 0.1 \cdot e_i$. The payoff formula is identical to the one in Deck and Nikiforakis (2012) and was used to ease comparison between our results. The best response to a strategy profile of effort levels chosen by player i's peers e_{-i} is $\min(e_{-i})$. A player has no incentives to increase her effort over the minimum of other group members' effort. She also has no incentives to decrease her effort below the minimum of other players' effort. Any level of effort between 1 and 7 represents a symmetric Nash equilibrium. A Nash equilibrium corresponding to effort level e Pareto-dominates any Nash equilibria corresponding to effort level $e' < e$. The payoff dominant Nash equilibrium is the equilibrium in which all players choose the largest possible level of effort, 7. The risk dominant Nash equilibrium is the equilibrium in which all players choose the smallest possible level of effort, 1.

2.2 Treatments

Subjects are randomly matched in groups of 6 and play 10 rounds of the stage game. The matching remains the same in each round. They have 60 seconds per round to decide on a level of effort. They choose a level of effort in real time by sequentially increasing or decreasing the previous chosen level by 1 unit. Subjects can change their level of effort within a period as many times as they want. Their payoff depends on their choice when time runs out. At the end of each round, all players observe everyone else's choice, the minimum effort, and their own stage payoff. Their overall payoff for the experiment is the sum of stage payoffs in all rounds.

The only difference between our two treatments is in the information the subjects have about other subjects' choices while choosing their own level of effort. In the baseline treatment, subjects have no real time information about other subjects' current choice. Using the terminology of network topology, we call this treatment the Null treatment. This treatment is identical to the Baseline treatment in Deck and Nikiforakis (2012), which in turn is identical to the classical treatments in Huyck et al. (1990). In the other treatment, subjects have some real time information about other subjects' current choice. One subject, the prominent member of the group, is seen by all other subjects as he changes his effort levels. He is also able to see everyone else's current choice in real time. The prominent group member remains the same in all rounds. The other subjects are only able to see the prominent group member's choice of effort level. The information flows form a star network, so we call this the Star treatment.

2.3 Procedure

The experiment took place during Fall 2012 and Spring 2013 semesters at University of Iowa. Participants were recruited using the available subject pool. We ran 6 sessions; all participants in a session are in the same treatment. Each subject participated in only one treatment. No session had only one group of players. We ran Null treatment in Sessions 1, 5, and 6 and Star treatment in the other sessions.

The experiment lasted approximately 1 hour. In the preliminary stage subjects were assigned an experiment ID number and asked to fill out a survey. The instructions were then distributed to the subjects and read aloud. Subjects had to complete a quiz testing their understanding of the game. After each subject finished the quiz, the experimenter checked their answers and revealed the correct answers.

2.4 Hypotheses

In the Null treatment, any choice of effort by any player at any time can be rationalized as the optimal response to a strategy profile. Furthermore, any choice of effort can be one of the Nash equilibria in the game. The theoretical literature lacks consistent predictions about how people choose among alternative Nash equilibria, especially when distinct ones might have distinct compelling attributes, such as risk dominance or payoff dominance. Our Null treatment is a replication of Baseline treatment in Deck and Nikiforakis (2012), which in turn replicates the basic results of Huyck et al. (1990). In all these treatments, as well as in the majority of subsequent studies, individuals fail to coordinate to the payoff dominant equilibrium. We expect them to do so in our experiment as well.

In the Star treatment, some actions cannot be rationalized in a one-period game. For example, the prominent member should never set a level of effort that is larger than the minimum of the group. Also, no regular member should set a level of effort that is larger than the level of effort they observe the prominent member chose. In a dynamic setup, however, such behavior can be rationalized. The prominent member might be willing to take a one-period loss in order to signal how his effort choices correlates with the choices of effort he observes the other group members are taking. The regular group members may also be engaged in similar signaling. We conjecture, however, that this kind of signaling or communication cannot be detrimental and can sometimes help groups to coordinate their efforts. This in turn should help groups obtain better economic outcomes. Thus our two hypotheses are:

Hypothesis 1: Groups in Star treatment are more likely to play a Nash equilibrium than groups in Null treatment.

Hypothesis 2: Groups in Star treatment coordinate to better outcomes than groups in Null treatment.

3 Results

Table 1 reports the main measures of interest for each group in both treatments, as well as the per-treatment group averages. Wasted effort for individual i in group j in a given period is defined as $WE_{i,j} = e_{i,j} - \min(e_{i,j}e_{-i,j})$, while wasted effort for group j is defined as $WE_j = \sum_{i=1}^{6} WE_{i,j} = \sum_{i=1}^{6} e_{i,j} - 6 \cdot \min(e_{1,j}, \ldots, e_{6,j})$. The output of group j in a given period is given by the players' minimum effort: $Y_j = \min(e_{i,j})$. We also report the players' surplus and total effort. Player i in group j gets a surplus in any given period of $S_{i,j} = 0.6 + 0.25 \cdot \min(e_{i,j}, e_{-i,j}) - 0.1 \cdot e_{i,j}$; the group surplus is simply $S_j = \sum_{i=1}^{6} S_{i,j} = 6 \cdot 0.6 + 6 \cdot 0.1 \cdot Y_j - 0.15 \cdot WE_j$. Total effort of group j is $TE_j = \sum_{i=1}^{6} e_{i,j}$.

Treatment	Group	Wasted Effort			Minimum Effort			Surplus			Total Effort		
		Periods			Periods			Periods			Periods		
		1-10	6-10	6-9	1-10	6-10	6-9	1-10	6-10	6-9	1-10	6-10	6-9
Null	1	6.6	0.8	1.0	5.2	6.8	6.8	7.6	9.6	9.6	37.8	41.6	41.5
Null	2	1.4	0.0	0.0	6.7	7.0	7.0	9.5	9.9	9.9	41.6	42.0	42.0
Null	3	16.0	12.2	11.8	1.5	1.6	1.8	3.5	3.8	4.0	25.0	21.8	22.2
Null	4	11.3	6.6	6.5	2.2	2.0	2.0	4.5	4.7	4.8	24.5	18.6	18.5
Null	5	6.9	0.8	1.0	1.0	1.0	1.0	3.8	4.1	4.0	12.9	10.4	11.0
Null	6	6.5	5.4	6.3	5.3	5.6	5.5	7.7	8.1	7.9	38.3	39.9	39.3
Null	7	17.9	19.4	19.3	2.4	2.0	2.3	3.9	3.4	3.7	32.3	31.4	32.8
Null	8	3.5	0.0	0.0	5.9	7.0	7.0	8.5	9.9	9.9	38.9	42.0	42.0
Null	9	10.8	8.0	8.5	2.7	3.4	3.3	5.0	5.8	5.6	27.0	28.4	28.0
Null	10	11.8	12.2	12.0	2.1	3.2	3.0	4.3	5.2	5.1	24.4	31.4	30.0
Null	11	3.0	1.0	1.3	5.8	6.8	6.8	8.5	9.6	9.6	37.8	41.8	41.8
	mean	8.7	6.4	6.5	3.7	4.1	4.2	6.1	6.7	6.7	30.9	31.6	31.7
Star	1	6.9	4.6	4.0	1.5	2.0	1.8	4.2	4.9	4.8	15.9	16.6	14.5
Star	2	7.7	3.0	3.5	2.0	2.0	2.0	4.6	5.1	5.1	19.7	15.0	15.5
Star	3	4.0	0.0	0.0	5.2	7.0	7.0	7.9	9.9	9.9	35.2	42.0	42.0
Star	4	2.5	0.4	0.5	2.7	3.4	2.8	5.8	6.6	6.0	18.7	20.8	17.0
Star	5	3.7	4.0	3.3	4.4	5.0	6.0	7.1	7.7	8.7	30.1	34.0	39.2
Star	6	4.5	0.0	0.0	6.1	7.0	7.0	8.6	9.9	9.9	41.1	42.0	42.0
Star	7	3.2	4.0	5.0	1.0	1.0	1.0	4.1	4.1	4.0	9.2	10.0	11.0
Star	8	2.5	3.0	2.3	1.0	1.0	1.0	4.2	4.2	4.3	8.5	9.0	8.3
Star	9	4.6	7.2	1.5	4.0	4.6	5.5	6.7	7.0	8.4	28.6	34.8	34.5
Star	10	5.9	2.2	1.5	4.1	5.2	5.8	6.7	8.1	8.6	30.5	33.4	36.0
Star	11	4.2	2.0	0.0	4.1	6.6	7.0	6.9	9.3	9.9	28.8	41.6	42.0
Star	12	7.5	5.6	5.3	3.0	3.2	3.0	5.6	5.9	5.8	25.5	24.8	23.4
	mean	4.7	2.9	2.2	3.2	4.0	4.1	6.0	6.9	7.1	24.3	27.0	27.0
Difference Null-Star		4.0	3.5	4.3	0.5	0.1	0.1	0.1	-0.2	-0.4	6.6	4.6	4.7
T test p-value		0.04	0.11	0.05	0.57	0.82	0.95	0.72	0.88	0.71	0.10	0.34	0.37
MWU test p-value		0.10	0.22	0.10	0.58	0.85	0.92	0.83	0.78	0.55	0.42	0.49	0.49

Table 1: Main measures of interest for all groups in Null and Star treatments. Measures are averaged for the whole experiment (periods 1-10), as well as for the second half of the experiment (periods 6-10) and for second half excluding the last period (periods 6-9). For all subsets of periods the mean measures for each treatment is also shown. The difference in means between treatments is tested for statistical significance using a T-test and a non-parametric Mann-Whitney test.

We report these measures of interest averaged for the whole experiment. To weed out behavior while groups learn how to play the game, we also report averages for only the last 5 periods. Our preferred time frame also excludes the last period from the analysis, in order to eliminate any last period effects.

3.1 Equilibrium play

We first test Hypothesis 1, whether the player's actions are more likely to constitute a Nash equilibrium in Star treatment than in Null. We examine how often a group's actions constitute a Nash equilibrium. The binary nature of this measure might mask the extent to which players best respond to others' choices. We extend the analysis by examining two variables meant to measure the extent of coordination. We look at how much effort groups waste: if players best responded to other players' choices, their choices of effort level would be identical and the effort wasted by the group would be zero. A large level of wasted effort would indicate a large degree of miscoordination within a group. We also examine how much effort groups exert in order to obtain a given output.

Result 1: Groups in Star are more likely to play Nash equilibrium than groups in Null.

Throughout the experiment, groups in Null reach a Nash equilibrium 21 times, or 19%. Groups in Star reach a Nash equilibrium 39 times, or 33%. The difference is statistically significant (p-value$=0.03$) in a Pearson chi-squared test of equality of proportions.[2] Extending the analysis at the individual level, one obtains similar results. A player best responds to his peers' choices 44% of times in Null compared to 66% of times in Star (p-value< 0.001). The difference remains statistically significant in the second half of the experiment: 56% of times in Null versus 73% of times in Star (p-value< 0.001).

The difference between treatments is even starker if one looks only at periods in which a group did not manage to coordinate at one of the natural focal points, the payoff dominant Nash equilibrium. In this case, groups in Star reach a Nash equilibrium 21 times, or 21% of times. In contrast, groups in Null never reach a Nash equilibrium unless they coordinate at the highest possible output. At the individual level, the proportion of instances in which a player best responds to the other group members' choices is 31% in Null treatment and 60% in Star (p-value< 0.001). This suggests that the actions of a prominent member do indeed serve as a coordination device allowing groups of players to select Nash equilibria distinct from the usual payoff dominant or risk dominant ones.

Result 2: Groups in Star waste less effort than groups in Null.

The first three columns of Table 1 show each group's wasted effort averaged over periods of interest for groups in Null and Star treatments. Over the entire length of the experiment groups in the Null treatment waste 8.7 units of effort per period. Groups in the Star treatment waste considerably less effort: 4.8 units, representing a 46% decline. In both treatments wasted effort declines in the second half of the experiment, showing that subjects learn how to coordinate as they play the game. In the last 5 periods the difference in wasted effort increases to 55%. Groups in Star treatment appear to be affected by the last period effect much more than groups in Null treatment. Examining only periods 6 through 9 in order to eliminate this effect reveals that groups in Star waste 66% less effort than groups in Null. To test the statistical significance of these differences across treatments we employ both a non-parametric Mann-Whitney U test and a t-test. At 10-percent significance level, the difference across treatments is significant for averages throughout the experiment as well as for averages for periods 6 through 9, after groups learned how to play the game but before they are affected by the last period.

Averaging group behavior over periods of time might hide important dynamic aspects. We exploit the time dimension of the data set to obtain a fuller understanding of how well groups coordinate over time. In the first two columns of Table 2 we report the estimated coefficients of group-level random effects regressions using all periods for each group in both treatments.

[2] Perhaps due to halving the sample size, the difference becomes smaller and statistically insignificant if one examines only the last five periods.

	Wasted Effort					
	Group		Individual			
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	12.98	14.01	2.16	2.33	1.45	2.33
	(1.35)***	(1.52)***	(0.28)***	(0.27)***	(0.26)***	(0.26)***
Star	−3.93	−5.9	−0.66	−0.98	−0.62	−0.87
	(1.63)**	(2.11)***	(0.28)**	(0.41)**	(0.28)**	(0.41)**
Time (T)	−0.78	−0.96	−0.13	−0.16		−0.16
	(0.12)***	(0.17)***	(0.03)***	(0.04)***		(0.04)***
Star x T		0.36		0.06		0.05
		(0.24)		(0.06)		(0.06)
Prominent					−0.22	−0.69
					(0.13)*	(0.22)***
Prominent x T						0.08
						(0.03)***
N	230	230	1380	1380	1380	1380

Table 2: Columns (1) and (2): group-level random effects models; columns (3)-(6): individual-level random effects models. The standard errors are shown in parentheses and are clustered at the group level. The dependent variable is group wasted effort in a given period in (1) and (2) and individual wasted effort in a given period in (3)-(6). Star is a dummy variable for the subject being in a group in Star treatment. Time is the period of the experiment. Prominent takes value 1 if the subject was in the Star treatment and was a prominent member. ***, **, and * represent significance at 1, 5, and 10 percent level.

The dependent variable in each specification is the effort wasted by a group in a given period. Specification in column (1) controls for any experience groups may accumulate while playing the game. Groups appear to learn to coordinate on a given equilibrium as they play the game, wasting on average 7.8 fewer units of effort by the time experiment ends. The coefficients in column (2) allow the effect of experience to be different for groups in Star treatment. In both specifications the coefficient on Star treatment is large and significant. One may wonder whether the groups in Null treatment would have eventually select an equilibrium and thus wasted little effort had the experiment lasted long enough. Figure 1 shows that this is not the case. The groups that play one of the Nash equilibria learn how to do so relatively quickly, but the groups that fail to coordinate quickly (for example, Groups 3, 4, 5, and 7) do not seem to do better over time.

The group-based analysis might miss important distinctions between the behavior of group members, especially in the Star treatment where not all group members have the same information. To correct for this, we replicate the group-based analysis at the players' level in columns (3)-(6) of Table 2. The usefulness of this exercise is limited by the fact that the independence of observations assumption is likely to be violated. Players' behavior may be influenced by other players' behavior, especially in Star treatment, and their behavior over time may be serially correlated. We attempt to correct this by clustering the standard errors at the group level. Individual wasted effort follows the same pattern as group wasted effort: individuals in groups with a prominent member waste less effort than individuals in groups without a prominent member. This difference remains statistically significant once one controls for players' experience or the group's output. Our Result 2 appears therefore to be robust and not to be caused by a few individuals in each group driving the entire behavior of the group.

Individual-level analysis is also useful for distinguishing between the behavior of regular and prominent members in Star treatment. The latter observe all their peers' choices in real time, so they can always reduce their wasted effort to zero without sacrificing any potential gains in the current period. Do they take advantage of this opportunity? Do they end up wasting less effort than the regular members? And how much of the advantage in coordination in favor of groups in Star treatment is due to the prominent members being able to reduce their wasted effort to zero?

Figure 2 plots the wasted effort of each individual in groups in Star treatment. The prominent member's wasted effort is plotted with thicker dashed red lines. It turns out the prominent members do in fact waste positive amounts of effort in most

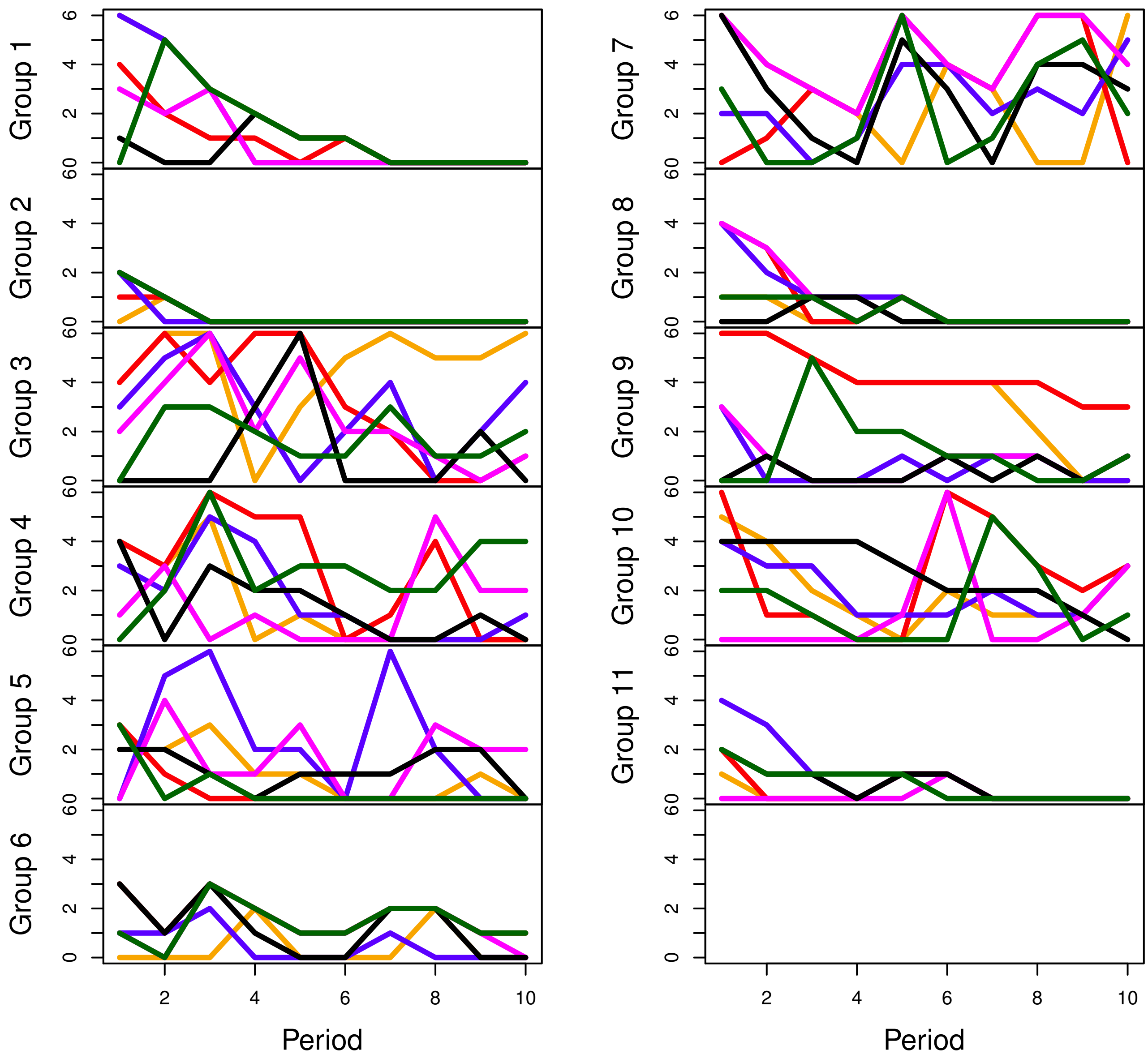

Figure 1: Effort wasted in each period by individuals in groups in Null treatment

periods in which other group members waste effort. Most of the time when the prominent member wastes zero effort, the rest of the group members also waste little effort. Columns (5) and (6) in Table 2 control for whether an individual in Star treatment is prominent: it appears that prominent members do indeed significantly better than the regular members. We summarize these findings in the following result:

Result 3: The prominent members waste significantly less effort than regular group members in Star treatment. Regular group members in Star treatment waste significantly less effort than group members in Null treatment.

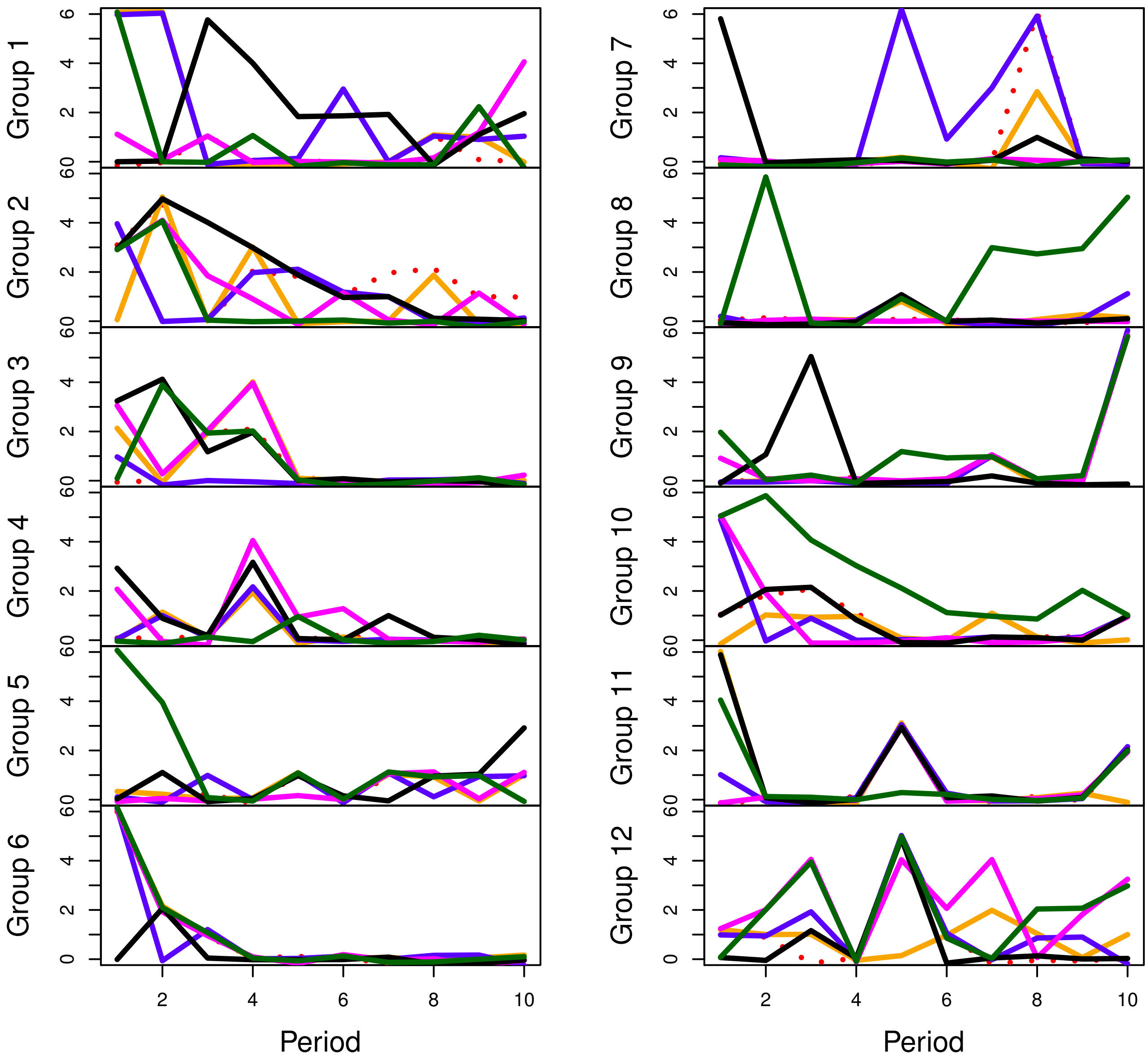

Figure 2: Effort wasted in each period by individuals in groups in Star treatment; the prominent member in each group is shown in dashed red lines

We finally examine total group effort, shown in the last there columns of Table 1 for groups in Null and Star treatments.[3] The difference across treatments is relatively large but it is not statistically significant in any of the time frames considered. Comparing raw averages in total effort without a reference to total output might be misleading. Increasing total effort is necessary to increase output, but not generally sufficient. The largest possible output can only be produced with 42 units of total effort. By comparison, the smallest possible output can be produced with total effort ranging from 6 to 36. Controlling for group output we obtain the following result.

Result 4: Although the difference in total effort across treatments is not statistically significant, groups in Star treatment exert significantly less total effort for the same output than groups in Null treatment.

The interpretation of Result 4 depends on the details of the situation considered. In some situations, such as production on an assembly line, the total output is given by the minimum group effort. Total effort is then useful only to the extent to which is raises the minimum. In these situations, Result 4 is a positive one, reinforcing the idea that a prominent member can achieve better coordination among group members. In other situations in which individuals are compensated based on the group minimum effort, total effort may be productive. For example, one's supervisor may be able to observe only the minimum effort of workers, perhaps because customers are likely to complain about bad customer service but not to praise good customer service. In these situations, an increase in effort above the minimum is wasted from the individuals's point of view, but not from society's or residual claimant's point of view. The difference in total effort between treatments in these situations can be interpreted as the shadow price the society or the firm owners are willing to pay in order to have a prominent member in a group. In these situations, Result 4 is a negative one. The residual claimants are not willing to pay much to have a prominent member in the group because that reduces the total output to the level of the lowest common denominator.

Together, Results 1 through 4 support Hypothesis 1 that players are more likely to play Nash equilibrium in groups with a prominent member. We turn our attention to testing Hypothesis 2.

3.2 Outcomes

Result 5: Groups in Star treatment do not achieve significantly larger output than groups in Null treatment.

Columns (4) through (6) of Table 1 show each group's minimum effort averaged over periods of interest for groups in Null and Star treatments. Groups in Null treatment are actually able to achieve slightly larger output than groups in Star. Over the entire duration of the experiment groups without a prominent member achieve an output of 3.7. Groups with a prominent member achieve an output of only 3.2. This difference is not statistically significant in either of the tests used. The difference becomes even smaller for the last five periods (0.1) and if one eliminates the last period (0.1); none of these are statistically significant. Looking at periods 6 through 9, three groups in Star treatment, compared to two in Null, manage to achieve the highest possible output. More groups in Star than in Null, however, achieve the lowest possible output.

Table 3 presents the regression coefficients of a series of regressions using various subsets of the 230 group-period decisions available.[4] Column (1) reveals that, without any controls, on average groups in Star treatment choose lower levels of output than groups in Null treatment. Columns (2) and (3) control for any experience groups might gather as a result of playing the game, perhaps differentiated for each treatment. For periods 1 through 10 the conclusion is maintained: groups in Null treatment choose larger levels of output than groups in Star treatment, but this difference is not statistically significant. It is customary to discard the first few periods of game play in which players might learn how to play the game. Columns (6) through (8) repeat the analysis using only the last five periods. Although the coefficients on the Star treatment dummy variable remain negative, they are economically as well as statistically insignificant in all these specifications.

[3]For brevity we omit the statistical analysis here. All the statistical analysis results are available upon request.

[4]Since by definition all individuals produce the same output, extending this analysis to the individual level would be misleading, artificially increasing the sample size.

	Group Output									
	All periods					Periods 6 through 10				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Const.	3.71	2.37	2.58	0.99	1.50	4.22	3.87	3.56	1.19	2.86
	$(0.56)^{***}$	$(0.57)^{***}$	$(0.57)^{***}$	$(0.39)^{***}$	$(0.55)^{***}$	$(0.33)^{***}$	$(1.35)^{***}$	$(1.92)^{*}$	(1.03)	(2.08)
Star	−0.45	−0.45	−0.85	0.01	−0.67	−0.22	−0.22	0.37	0.43	0.15
	(0.78)	(0.78)	(0.79)	(0.49)	(0.62)	(0.46)	(0.46)	(2.66)	(1.31)	(2.61)
Time (T)		0.24	0.2	−0.04	0.15		0.04	0.08	−0.08	−0.02
		$(0.01)^{***}$	$(0.02)^{***}$	(0.06)	$(0.07)^{**}$		(0.16)	(0.24)	(0.12)	(0.24)
T x Star			0.07	−0.01	0.10			−0.07	−0.07	0.01
			$(0.02)^{**}$	(0.07)	(0.10)			(0.33)	(0.16)	(0.32)
Lag Output				0.84					0.87	
				$(0.04)^{***}$					$(0.04)^{***}$	
1st Output					0.53					0.55
					$(0.12)^{***}$					$(0.18)^{***}$

Table 3: The dependent variable is group output in a given period. Specifications in columns (1)-(3) and (6)-(8) are group-level random effects models; the rest are ordinary least squares models. There are 230 observations in each specification except (4), (5), (9) and (10): 10 periods for each one of 23 groups in both treatments. Star is a dummy variable for the subject being in a group in Star treatment. Specifications (4), (5), (9) and (10) use lagged output as an independent variable, so there are only 207 observations. Time is the period of the experiment. Minimum Effort represents the output of the group. 1st Output represents the output of the group in the first period. ***, **, and * represent significance at 1, 5, and 10 percent level.

Group behavior may be correlated over time, with the output in the current period being influenced by output in the previous periods. In columns (4) and (5), for the whole sample, and (9) and (10) for the last periods, we attempt to control for this time-dependence by introducing the lag of group output and the group output in the first period, respectively. Columns (4) and (9) show that controlling for the output in the previous period, groups in one treatment do not do significantly better than groups in the other both throughout the experiment and only in the later periods. Columns (5) and (10) reach the same conclusion after controlling for the behavior in the first period of the game.

Result 6: Players' surplus (subjects' payoff) is not significantly larger for groups in Star treatment compared to groups in Null treatment.

The players surplus is shown in next to last three columns in Table 1. The differences across treatments are small and statistically insignificant. The difference in player surplus between treatments can be interpreted as the shadow price the workers would be willing to pay in order to have a certain type of monitor. This monitor is able to observe the group members' efforts and is in turn be observed by them, but cannot otherwise punish or recompense the workers. Our first sets of results suggest that having such a monitor might be valuable: although it would not necessarily improve output, the same output would be obtained without wasting effort and thus with less total effort. It turns out that the shadow price of such a monitor is small and statistically insignificant in all periods of interest. In our preferred time frame, a group would be willing to pay 0.4 dollars per round to have such a monitor, although this amount is not statistically different from 0.

Results 5 and 6 reject our Hypothesis 2. Groups with a prominent member do not select Pareto-superior equilibria compared to groups without a prominent member. Individuals in Star treatments do not manage to obtain better payoffs than individuals in Null treatment. Although prominent members appear to help groups select a Nash equilibrium, they fail to induce groups to select the payoff dominant equilibrium.

4 Discussion

We first examine how having additional information about the prominent member's actions affects the evolution of group outcomes. Specifications (4) and (5) in Table 3 reveal a strong time dependency of group output. One natural way to think about such a time dependent behavior is by assuming that it follows a one-period Markov Chain. Figure 3 plots the current group output against the group output in the previous period; the size of the dots indicates the one-step transition probabilities. Figure 3 reveals a few interesting facts about group outcomes dynamics.

On the one hand, groups in Star can reach the highest possible outcome relatively fast. They can evolve from an output of 4, or even an output of 1, to an output of 7 within one period. The second-shortest path from an output of 1 to an output of 7 in Star is 3 periods, which is shorter than the 4 periods that a group in Null treatment would take to evolve from an output of 1 to one of 7. Groups in Null have relatively less information than groups in Star, so it makes sense that they evolve at a slower pace: the maximum one-period improvement among groups in Null treatment is 2, compared to 6 in Star. On the other hand, group output is relatively stable over time in the Null network groups, especially at the payoff dominant equilibrium. Once a group in the Null network treatment has reached the best possible equilibrium it never chooses any other outpur, so the payoff dominant equilibrium appears to be an absorbing point in Null treatment. In Star treatment, output is relatively volatile. Groups in Star can decrease their output from the best possible output and are more likely to end up with the worst possible output from any given current level of output. It appears that common knowledge information about one group member's behavior may not always be helpful.[5]

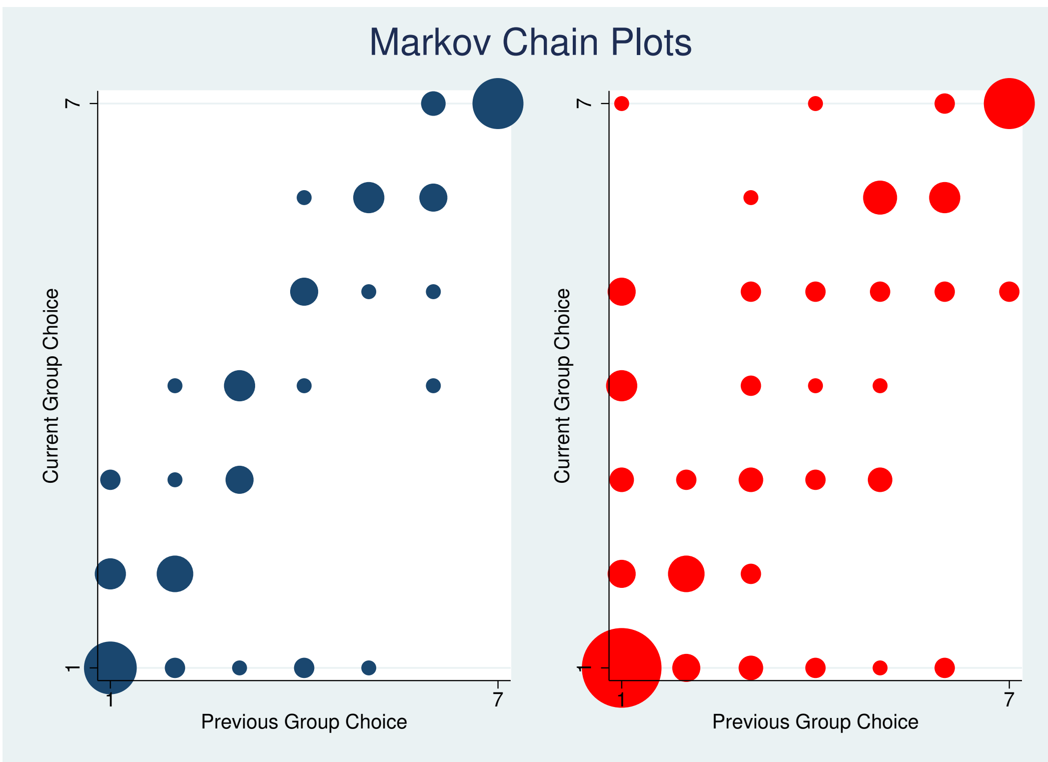

Figure 3: One-step transition probabilities for group outcome in Null (left, blue) and Star (right, red) treatments

We then examine how observing a prominent member is able to make a difference in equilibrium play. Figure 4 graphs the wasted effort by each individual in a given period against the group minimum effort. One of the starkest differences between treatments is the absence of periods in which groups in Null treatment waste zero effort. Except when the maximum possible

[5]We test whether the differences above are statistically significant using maximum likelihood ratio tests. We use maximum likelihood estimations of the parameters governing the Markov Chain probability transition matrix. The restricted model pools all groups together, while the unrestricted model allows for treatment-specific parameters. We fit the following one-step transition models. In the first model, output remains unchanged with a certain probability common to all output levels; if output changes, output can take any other value. The second model is a more flexible version of the first, allowing the probability of output remaining unchanged to vary with the current level of output. In both models, we fail to reject the hypothesis that the coefficients governing the transition probabilites are the same for both groups. These results are available upon request.

output is achieved, and thus wasted effort is by definition 0, groups in Null never waste zero effort. In contrast, many groups in Star are able avoind wasting any effort at various level of output. Thus, a prominent member can induce groups to coordinate to a larger range of equilibria than are usually observed without a prominent member. In contrast, in Null treatment, some groups members always over-shoot the best response when that is possible. This suggests that observing a prominent member does indeed reduce strategic uncertainty, giving sometimes enough information to the other players to perfectly coordinate, although not always at the best possible outcomes.

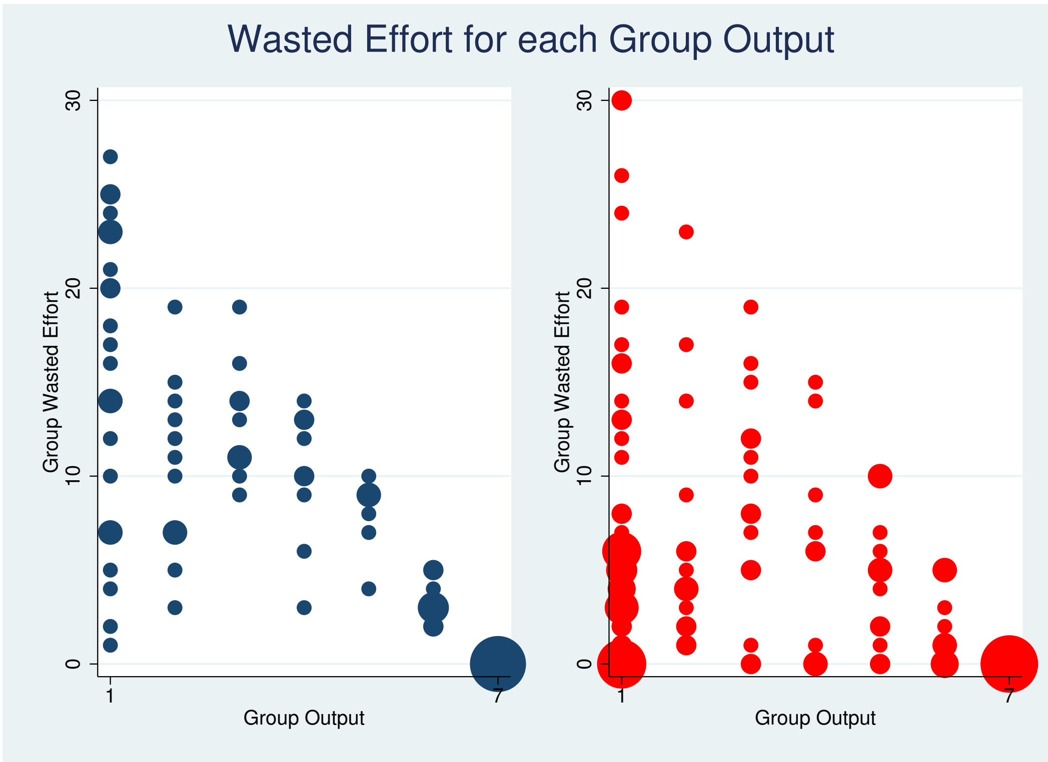

Figure 4: Wasted effort for each group output in Null (left, blue) and Star (right, red) treatments

Finally, we offer some support for the conjecture that the failure of groups in Star to coordinate to the best possible outcomes is due to information uncertainty. While the groups in Star treatment have *common knowledge* of one player's actions, they lack *common meaning* of these actions. The prominent member might choose a level of effort in order to maximize his own one-period payoff. In that case, he should choose the minimum level of effort he observes among the rest of the players. If the other group members share this meaning of the prominent member's actions, they could easily coordinate to that level of effort. Groups should waste zero effort, but they should reach random outcomes. This is not what we observe in the data. Alternatively, the prominent member could try to lead other group members. She could choose her effort level to indicate what level of effort other members should choose. If group members interpet the prominent member's actions in this way, coordination may not succeed from the beginning, but over time players that observe a prominent member might be able to do considerably better than those in the Null. This is again not what we observe in the data.

Whatever one group member believes about what the prominent member is trying to achieve with his actions, group members are also hindered in their attempt to coordinate by not being certain that others share their own belief. However, in certain situations, information uncertainty is reduced to a minimum. If the prominent member chooses effort level 1, the regular members should also pick 1, no matter what others infer from the prominent member's choice. This is supported by the data. Groups in Star waste 10 fewer units of effort when the prominent member chooses effort level 1 compared to when another group member chooses 1, a statistically significant reduction of 74%. Controlling for the group output, groups in Star waste 7 fewer units of effort, a statistically significant reduction of 57%, when the prominent member chooses effort level 1.[6] When it is easy to interpret what the prominent member is trying to achieve, groups in Star treatment coordinate very well.

5 Conclusions

Situations in which one group member's actions are common knowledge among group members are prevalent outside the laboratory: for example, captains in athletic teams, managers at the workplace, political leaders in a society. It is important to understand the extent to which common knowledge about prominent member's actions is able to help the group achieve better outcomes in situations requiring individuals to coordinate. Observing one member's actions may reduce strategic uncertainty, leading to better coordination. On the other hand, information uncertainty is not necessarily decreased, because group members might have difficulties interpreting the prominent member's actions.

We find that common knowledge of a prominent member's actions helps groups play a Nash equilibrium. When other players can observe in real time how a given group member chooses his actions, their actions are more likely to constitute a Nash equilibrium. However, groups with a prominent member do not achieve larger output than groups without a prominent member. This seems to happen because of severe information uncertainty. Regular members are not able to tell whether the prominent member signals to them the optimal current choice or whether she is leading by example, showing them what actions might give them better outcomes. The information uncertainty is reduced to a minimum when the prominent member chooses the lowest possible level of effort: in these situations, groups with a prominent member are able to coordinate very well.

We also observe considerable heterogeneity among groups with a prominent member: some manage to coordinate extremely well, while others fail. It would be interesting to learn what characteristics of the prominent member or of the regular group members lead to better coordination and how precisely the successful prominent members are able to achieve better outcomes. Finally, in our experiment the identity of the prominent group member, as well as the structure of the network are exogenously determined by the experimenter. Outside the laboratory, prominence is achieved endogenously, either by some members distinguishing themselves, becoming natural group leaders, or by a principal assigning prominent roles to certain individuals, such as a team manager designating team captains. It would be interesting to learn which individuals emerge endogenously as prominent members and whether these natural group leaders are able to obtain better results than the ones randomly selected by the experimenter. The structure of one's social network is also determined endogenously outside the laboratory, so it would be interesting to know what kinds of networks emerge endogenously when players can choose to which players to pay attention. We leave answering these questions to future research.

[6] These results are available upon request.

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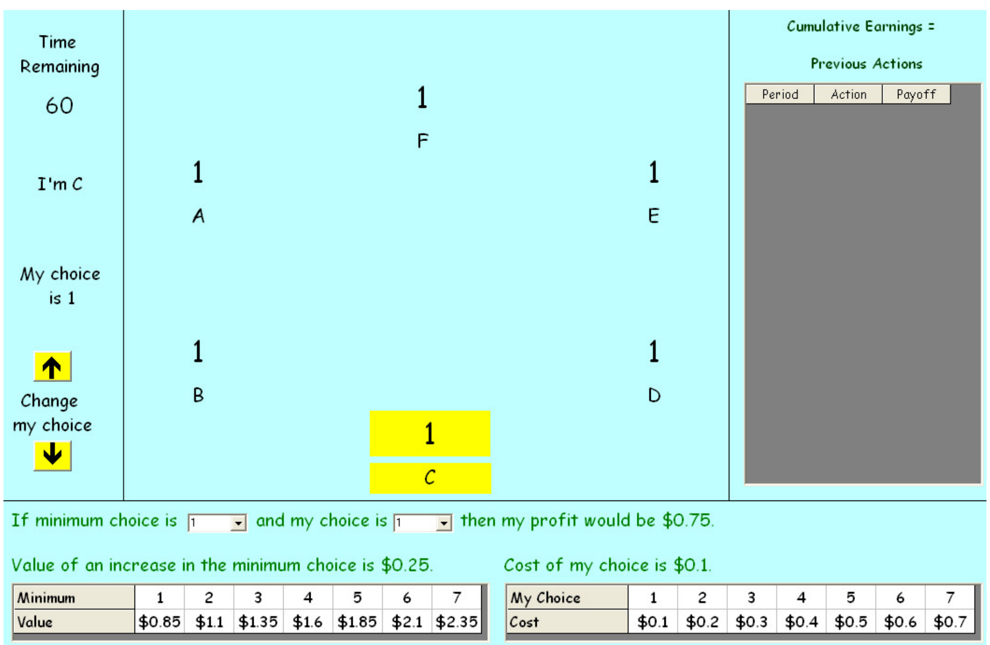
Appendix 1: Instructions for Star Treatment

Below are the instructions for Star Treatment. The instructions for Null Treatment are identical to the instructions for the Baseline Treatment in Deck and Nikiforakis (2012).

In this experiment, you will be paid an amount based upon your decisions and the decisions of the other participants. Therefore, it is important that you understand the directions completely. If you have any questions, please raise your hand and someone will come to answer it privately.

What types of decisions will I make? You and 5 other participants are grouped together. You and 5 other participants each must choose a number between 1 and 7. Your base earnings are \$0.60. Earnings will depend on the minimum number anyone picks. The larger the minimum the more everyone earns. An increase of 1 in the minimum number increases each participant?s earnings by \$0.25. However, it is costly to increase your number. It costs you \$0.10 to increase your number. Therefore, your earnings will be \$0.60 + \$0.25 · (minimum number) - \$0.10 · (your number). Tables at the bottom of your screen will show you the value and costs associated with various number choices and a dropdown tool will allow you to determine your profit for any combination of numbers. Keep in mind that the minimum number cannot be greater than your own number.

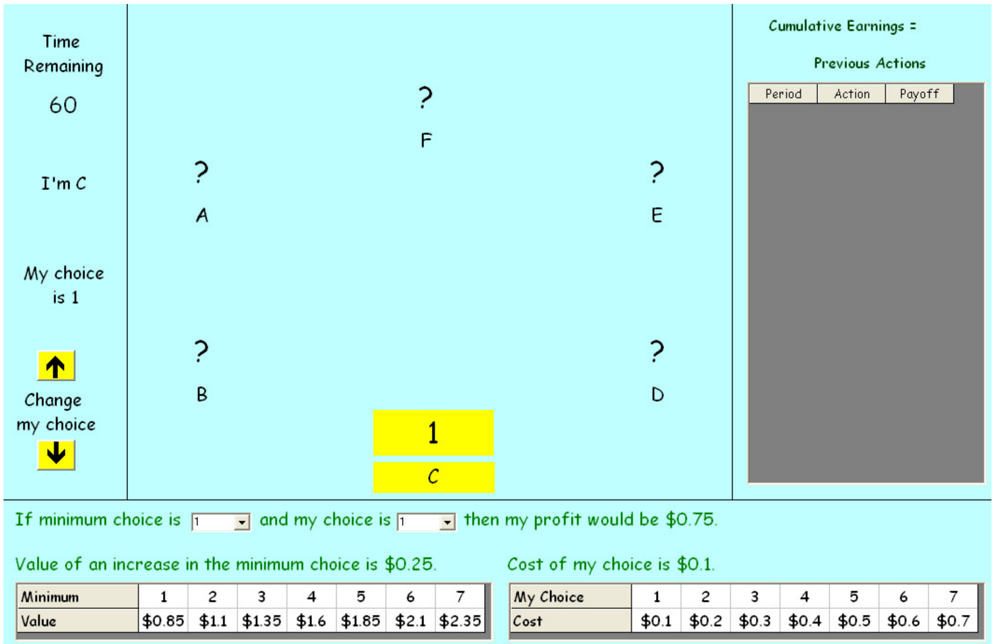
How do I make a choice? Your location and current choice will be identified on the left hand portion of your screen. Your current choice will also be highlighted in yellow in the center of the screen. You and the other participants will have 60 seconds to determine your choice. Remaining time will be displayed on the left hand side of your screen. You can change your choice by clicking on the yellow arrows on the left edge of your screen. Your decision will be whatever you have selected when time runs out.



What information do I have? In this experiment, not every participant in a group has the same information. In each group, there is one prominent participant, whose identity is randomly determined. The prominent participant?s choice is seen by all other participants. The prominent participant is also able to observe all other participants? choices. The other participants in the group are only able to observe the prominent participant?s choices, and naturally their own choices, but not anyone else's choices.

The figure above shows the screen seen by subject C during the experiment **if he or she happens to be the prominent participant in the group**. He or she is able to observe everyone else's choices.

The figure below shows the screen seen by subject C during the experiment **if he or she is not the prominent participant in the group**. Since subject C knows the choice of the prominent participant (subject B) his or her choice "2" is shown on the screen. Subject C does not know the choice of the rest of the participants, so a "?" will appear on the screen for those locations.



After the time has expired, everyone will be able to see the decisions of all of the other participants. You will also be informed of how much you earned for that decision.

How am I paid? In the experiment, you will go through this decision process 10 times. A table on the right hand edge of your screen will record your earnings each time. The people with whom you are interacting as well as your location will always be the same. The prominent participant will be the same each time. Each time you will be paid an amount equal to your earnings. At the end of the experiment, you will be paid the cumulative amount you have earned.

Now that you have finished the instructions, please answer the following questions. Your answers will not impact your payoff in any way, but are intended to ensure that everyone understands the experiment before it starts. If you have any questions while completing theses questions, please raise your hand.

Q1. Suppose that when the 60 seconds ends you observe the following choices.

A chose 6
B chose 4
C chose 2
D chose 5
E chose 4
F chose 7

How much would each person earn?

A: $0.6+ $0.25 · (2)-$0.10 · (6)=$0.50
B:
C:
D:
E:
F:

Q2. What would the person at C earn if he or she had chosen 4?

Q3. What would the person at C earn if he or she had chosen 6?

Q4. What would the person at D earn if he or she had chosen 1?

Q5. What would the person at D earn if he or she had chosen 2?

Q6. What would the person at D earn if he or she had chosen 3?

Q7. What would the person at D earn if the person at C had chosen 4?

Q8. What is the maximum you could earn each time? What is the minimum?

Q9. Suppose you are the person C and the person B is the prominent participant. If you choose 4, what would the person B know you chose?

Q10. Suppose you are the person C and the person B is the prominent participant. If you choose 4, what would the person D know you chose?

Q11. Suppose you are the person C and are the prominent participant. If you choose 4, what would the person B know about your choice?

Q12. Suppose you are the person C and are the prominent participant. If you choose 5, does the person A know that the person B knows you chose 5?

Once you have finished answering the questions, please raise your hand so that an experimenter may check your answers.