Communication, Coordination and Fairness in a Median Game

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Abstract

I explore within a laboratory setting the extent to which communication can increase efficiency within a game where the coordination task cannot be separated from the allocation. Subjects played a median game in which earnings are a multiple of the group's median minus a cost associated with an individual's effort. This structure retains the coordination problem of Pareto ranked equilibrium from the standard minimum effort game, but efficiency is now asymmetric and requires a minority to exert the minimum effort. Communication results in large gains to both effort levels and group medians with the gain relative to a no communication benchmark growing across periods. The effect is most dramatic directly following communication, and dissipates with each repetition.

Subjects were found to be interested both in coordinating to the highest possible median as well as achieving an equitable distribution of gains. Within group communication they suggested unanimous high effort most commonly, but a robust minority advocated a series of rotating free riders. A small minority announced an intention to free ride all iterations, and depend upon the remainder of the group's effort for a high median. Individuals were found to be most sensitive to receiving a free riding message, with a corresponding increase in one's own effort. This effect was not substantial enough to overcompensate for the free riding, with medians negatively impacted by free riding strategies. Efforts were not particularly sensitive to the message type, with two notable exceptions: aggressive, threatening style messages were found to induce higher efforts and trust based messages corresponded with higher efforts across all iterations.

1 Introduction

Pre-play cheap talk communication has been shown to promote efficiency and increase coordination within games with multiple equilibrium. This effect has been found in a minimum effort game, for instance in Blume and Ortmann (2007) and with the cheap talk only from past players in Chaudhuri, Schotter and Sopher (2009) as well as in stag hunt games, see for example Charness (2000). Crawford (1998) provides a summary of earlier results incorporating costless communication and Devetag and Ortmann (2007) provides a recent survey of the experimental results in coordination games.

Yet within these results, the coordination games tend to have Pareto ranked equilibrium that are symetric, thus avoiding any allocational issues. To the extent that cheap talk can increase efficiency, either by increasing the rate of equilibrium selection or by moving behavior from a risk dominant to a payoff dominant equilibrium, the robustness of this result is still in question. I extend the finding on the efficacy of cheap talk, asking to what extent communication can increase efficiency within a game where the coordination task is not separable from the allocation question. To explore this, experimental subjects played a finitely repeated version of a static single period 'median' game in which the earnings of the subjects were a multiple of the group's median minus a cost associated with the individual's effort.

The median game studied here is distinct but similar to the ordered static coordination games of Van Huyck, Battalio and Beil (1990) with sets of Nash equilibrium for each possible effort level that can be ranked by payoff dominance. In the minimum game, indivdual payoffs were given by a multiple of the group's lowest effort minus a cost of an indivuals effort. The median game of Van Huyck et all (1990) and repeated in Blume and Ortmann (2007) and elsewhere, individual payoffs were set equal to a multiple of the group's median minus a penalty for the gap between the individual's choice and the group's median. In both of these formulations, matching the group's ordered static is a best response in a single play game. For both games, this creates tiers of symmetric equilibrium corresponding to each possible effort level. While the Nash Equilibrium with highest effort level is payoff dominant in both games, the games differ with the risk dominant Nash Equilibrium occuring at the lowest effort level in the minimum game and at the middle effort level in the median game.

In contrast, the median game studied herein keeps the structure from the minimum game that effort is individually costly while employing the group's median for payoffs. This structure adds the wrinkle that, for any single period play, all individuals exerting the maximum effort level is no longer stable or efficient. Instead, within this version of a median game, diverging from the group's ordered static can be optimal. Free riding and exerting the lowest effort possible is both a single play best response and allocatively efficient, so long as it does not cross the threshold of lowering the group's median. The single play median game here is characterized by pure strategy equilibrium consisting of a majority of the group exerting the same effort level, and a minority free

riding by exerting the minimum possible effort level. These equilibrium are thus assymetric for all but the lowest median level, where unanimous low effort is the unique risk dominant Nash Equilibrium.

While the optimal response patterns very significantly, the median game studied herein and the standard minimum effort game each can be viewed as members of a more generalized class of games with payment based off the n-th lowest input in the group, with the median game corresponding to a higher number n. Despite the inherent assymetry of all but the lowest equilibrium, the equilibrium can be (partially) characterized by the ordered static, with payoff dominance occuring at the Nash Equilibrium with the group's median equal to the highest possible effort level. However, the median game studied here confounds the simple coordination task of achieving the higher group payoff variable with an allocational task of determining who, if anyone, should receive the lower costs associated with free riding.

To the best of my knowledge, this game structure is novel to this study, and differs strategically from the weak link or minimum game, a voluntary contribution mechanism public goods game, and the earlier version of a median game employed in Van Huych et all (1990) and repeated since. In this manner it may be viewed as a more comparable to a multiplayer battle of the sexes game, then the standard order static coordination game. Within a two player setting, Cooper, DeJong, Forsythe and Ross (1989), found that communication resulted in some gains in a symmetric battle of the sexes, although these gains were higher with one way communication and fell considerably short of full efficiency. The median game studied here expands this setting to include multiple players and mulitiple levels at which an assymetric equilibrium could be split. This increased range of actions also corresponded with an increasing in the scope of communication with unfettered public communication allowed between the group for ninety seconds, compared with Cooper et all (1989), who restricted communication to one or three messages sent. To the extent that the results can be related, they are found broadly comparable, with the structure of communication herein allowing the pursuit of why communication sometimes improves coordination and at other times fails.

By reducing the draconian structure of the minimum game, in which the chain is only as strong as the weakest link, the median game can correspond with a variety of situations. One example of a situation which might be represented by the median game structure is a political setting in which politicians must vote on passing a version of an unpopular law that is necessary; examples might include spending cuts or tax increases to combat a growing budget deficit. Each politician individual prefers the strongest possible law be enacted, the problem is as aggressively fixed as possible, but at the same time would benefit from the ability to disclaim responsibility for the costly policy. Public utility may be increasing with the steepness with which taxes are raised or government services cut to close a budget gap, but each politician would prefer if this majority excluded them. Another setting where this incentive structure occurs is a group project or a multiple co-authorship production where, due to a redundancy of inputs, the group's output is not hindered by some limited free riding.

Multiple experiment treatments were run, both including a round of pre-play communication and a baseline of no communication. Communication was found to have a significant and positive effect on the average individual efforts and group medians, resulting in increased payoffs. The effect was most robust in the initial play of the game, with the communication gains relative to the benchmark declining across repetitions within fixed groups. The impact of communication increased over regroupings and new plays of the game. The no communication treatments found significant deterioration in initial effort choices, while the communication treatments had stable initial choices. Communication thus appeared to stabilize expectations and prevent learned pessimism, enabling hope to spring eternally even as its effect was continually eroded across repetitions of play within a fixed group.

Finally, the content and impact of the specific communication is examined. This follows the approach found in Brandts and Cooper (2007), and attempts to answer to what extent the process by which cheap talk induced higher effort levels can be isolated and the communication that is most effective identified. In particular, I examine which arguments correlate with an increased effort when sent and when received. Messages almost always centered on the highest effort level, and were broadly allocated into several categories based upon the appeal used, ranging from explicit appeals for trust to (empty) threats and insults. In addition to explicit effort levels, subjects often communicated about a coordinated group strategy, with a unanimous high effort plan espoused most often but a robust minority of groups discussed a rotation of low effort individuals. A small minority of subjects pre-announced a strategy of minimum effort and full free riding in each play. Altogether subjects communicated in 93.5% of the times it was possible.

2 Experimental Design

The experiment was conducted during the Fall of 2010 at the Gregory Wachtler Experimental Economics Laboratory, part of the Center for Economic Behavior, Institutions and Design at Rutgers University, New Brunswick, NJ. Subjects were undergraduates at Rutgers University and signed up through online recruitment software. The experiment was programmed in Ztree (Fischbacher, 2007), and included 190 subjects across 10 treatment sessions.

Each session was either assigned to a no communication treatment, or one with communication via a shared chat box prior to the start of each period. Within the communication treatment, a temporary alias was assigned each period of communication to ensure anonymity and prevent reputation building effects. Each period, subjects were grouped into groups of five, and following communication if applicable, they separately answered their effort choice. After all five effort choices were selected, the group's median and their individual payoff were revealed to each member. Individuals were not presented with the full distribution of effort choices. Within a fixed group, subjects repeated the median game for six iterations, before regrouping and starting the next period.

Figure 1: Low Effort Cost Payoff Matrix

		Median Value Chosen by Group						
		7	6	5	4	3	2	1
	7	9.30	8.30	7.30	6.30	5.30	4.30	3.30
	6	9.40	8.40	7.40	6.40	5.40	4.40	3.40
Your	5	9.50	8.50	7.50	6.50	5.50	4.50	3.50
Effort	4	9.60	8.60	7.60	6.60	5.60	4.60	3.60
Choice	3	9.70	8.70	7.70	6.70	5.70	4.70	3.70
	2	9.80	8.80	7.80	6.80	5.80	4.80	3.80
	1	9.90	8.90	7.90	6.90	5.90	4.90	3.90

A total of ten periods were done in all but the first session, which ended after six periods.

Each period subjects were presented with one of two possible payoff tables, varying only in the cost of effort. In the first four periods, all individuals shared the same effort cost and payoff matrix, and this was presented as common knowledge. For the last six periods, individuals were assigned one of the two payoff matrices randomly, and were informed that each member of their group had similarly been assigned an effort cost and so effort costs might be dissimilar across group members. A full copy of the instructions can be found in Appendix 1. Final pay was based on cumulative results, and averaged in the range of $24 including a $5 show up fee.

Formally, each period of the game $n = 5$ subjects were randomly divided into a group. Within the sessions with communication, each member then had 90 seconds to send costless and non-binding messages $\gamma \in \Gamma$ to the other 4 members of his group. Given the messages sent and received, each subjects would then have some information set Π_i containing a set of beliefs about the other agents. The information set is quite complex, and includes the actions the other agents are likely to take each each iteration of the game, how these actions might change with a given realized group median and what the other agents' beliefs are. Following communication (when possible) subjects chose effort levels $\varepsilon_i \in (1, 2, \ldots, 7)$. Individual profit was then given by $\pi_i = a + bMedian - c_i\varepsilon_i$; with $a = 3$, $b = 1$ and $c_i \in (.1, .5)$ fixed per individual per period. The median (the third highest effort level in the group) and individual payoffs were reported to each subject, who then updated his set of beliefs. This effort choice problem with the same payoffs was then repeated with the same group. This occured for a total of 6 iterations prior to regrouping, when a new random group of 5 would begin the process. The payoff tables are displayed in Figure 1 and Figure 2.

3 Results

Communication was found to dramatically raise average effort levels, group medians and ultimately individual payoffs. The effect is most noticeable directly

Figure 2: High Effort Cost Payoff Matrix

		Median Value Chosen by Group						
		7	6	5	4	3	2	1
	7	6.50	5.50	4.50	3.50	2.50	1.50	0.50
	6	7.00	6.00	5.00	4.00	3.00	2.00	1.00
Your	5	7.50	6.50	5.50	4.50	3.50	2.50	1.50
Effort	4	8.00	7.00	6.00	5.00	4.00	3.00	2.00
Choice	3	8.50	7.50	6.50	5.50	4.50	3.50	2.50
	2	9.00	8.00	7.00	6.00	5.00	4.00	3.00
	1	9.50	8.50	7.50	6.50	5.50	4.50	3.50

after communicating, with the gains from communication decaying across iterations. Despite that, in each new period communication was found to have a similar effect, with the gains resilent against any learned pessimism. Treatments without communication instead had steadily decreasing effort and median levels. As expected, effort cost is a significant factor in subject choices. Efforts were not particularly sensitive to the messages sent, although there were several exceptions to this. Following is a roadmap of the results that follow.

Section 3.1 analyzes the impact of having communication possible, without analyzing the actual messages sent. The raw distribution of efforts, cumulatively as well as isolated for the treatments with and without communication are displayed in Tables 1 – 3. Tables 4 – 6 replicate this breakdown for the group medians. After the raw data distributions, generalized least square regressions follow on the individual efforts and medians with Table 7 and Table 8 presenting these findings respectively.

The content of the messages sent are then incorporated into the results in Section 3.2, with Table 9 demonstrating the frequency of different message strategies and appeals. Table 10 and Table 11 repeat the GLS analysis on efforts and medians, incorporating the strategies and appeal types. This analysis is restricted to the first iteration following communication, to prevent the confounding effect of other group members actions and past realized medians. Table 12 presents a regression of subjects' messages on their own efforts. Finally Table 13 and Table 14 present the GLS results on efforts and medians including message strategy and appeal types, only after dropping the restriction of the first iteration. These last results should be interpreted carefully, especially in regards to causation, but are informative of the types of communication that ultimately resulted in higher outputs. Section 3.3 presents areas for further research before Section 4 concludes.

3.1 Results: Raw Communication

The median game studied herein had the effect of focusing behavior into the extremes of either the highest or the lowest possible effort. Table 1 presents the distribution of individual efforts, demonstrating this distinctively bimodal

Table 1: Distribution of Effort by Iteration: All Response Data

Iteration	Individual Effort Level Frequency						
	7	6	5	4	3	2	1
1	42.01%	7.83%	8.32%	7.99%	4.46%	3.91%	25.49%
2	37.12%	7.55%	8.64%	7.07%	5.38%	5.38%	28.86%
3	33.97%	8.21%	7.88%	7.50%	5.16%	4.78%	32.50%
4	32.28%	7.99%	7.34%	7.23%	5.33%	5.60%	34.24%
5	30.76%	7.17%	7.07%	6.85%	5.11%	5.98%	37.07%
6	27.17%	5.98%	6.79%	6.63%	4.46%	5.27%	43.70%
Total	33.89%	7.45%	7.67%	7.21%	4.98%	5.15%	33.64%

pattern. Across all treatments and iterations, an effort level of 7 or of 1 each occurred individually with a frequency greater then all other efforts combined. This effect was particularly pronounced within the treatment with communication, see Table 2, where 80.10% of all efforts were at one extreme or the other. In contrast, the no communication baseline shows a significant distribution of efforts at all intermediate levels, with a single modal mass at the lowest effort level.

The prevalence of subjects coordinating on the highest level of effort was thus one of the largest distinctions between the experimental sessions that included communication and those that did not. The different distributions of raw efforts depending on the presence of a pre-play communication round contain a pronounced distinction in terms of the frequency of highest possible efforts. The percentage of maximum efforts in the communication treatment was approximately 46%, in contrast to only 18.17% without the possibility to chat before playing the game (see Table 2 and Table 3).

The other salient pattern in the raw effort levels is a significant time series effect across iterations within the same fixed group. The time trend combines a decline in the percentage of high efforts, and a corresponding increase in the percentage of low efforts. The latter occurred similarly in both the communication and the no communication treatments The percentage of low effort choices rose from 24.81% to 45.96% and from 26.38% to 40.75% from iteration 1 to iteration 6 with and without communication respectively. The percentage of high effort choices in the communication treatment dropped from 58.27% directly following communication to 33.56% in the sixth iteration suggesting that much of the gains from communication diminish rapidly. Without the communication boost to high effort levels in iteration 1, the no communication baseline has a relatively stable level of high efforts, with the percentage dropping only by two percentage points.

Group medians demonstrate similar patterns to the individual efforts. Table 4 presents the aggregate results, Table 5 the communication only treatment and Table 6 the no communication treatment. Looking at the data shows that there is a glaring juxtaposition between the communication and no communication benchmark. The percentage of groups achieving the highest possible median

Table 2: Distribution of Effort by Iteration: With Communication

Iteration	Individual Effort Level Frequency						
	7	6	5	4	3	2	1
1	58.27%	6.63%	3.94%	2.79%	1.44%	2.12%	24.81%
2	50.96%	5.77%	6.06%	2.98%	2.31%	2.88%	29.04%
3	47.21%	5.58%	6.15%	3.46%	2.02%	2.60%	32.98%
4	43.94%	5.96%	6.35%	3.94%	2.12%	2.40%	35.29%
5	41.92%	6.15%	5.67%	3.65%	2.69%	3.27%	36.63%
6	33.56%	5.00%	6.06%	3.17%	2.88%	3.37%	45.96%
Total	45.98%	5.85%	5.71%	3.33%	2.24%	2.77%	34.12%

Table 3: Distribution of Effort by Iteration: Without Communication

Iteration	Individual Effort Level Frequency						
	7	6	5	4	3	2	1
1	20.88%	9.38%	14.00%	14.75%	8.38%	6.25%	26.38%
2	19.13%	9.88%	12.00%	12.38%	9.38%	8.63%	28.63%
3	16.75%	11.63%	10.13%	12.75%	9.25%	7.63%	31.88%
4	17.13%	10.63%	8.63%	11.50%	9.50%	9.75%	32.88%
5	16.25%	8.50%	8.88%	11.00%	8.25%	9.50%	37.63%
6	18.88%	7.25%	7.75%	11.13%	6.50%	7.75%	40.75%
Total	18.17%	9.54%	10.23%	12.25%	8.54%	8.25%	33.02%

is 48.16% with chat versus 6.98% without. And again, the data shows a time series deterioration across iterations. Within the communication treatment this can be seen at the extremes; the highest effort declined from 66.35% to 26.92% of all group results while the lowest effort increased from 10.10% to 37.98% of all group results. The without communication median's were fairly uniformly dispersed, yet also show this increase in the prevalence of the lowest possible group medians. The no communication results initially had a modal mass at the center of the effort ranges before a spike in the percentage of low effort medians in the last two iterations.

Comparing the raw distribution of efforts and medians shows that the efforts alone understate the gains from communication. The communication treatment had a higher occurrence of medians at the upper limit of 7 then efforts, suggesting successful coordination and less wasting of efforts. This is particularly important as it indicates that some of the instances of the low efforts are actually efficient free riding versus median reducing inefficient choices. In contrast, while the no communication treatment had over 18% of efforts at the highest level of 7, slightly less then 7% of all groups there achieved a median of 7. Thus, the instances of high individual effort were more likely to be indicative of wasted effort then emblematic of group coordination and high payoffs.

A panel data GLS regression was run on individual effort choices to identify the full magnitude of communication on individual behavior within the Median

Table 4: Distribution of Median by Iteration: All Response Data

Iteration	Median Effort Level Frequency						
	7	6	5	4	3	2	1
1	40.76%	9.78%	12.77%	11.68%	7.88%	6.25%	10.87%
2	35.60%	8.15%	14.40%	11.96%	9.78%	8.15%	11.96%
3	31.52%	11.14%	10.87%	10.87%	9.51%	7.88%	18.21%
4	28.53%	10.60%	10.60%	13.04%	8.15%	9.24%	19.84%
5	26.36%	9.24%	11.14%	9.24%	9.24%	11.41%	23.37%
6	18.75%	9.78%	10.05%	10.60%	6.79%	9.24%	34.78%
Total	30.25%	9.78%	11.64%	11.23%	8.56%	8.70%	19.84%

Table 5: Distribution of Median by Iteration: With Communication

Iteration	Median Effort Level Frequency						
	7	6	5	4	3	2	1
1	66.35%	8.65%	6.25%	3.37%	2.40%	2.88%	10.10%
2	58.17%	7.21%	12.50%	4.81%	3.85%	3.85%	9.62%
3	50.00%	9.13%	9.13%	4.81%	3.37%	3.37%	20.19%
4	46.63%	9.62%	11.54%	5.77%	1.92%	2.40%	22.12%
5	40.87%	10.10%	9.13%	6.73%	3.37%	7.21%	22.60%
6	26.92%	9.13%	10.58%	6.25%	2.88%	6.25%	37.98%
Total	48.16%	8.97%	9.86%	5.29%	2.96%	4.33%	20.43%

Table 6: Distribution of Median by Iteration: Without Communication

Iteration	Median Effort Level Frequency						
	7	6	5	4	3	2	1
1	7.50%	11.25%	21.25%	22.50%	15.00%	10.63%	11.88%
2	6.25%	9.38%	16.88%	21.25%	17.50%	13.75%	15.00%
3	7.50%	13.75%	13.13%	18.75%	17.50%	13.75%	15.63%
4	5.00%	11.88%	9.38%	22.50%	16.25%	18.13%	16.88%
5	7.50%	8.13%	13.75%	12.50%	16.88%	16.88%	24.38%
6	8.13%	10.63%	9.38%	16.25%	11.88%	13.13%	30.63%
Total	6.98%	10.83%	13.96%	18.96%	15.83%	14.38%	19.06%

game. Explanatory variables included the period of the experiment (the round of regrouping, ranging from 1 to 10), the iteration of the experiment (the round of repetition within a fixed group, ranging from 1 to 6), the effort cost which took a binary value of either .1 or .5, a dummy for the presence of an opportunity to communicate, and lastly cross intercept dummies between communication and period, iteration and effort cost. This generalized structure enabled fitting in effect two separate regressions, one for the treatments with communication and one without communication without imposing any structural continuity between the two. Table 7 presents the results of the Generalized Least Squares regression on effort, which was derived from 11,040 individual observations about 190 subjects.

Communication was found to result in an increased effort by .84, nearly a single degree out of the seven available higher and statistically significant at the 1% level. As displayed in Tables 1 – 6, effort choices declined across iterations. The GLS regression attributing a coefficient of -.126 per iteration to effort. For the treatments with communication, this effect was further exaggerated, with an additional coefficient of -.126. Both coefficients were significant at the 1% level. Period also was found to have a negative impact on effort choices, with a raw coefficient of -.102. Communication however was found to have an opposite effect when combined with period, with a dummy slope intercept fitted at .099. Testing that the combined coefficient for the communication treatment is equal to zero returns a Chi Squared Statistic of .10, so the null hypothesis that the period is insignificant in the communication treatment cannot be rejected.

While subjects without the opportunity to discuss the experiment slowly became more pessimistic in their actions, subjects in the communication treatments approached each new grouping as optimistic as the last. This optimism reoccurred despite the fact that efforts appeared to quickly disintegrate within each grouping. Finally, effort cost was found significant at the 1% level, with a negative coefficient that corresponds to a .86 difference in average efforts between payoff grids. A communication and effort cost dummy was significant at the 10% level but not at the 5% level, with a marginal reduction in effort when moving from the low to the high cost payoff matrix of .15.

Conducting the same analysis on group medians reveals the same patterns, with an increase in the magnitude of the coefficients. Medians are decreasing in period and iteration by coefficients of -.147 and -.137 respectively, both significant at the 1% level. Communication increases medians by 1.531, nearly double the effect on individual efforts. Once again this result declines across iterations, here by the steeper -.238 per iteration. Finally, the dummy slope intercept on communication and period again is large enough to negate the no communication decline across periods. In fact, the combined coefficient of the time series effect for the communication treatment is statistically greater then zero at the 1% level, with a Chi Squared Statistic of 9.53.

The main results found in analyzing the impact of a pre-play round of communication are consistently higher effort and medians directly following communication. These efforts and medians then experience a quick decay across iterations, losing significant after four or five repetitions. However, with each

Table 7: GLS on Effort

Variable	Coeficient	Standard Error
Constant	5.255	.177
Communication	.840	.233
Period	-.102	.011
Iteration	-.126	.018
Effort Cost	-2.157	.156
Period with Communication	.099	.014
Iteration with Communication	-.126	.024
Effort Cost with Communication	-.386	.209

Table 8: GLS on Median

Variable	Coeficient	Standard Error
Constant	5.267	.116
Communication	1.531	.153
Period	-.147	.010
Iteration	-.137	.017
Effort Cost	-1.403	.146
Period with Communication	.175	.013
Iteration with Communication	-.238	.022
Effort Cost with Communication	-.809	.195

new grouping and pre-play communication round, efforts began again flat with where they had started the previous round. In contrast, the no communication treatments demonstrated carry over effects and thus lowered initial efforts with each subsequent grouping. The inter-temporal stability of first iteration efforts and medians within the communication treatment, despite the seemingly inevitable decline in group medians, suggests that the communication in effect prevented the learning and adapting to this negative pattern. These results were self-fulfilling, with communication subjects rewarded with higher medians and payoffs.

3.2 Results: Distribution and Content of Messages

Since the raw possibility of communicating resulted in a dramatic increase in both individual efforts and group medians, the question naturally follows to what extent this effect can be isolated, and the individual messages that boost payoffs be identified. Examining the chat transcripts reveals that the individual comments typically fell into one of the categories of numerical messages, group strategy suggestions, or one of several different categories of appeals for higher efforts. The messages sent by each individual in each period were coded as to whether they fell into each of these categories, with messages often falling into several of them. In addition, the messages individuals recieved as well as the number of group members they received them from were also identified.

The numerical messages matched the effort range from 7 to 1, although the vast majority were all for full effort. Strategies included unanimous full effort by the group, an intricate series of rotating free riders, and occasionally a personal free riding strategy in which the other members of the group would be told the median depended solely on them and that that subject would chose the minimum each time. Lastly, participants often tried to talk other members into higher efforts, and the major categories of these appeals were identified as threat based, fairness based, coordination based, risk based and trust based. These appeal based categories were not mutually exclusive, and a subject could be coded as using one or more of the message types as applicable. The full distribution of messages sent and their frequency within the communication treatment is displayed in Table 9.

The most prevalent message consisted of indicating the highest level of effort at 7. A full 65.58% of all possible individual communication periods included this. In contrast, the next most prevalent numerical messages were 1 and 6 with frequencies of 6.54% and 4.23% respectively. Indeed, the prevalence of messages of 7 and the near absence of lower effort messages was so common as to make the numerical message sent entirely uninformative within subsequent regressions upon the efforts that individuals took after communication. Strategies most frequently were some version of a plead for unanimous high efforts. However, a robust minority of groups across different sessions had members recommending an equal distribution of free riding gains by rotating turns of low effort. Lastly, a handful of individuals declared themselves as permaneant free riders, with a strategy to exert low effort each iteration and depend upon the rest of the group to coordinate a higher median.

Examples of messages coded as a unanimous strategy include: "all 7s," "everyone do all 7," and "okay since obviously we cannot collaborate, can we all just do 7?" The rotation strategy included both calls for one and two low effort members, and often detailed the order of low effort based upon the visible aliases identifying group members. The range of messages spanned from "we can alternate who hits 1," to "hey since the median counts, do you guys want to take turns, putting in 1? like D puts in 1 first, n then), then S, then Q, rthen P." Examples of the type of strategy messages that were coded as free riding include: "im always going to go 1, i just told you what i am doing, plan accordingly," and "i always pick 1, so if we get 1, you will know that i am one of them."

Subjects often pleaded to other subjects to adopt their preferred strategy and to pick a high effort level, with the appeals commonly falling into one (or more) of several categories. The most common type of appeal was a coordination based argument, in which subjects argued that the gains from efficiently free riding would be swamped by the increased chance of the group failing to achieve a high median. The typical coordination message was something similar to "everyone thinks that they will be the one to switch to 1 it does not work." The next most common category of appeals were threats, which included cursing and hostile language. Just under 10% of all communication was of this type, with examples such as "yeah all 7's...no one be an a hole and switch it up," which includes the

Table 9: Communication and Messages Sent

Communication Category	Frequency
Message of 7	65.58%
Message of 6	4.23%
Message of 5	1.83%
Message of 4	1.15%
Message of 3	0.00%
Message of 2	0.48%
Message of 1	6.54%
Unanimous Strategy	29.60%
Rotation Strategy	5.87%
Personal Free Rider Strategy	1.83%
Threat Based Appeal	9.52%
Fairness Based Appeal	8.46%
Coordination Based Appeal	10.19%
Risk Based Appeal	4.62%
Trust Based Appeal	6.63%
Silent	6.54%

unanimous strategy recommendation, to the blunt "if u press 1 u fuck it up and we all make no money," to "and YOU the one that is going to screw someone over by putting 1 DONT DO IT."

The last message focuses on the effect of a low effort choice as "screwing" the other group members, which was one of the more common word choices. These messages appeared to have a dual connotation, both one of the threatening and hostile nature, and also that there is an unfairness in the choice, and therefore were coded as belonging to both categories. The fairness category also included messages directly referencing fairness, such as "and then it's all fair cuz we all make the same." Similarly, trust based appeals were those in which subjects said some variant of trust me or "we have to trust each other." Lastly, risk based appeals were just under 5% of all communication and typically featured a contrast between the gains from reducing one's effort with the loss if the median fell; "everyone tries to save like .50 cents and we all lose like 5 dollars," or simply "is it worth it to risk that for 0.6?"

The messages receivced by an individual before the first iteration can be thought of as an input into the effort choice, and are logical variables to include within a regression analysis. Table 10 presents just this, with GLS results of including the strategy messages received on first iteration effort. In addition, Table 10 also includes the same GLS analysis run on the group's median in the first iteration following communication. While individual efforts are the direct factors in determining the median, to the extent that the messages sent might be suggestive of these actions this analysis can be informative. However, it is important to note that the median regression results should not be interpreted as causal coefficients. Even with the restrictions of a first iteration following

Table 10: GLS on 1st Iteration Including Strategies Received

	On Effort		On Median	
Variable	Coeficient	Std Error	Coeficient	Std Error
Constant	5.629	.220	5.812	.156
Period	-.024	.026	.019	.023
Effort Cost	-1.829	.340	-1.839	.304
Unanimous	.068	.073	.340	.061
Rotation	.057	.125	.409	.107
Free Rider	.535	.269	-.265	.223

communication, there was still a significant database of 1040 observations on 110 subjects.

Messages for both a unanimous and a rotation strategy were found to have a statistically significant impact on the effort chosen. When confronted with a free rider, subjects did not retaliate with low efforts as well but instead attempted to overcompensate. This response was of a .5 higher effect and was found significant at the 5% level. Medians tell a different story. Here we see that both unanimous and rotation strategy messages are significantly associated with higher medians. Discussion about the group's strategy is a good sign for the upcoming median even if it did not lead to a statistically significantly improve the individual efforts. The one exception to this is the free rider strategy, where even though the other group members attempted to over compensate, the median that failed to increase.

The type of appeals received are included as an explanatory variable in Table 11. The only type of appeal that was found to have significance on the first effort following communication was threats. Threats, which included hostile and derogatory language, were found to increase effort by .23, with a significance level of 5.2%. All other appeal types were not significantly different from zero. In addition to the results on effort, Table 11 also includes the same analysis on the first iteration median, with the same caveat holding again that these results should be interpretted carefully. Medians are found to be positively associated with fairness, coordination, and risk based appeals. These variables each had a coefficients between .26 and .31 and were significant at the 5% level. Threats and trust based arguments were positive but not statistically significant.

Since medians show significance for receiving strategies and appeals that are not statistically significant on effort levels, to what extent can this be reconciled. It is possible that the medians are capturing small nudges in the group behavior that the efforts are not sensitive enough to. Similarly, they could be capturing the effects of an increase in coordidination, in which net efforts are constant but efficiency and medians increase. The alternative possibility is that the cheap talk is informative of the actions that the sending agents will take, and the regressions on the medians are just identifying the communication that proxies for higher efforts from the senders. To address this alternative, the messages individuals send was regressed on the subject's own effort choices. The results

Table 11: GLS on 1st Iteration Including Appeals Received

	On Effort		On Median	
Variable	Coeficient	Std Error	Coeficient	Std Error
Constant	5.675	.218	5.954	.154
Period	-.034	.027	.019	.024
Effort Cost	-1.830	.337	-1.798	.305
Threat	.231	.119	.115	.106
Fairness	.125	.123	.271	.108
Coordination	-.064	.111	.264	.095
Risk	.166	.164	.311	.144
Trust	.038	.116	.116	.097

Table 12: GLS on Effort and Messages Sent

Variable	Coeficient	Standard Error
Constant	5.626	.214
Period	-.039	.025
Effort Cost	-1.766	.334
Unanimous	.645	.177
Rotation	.916	.319
Free Rider	-3.083	.602
Threat	.097	.246
Fairness	.050	.262
Coordination	-.166	.235
Risk	-.055	.356
Trust	.246	.291

are presented in Table 12.

Unsurprisingly, individuals who claimed they would free ride did so, with the regression fitting a effort drop of 3 for these individuals. While no appeals were significant, both a rotation strategy and a unanimous strategy were suggested by individuals who put in high efforts. Again, these results should not be interpretted in the standard causal fashion with the messages a subject sends causing them to pick an effort, but instead as a measure of the association between the two actions. With that disclaimer said, the results support the hypothesis that the increased medians in Table 10 were the effect of coming from high effort individuals, and not neccessarily a product of the strategy messages themselves. However, there is no evidence to support this interpretation when understanding the impact of the fairness, coordination and risk based appeals.

The raw data painted a compelling picture of communication gains, but with the gains quickly diminshing across iterations. Unfortunatey, any analysis across iterations includes a significant confounding effect of the path of the game play. Still, repeating the analysis of the strategy and appeal messages without restricting the domain to the initial iteration following communication provides

Table 13: GLS on All Iterations Including Strategies Received

	On Effort		On Median	
Variable	Coeficient	Std Error	Coeficient	Std Error
Constant	6.050	.167	6.743	.104
Period	-.014	.011	-.001	.011
Iteration	-.252	.016	-.375	.016
Effort Cost	-2.543	.147	-2.216	.146
Unanimous	.065	.032	.208	.031
Rotation	.044	.055	.051	.053
Free Rider	.166	.118	-.663	.114

insight into what type of effect persists and which do not. The full results, taken from 6240 observations on 110 individuals, are presented in Table 13 and Table 14.

While both a unanimous strategy and a rotation strategy was tied to higher medians when restricting analysis to the first iteration, only the unanimous strategy retains its significance across all iterations. The rotation strategy, while more efficient then having wasted effort of everyone exerting the highest effort, is inherently more unstable. Across iterations, the instability was significant enough to deteriorate the coordination and make the gains disappear. Similarly, groups initially could almost compensate for a free rdier, but as the game was repeated the impact of a free rider increased dramatically. When looking across all iterations, receiving a free rider message did not cause individuals individuals to have effort levels significantly different then zero, while medians declined with a coefficient of -.66 that was significant at the 1% level.

When the analysis is expanded to include all iterations followiung communication, trust based appeals emerge as highly influential. Trust based appeals are found to have a .22 coefficient on individual efforts and a .43 coefficient on medians, both significant at the 1% level. Threats are still significant at the individual effort level, but this does not correspond to group success and the coeffician on medians is insignificant. Fairness is significant at the 10% but not the 5% level for medians. Cordination and risk based arguments that were initially significant have lost their significance as the game play progressed.

3.3 Areas for further research

The impact of cheap talk communication within a broader context where equity and efficiency are both complementary and competing considerations suggests a wide range of parallel pursuits. Of particular note is that within the current research project all communication was done within an open complete network, thus making all communication public and inherently on an equal level. In contrast, communication often occurs within incomplete or hierarchical networks and the impact of communication and particular message types across network structures may not be universal. As an example, a network with one central

Table 14: GLS on All Iterations Including Appeals Received

	On Effort		On Median	
Variable	Coeficient	Std Error	Coeficient	Std Error
Constant	6.104	.166	6.822	.101
Period	-.026	.012	-.011	.011
Iteration	-.252	.016	-.375	.016
Effort Cost	-2.528	.146	-2.180	.145
Threat	.110	.052	.045	.051
Fairness	.036	.053	.095	.052
Coordination	.001	.048	.005	.047
Risk	-.037	.071	.067	.070
Trust	.220	.051	.432	.049

communicator who communicates individually with all other group members might lessen the impact of arguments for fairness, while the structure adds salience to trust based appeals.

In addition to the communication structure, the feedback loop from the experiment itself poses a significant avenue of future research. Within the current experiment, subjects were reported their effort choices, as well as the group's median, and finally their payoffs. While these summary statistics provided a meaningful description of the level of overall payoffs achieved by the group, they do not provide the exact distribution of efforts. As a demonstration, consider an individual who chooses an effort level 7, and is returned that the group's median was 5. That subject will be aware that the group's median was less then their effort, and thus any effort above the median was wasted. But the same individual is unaware if the true distribution of actions by the other four agents was (5, 5, 5, 5) or (7, 5, 1, 1), with the first allowing free riding down to 1 while the second requires an effort of at least 5 to maintain the median.

Individual efforts thus would not be expected to converge to a stable outcome as some level of experimentation could be beneficial. Indeed, this is what was found in the data from iteration to iteration, with medians migrating both down and up to subject experimentation. In contrast, the standard minimum game has efforts converging to the group's minimum and thus minimums are always found to be flat or decreasing across same group repetitions. Introducing additional feedback about the full range of efforts is conjectured to have the effect of eliminating this systematic experimentation, although the welfare implication of this is unclear. Both this and the role of the network structure are examined in a following work.

Finally, to the extent that this research has identified the type of appeals and strategies directly associated with higher effort levels by receiving members, there is an open question as to if this effect can be harnessed. Instead of relying on endogenous appeals that may or may not occur during communication, can subjects be equally effectively primed with an auto generated message? To the extent that it can, it would be possible to achieve the gains from communication

without the very communication it is based upon.

4 Conclusion

The median game provided a dynamic setting for testing the impact of communication within a group situation. Treatments without any communication demonstrated a significant decline in efforts and medians across periods. One of the big gains from communication was that it provided a stabilizing effect on the expectations of the subjects, with each period approached with a similar level of optimism and initially high efforts. This effect itself is somewhat surprising, because while communication provided an initial surge in group medians, the effect disipated the further from the communication. The ability to discuss the game with the new group members thus appears to have enabled subjects to convince themselves that this time it would be different, even as it would quickly become not so.

Communication allowed the groups to all identify the higher median as the desirable result, but it also opened the question of whether every member needed to exert that effort, and if not who. Strategies with everyone exerting high efforts and those with rotating free riders each worked initially, athough the more fragile rotation strategy did not suceed across iterations. Similarly, the appeals that focused on fairness and trust where the only ones that had a lasting impact on the medians achieved by the groups.

Returning to the political example introduced as a corollary for the median game earlier, these results would correspond with a prediction that, within a group, contraversially policies are unlikely to be strategically voted against. While gains exist that could be captured and evenly distributed by allowing a minority to vote against an unpopular bill, any regime attempting to implement this strategy would be unstable enough to realize the gains for long.

The efficacy of fairness and trust based appeals, and even the emergence of a complex strategy aimed at equally distributing free rider gains, highlight the importance of these considerations. In contrast, language based upon risk and coordination was found to have no long term effect. This matches findings in other studies, and suggests the need to incorporate the concept of fairness into economic decision making and any model explaining human behavior.

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