Communication in Asymmetric Group Competition over Public Goods

Jingjing Zhang*

June 15, 2009

Abstract

This paper examines whether and how communication can facilitate within-group coordination when two groups compete for a public-good prize by making costly contributions. Allowing group members to communicate before making individual decisions on whether or not to contribute their endowments leads to better coordination. To measure how much miscoordination still remains, we employ a control treatment where miscoordination is eliminated by asking individual members to reach a unanimous group decision on how much to contribute. Group level contributions are not significantly different in the two cases. Communication therefore completely solves miscoordination within groups and leads group members to act as one agent when making decisions. Content analysis of group communication reveals that after the reduction of within-group strategic uncertainty, groups were able to reach self-enforcing agreement on how much to contribute based on the essence of implementing mixed strategy equilibria and designate specific contributors following a rotation scheme across periods.

JEL Classification: C72, C92, D72, H41

Keywords: Group competition; Threshold public goods; Coordination; Cheap talk Communication; Content analysis; Experiments

---

* McMaster University, Department of Economics, 1280 Main Street West, Hamilton, ON, L8S 4M4, Canada, phone +1-905-525-9140 ext 24527, fax +1-905-521-8232, jjzhang@mcmaster.ca. This project was developed while I was at Purdue University, which provided an excellent research environment. I am particularly grateful to Timothy Cason for excellent guidance and support. I thank the National Science Foundation *(SES-0721019)* for financial support. I thank Jack Barron, Marco Casari, Stuart Mestelman, Andrew Muller, Roman Sheremeta as well as seminar participants at Purdue University for helpful comments. I benefited from presentations at 2007 Asia-Pacific Meeting of Economic Science Association in Shanghai and 2007 North American Meeting of Economic Science Association in Tucson. Any remaining errors are mine.

1. Introduction

The notion of public good provision in group competitions has important applications in political science and economics. Examples include political races, rent seeking, and R&D contests in which groups compete by expending resources (e.g., money, effort, time) to achieve power, secure governmental subsidies or capture monopoly privileges. This notion was first modeled as a voter participation game involving two or more groups by Palfrey and Rosenthal (1983, hereafter P&R). Each group member decides whether or not to cast a private vote at some cost. The group with the highest turnout gets the prize which is evenly distributed among group members. It is a winner-takes-all election which can be seen as a step-level public good game played within the groups, with the threshold determined by the turnout of the other groups. P&R prove that Nash equilibrium with positive turnout exists. And in some cases, majority group turns out less heavily than minority group.

It is difficult to study voter turnout and test the theoretical predictions in P&R using field data.[1] Experimentalists study this decision problem in a controlled environment, especially in asymmetric conflicts as they are most common in real life: military combat, political disputes, a competition between a big incumbent company and a small challenger, to name just a few. The experimental results are mixed regarding to the asymmetric size effect. Levine and Palfrey (2007) find that minority turns out more than majority, while no significant difference is reported based on two independent sessions in Schram and Sonnemans (1996a).[2] We need more experimental data to systematically examine the asymmetric-group-size effect.

This paper thus examines a more general environment of competitions between two unequal-sized groups for a monetary prize. We construct the experiment around the static voting model proposed by P&R. The individual's strategy space is restricted to a binary decision between contributing and not contributing to the group account.[3] The group with highest contributions in the account wins the prize. The prize is shared equally by the members of the winning group,

[1] In post-election surveys, reported turnout is typically significantly higher than the actual turnout in the election concerned (Himmelweit et al., 1978).

[2] Levine and Palfrey (2007) study a model with heterogeneous and privately known voting cost which leads to a unique Nash equilibrium under their parameters. The size of groups ranges from 1 voter to 34 voters. Schram and Sonnemans (1996a) compare the participation rates between a group of 6 and a group of 8 with a homogenous voting cost. Neither of the papers investigates the effect of communication.

[3] The effects of communication reported here are robust even when we make the strategy space continuous, i.e., individuals decide how much to contribute instead of whether or not to contribute. A detailed discussion can be found in Zhang (2009).

regardless of the level of their costly individual contributions to the group's success. There are two levels of conflict in the competitions. Within groups, there is an incentive to free ride on the other members' costly contributions. Between groups, there is an incentive to compete for the prize. Thus this environment departs from the classic single-group public goods game by introducing between-group conflict. It also differs from the literature on contest games where the competitors are modeled as unitary players, which rules out within-group conflict.

Moreover, often times, groups, especially those participating in research and other group-based contests, either do not know all of the other competitors or do not trust the information revealed by their competitors. Yet communication among group members is especially important when the group's respective success in solving the within-group dilemma determines the outcome of the between-group competition. This motivates us to study the effect of within-group cheap talk communication in this environment.[4] Our game closely resembles the following situation. When a small group of people, such as boards of directors, legislatures, committees, or lobbying groups need to reach a decision, communication usually takes place within subgroups before individual votes are cast. The final decision tends to favor the subgroup with more votes.

Although cheap talk communication is non-binding and costless, previous experimental studies have demonstrated that communication can nevertheless change behavior rather dramatically. For example, communication improves cooperation in public goods games (Ledyard, 1995), common pool resource games (Hackett et al., 1994), and trust games (Charness and Dufwenberg, 2006). Communication facilitates coordination and enhances efficiency in games with Pareto-ranked equilibria (Van Huyck et al., 1992). While these games allow researchers to investigate the impact of communication on strategic interactions within groups, there have been few experimental studies like ours examining how communication affects behavior when strategic interactions take place both within and between groups.

There are four aspects of our study make it novel compared to the literature.

First, the competition we study is between groups of different sizes. Very few experimental studies have examined this type of asymmetric conflict and even fewer focuses on the effect of communication in this environment.[5] Schram and Sonnemans (1996a, b) and Rapoport and Bornstein (1989) are the most related studies we are aware of. In Schram and Sonnemans

[4] All discussions about communication hereafter refer to this type of communication, unless otherwise stated.

(1996b), a voting game is played by two groups of 6 subjects. They report that communication significantly increases the participation rates of both groups. A point worthy to note here is that they use within-subject design with the same subjects play 20 periods of the game in no communication treatment followed by 5 periods in communication treatment. Thus the reported communication effect is confounded with learning effect in their design. Rapoport and Bornstein (1989) analyze the effect of communication in an asymmetric group competition for public goods between a group of 3 and a group of 5. Their results show that communication increases the participation rate in the large group but not in the small group. Their experiment is run as one shot game preventing them from observing the impact of communication on group behavior in a dynamic repeated game environment. Moreover, they do not provide game-theoretical predictions for rational individuals. Last, the prize in their experiment is a "pure" public good. That is, the value of the prize to each individual does not decrease as group size rises. In contrast to the "perfect non-rivalry" characteristic of the "pure" public good, the prize in our study is an "impure" public good. That is, the value of the prize to each individual is smaller in the large group than in the small group. In a single-group public goods game, Isaac and Walker (1988a) find that more members free ride as group size increases in the provision of an "impure" public good but not in the provision of a "pure" public good. Thus our design presents a more sever free-rider problem for the large group relative to the small group.

Second, the two studies mentioned above let subjects communicate face to face only once before they make any decisions.[6] In contrast, subjects in the communication treatment of our experiment had the ability to send free-form non-binding messages to each other through a chat window for 90 seconds at the beginning of each period. They were informed that their messages would be recorded and they would be required to follow several simple rules: be civil to each other, use no profanity and do not identify themselves. Compared to face-to-face communication, chat-room communication preserves anonymity and excludes facial expressions and other non-verbal stimuli as the chat program assigned subjects an id number in the order they sent messages. Yet chat-room communication still captures interesting social dynamics inherent in naturally-occurring communication and it has been found almost as efficient as face-to-face communication in voluntary contribution experiments (Bochet et al., 2006). Also, by enabling

[6] In Rapoport and Bornstein (1989), communication lasted for 10 minutes before subjects played the one shot game. In Schram and Sonnemans (1996b), after 5 minutes and no further communication, subjects played 5 periods of the game.

chat at the beginning of every period, we are able to observe how subjects respond to the history of the play or layout and adjust a plan across periods as they articulate them in the chat.

Third, unlike most studies in the communication literature, we not only document whether communication affects group decision making, but also explicitly reveal why and how communication has such effect by systematically employing content analysis, a well-developed methodology used commonly in many fields of social science but rarely in economics. Content analysis involves taking all the recorded chat messages, developing a coding scheme which classifies messages into different categories and then hiring multiple coders, who are trained separately and independently, to read all messages and code them into a variety of numerical codings. Thus we take the qualitative information of the chats, translate it through a coding scheme into quantitative measures and then relate those quantitative measures to the observed outcomes in the experiment. Among the few published experimental papers with content analysis and multiple coders, the majority use average percentage of agreement across categories to measure coding reliability. This is problematic because average percentage of agreement across categories is sensitive to the number of coding categories and overstates the coder agreement, since some agreement occurs by chance. For binary data, agreement by chance is at least 50%. To correct this, we use Cohen's Kappa K as the measurement for each category, which accounts for the agreement that would result if coders merely make random assignments (Krippendorf, 2004, Hayes, 2005).

Fourth, besides the communication and no communication treatments, two control treatments are conducted. In one treatment, free-riding and coordination incentives are eliminated by the design and groups have to reach unanimous decisions on how much to contribute. By comparing the outcomes of this control treatment to those in the original communication treatment, we are able to isolate how much miscoordination still remains in the original communication treatment when free riding and coordination problems are present. This goes one step further than the existing literature documenting how much free riding is reduced or coordination is reached via communication. When there is no communication, we identify a particular mixed strategy Nash equilibrium from other multiple mixed strategy equilibria as the most behaviorally relevant equilibrium, where the participation rate is higher in small groups than in large groups. Large groups win only about half of the time despite the size advantage. When we add communication, we find that communication promotes large group participation and deters small groups from participating. Large groups win around 90% of the time. This is because large groups can coordinate better when communication is allowed and are more likely to avoid free-riding and achieve the optimal group outcome. Anticipating this, small groups are discouraged from competing with large groups. More surprisingly, behavior in the communication treatment is well approximated by a different mixed strategy Nash equilibrium which models the small group and the large group each as one agent in the game. Outcomes in the communication treatment are not significantly different from the control treatment featuring unanimous group decisions.

Outcomes do not differ in another control treatment in which two individuals are competing with each other. Communication therefore completely eliminates miscoordination and free-riding within groups and leads group members to act as one agent in making decisions. Content analysis of group communication reveals that the most effective strategy for the large group is to explicitly designate specific contributors following a rotation scheme, and that group members understand the essence of mixed strategy equilibrium as they emphasize the need to be unpredictable in their contribution decisions in the chats.

In summary, this paper makes contributions to two research areas: it fills a gap in the participation game literature by testing the theory with asymmetric group competition and examining the effect of communication in which is missing in the theory; and it adds to the development of laboratory methodology for the study of rich communication which not only allow us to document how communication influences decision making, but also reveals the mechanisms that are involved.

The remainder of the paper is organized as follows. Section 2 characterizes the structure of the game. Section 3 describes the experimental design and procedures. Section 4 reports the results. Section 5 elaborates on content analysis, and section 6 concludes.

2. Theory

The experiment is structured around P&R's voting model. There are two groups A and B with n_A and n_B members respectively; each member of Group A and Group B receives an endowment of size $e > 0$ and then he or she must decide independently and anonymously whether to keep the endowment or contribute all of it toward the group's benefits. The group with the most contributors wins the game and receives a prize R, while the losing group gets no prize. If the numbers of contributors are equal among the two groups, each group gets half of the prize. The contributions are non refundable. The public-good prize is then shared equally among the group members irrespective of whether or not each group member made a contribution. Thus if group G $(G = A, B)$ is the winning group, each member in the winning group is rewarded $r_G = \frac{R}{n_G}$. In addition to the share of the group's benefit, each member in each group earns any endowment that is not contributed to the group. The ordinal relation between the payoff parameters for an individual player in the model satisfies the inequality $r_G > \frac{r_G}{2} + e$, where e is the cost of the contribution (equal to the endowment), r_G is the utility of a win and $\frac{r_G}{2}$ is the utility of a tie. Given the inequality, a payoff maximizing player should contribute when his or her contribution is critical to winning the game. The inequality can also be reduced to $\frac{r_G}{2} > e$. This ensures that a payoff maximizing player has an incentive to contribute when his or her contribution is critical to tying the game. There is no pure strategy Nash equilibrium for this game.

P&R show that this game has two classes of mixed strategy Nash equilibria:

1) Mixed-pure strategy equilibria where all members of one group contribute with a positive probability and members of the other group are divided into subgroups of contributors and non-contributors. P&R consider these equilibria implausible.[7] This paper thus focuses on the second class of Nash equilibria.

2) Totally mixed strategy quasi-symmetric equilibria (hereafter, mixed strategy equilibria) where all members in the small group contribute with the same probability p and all members in the large group contribute with the same probability q.

The mixed strategy equilibria are determined by equating the expected payoff from contributing to the expected payoff from not contributing so that no one can increase or decrease his or her payoff by changing the contribution decisions unilaterally. Specifically, for any player i in Group A to be willing to randomize, that is, he or she is indifferent to contribute or not, it must be the case that: $EV_i^A(Contribute) - EV_i^A(Not\ to\ Contribute) = 0$, which is a function of two unknowns p, q and can be simplified to $\frac{(P_1+P_2)}{2} = \frac{e}{r_A}$ where P_1 is the probability that the contribution of player i will change a losing situation into a tie and P_2 is probability that the contribution of player i will break a tie and lead to a win. Thus if $\frac{(P_1+P_2)}{2} = \frac{e}{r_A}$, i.e., the

[7] The mixed-pure strategy equilibria involve coordination that is especially implausible when within-group communication is not allowed or is not enforceable.

probability of being critical exceeds the cost to benefit ratio, player i should choose to contribute. Similarly, we can get another function of p, q for players in Group B such that $EV_i^B(Contribute) - EV_i^B(Not\ to\ Contribute) = 0$. With two functions and two unknowns, we can analytically solve for the mixed strategy equilibria.

3. Experimental Design and Procedures

Our experiment consists of 35 statistically independent competitions between two groups with a total of 184 subjects across four different treatments, as summarized in Table 1.

Table 1: Summary of Experimental Design

Treatment	# of Competitions	# of subjects in each competition	Communication	Decision	Free-riding Incentives
3x5 NC	6	8	No	Individual	Yes
3x5 C	6	8	Yes	Individual	Yes
1x1 G	7	8	Yes	Group	No
1x1 I	16	2	No	Individual	No

Treatment 3x5 NC: A group of 3 members and a group of 5 members compete for a prize of $R = 18$ tokens in the game.[8] Each member is endowed with one token and decides whether to contribute the token to the group account or keep it for him or herself. The group with more tokens in the group account wins the prize, which is shared equally among the contributors and non-contributors. When there is a tie, the prize is split between the two groups. There is an incentive to free ride because only the contributors bear the cost of contribution. No form of communication is permitted.

Treatment 3x5 C: This treatment adds to treatment 3x5 NC, it allows group members the opportunity to communicate with one another at the beginning of each period. Group members have 90 seconds to send free-form messages to each other through a chat window before deciding whether to contribute the endowed token. Communication is non-binding—group

[8] The asymmetric competition is between a small group of three members and a large group of five members. With at least three members, coalitions can be formed and some kind of organization is present. Also, in treatment 1x1 G, we ask groups to reach a unanimous decision. The odd-numbered group makes it easier since it admits the possibility of a decisive majority vote to reach a group decision. Without loss of generality, individual endowments are set to be unity. That is, the un-refundable cost of contribution equals one.

members (who make their contribution decisions privately and anonymously) are not constrained to keep any agreement that they may have reached during the chat period.

Treatment 1x1 G: This treatment differs from treatment 3x5 NC and 3x5 C in the way that tokens are endowed. Tokens are distributed collectively, to the entire group, instead of separately to each individual. The large (small) group decides how many of the 5 (3) endowed tokens to contribute. The group with higher contributions wins a prize. Group members share the prize and the retained endowment equally. There is no incentive to free ride because the cost of the contributions is born by every group member. Again, non-binding, within-group communication is allowed for 90 seconds before group members make the actual decisions simultaneously and anonymously in the beginning of each period. The unanimous decision selected by all members in the group is implemented as the group decision. Each period, each group has up to 10 rounds to reach a unanimous decision. If a unanimous decision is not reached by the 10^{th} round, the choice of allocating "0" tokens to the group account is automatically implemented as the "group decision". Communication is only permitted for the first round at the beginning of each period.

Treatment 1x1 I: Two individuals rather than groups compete for a prize of 18 tokens in this treatment. One individual is endowed with 3 tokens and the other is endowed with 5 tokens. Each of them is asked to decide how many tokens to contribute. The individual with higher contributions wins the prize. Any tokens that are not contributed are added to the individual's benefits. The intra-group level of conflict is eliminated in this game. No communication is permitted in this treatment.

The effectiveness of communication in solving miscoordination and free-riding problems within groups is examined in the pair-wise comparisons of the first three treatments: 3x5 NC, 3x5 C and 1x1 G. More specifically, treatment 1x1 G should be equivalent to the case where communication completely eliminates miscoordination and free-riding. The difference between treatment 3x5 NC and treatment 3x5 C allows us to measure the degree to which miscoordination and free-riding is reduced by communication, while the difference between treatment 3x5 C and treatment 1x1 G conveys the extent to which miscoordination and free-riding still remain. The comparison between treatment 1x1 G and treatment 1x1 I indicates whether individual choices differ from group decisions in this paradigm. This contributes to the experimental literature concerned with the general differences between the decisions of individuals and groups. [9]

All subjects were recruited from a wide cross-section of undergraduates at Purdue University. A computerized interface using the software z-tree was adopted to implement the experimental environment (Fischbacher, 2007). Instructions were read aloud while subjects followed along on their own copy. Subjects were given a quiz on the computer to verify their understanding of the instructions before the games were played. For each correct answer, they earned 50 cents. More than 90% of the quiz questions were answered correctly in all sessions.

In treatment 3x5 NC, treatment 3x5 C and treatment 1x1 G, 16 subjects were randomly and anonymously placed into either a 3 or 5-person group. Each 3-person group was then paired with one of the 5-person groups to form a single session of 8 subjects. Group compositions remained the same for the 10 periods. Subjects were informed of their own group decision, the decision of the opponent group, their individual earnings for each period and the cumulative individual earnings at the end of each period. Similarly, in treatment 1x1 I, 16 subjects were randomly split into 8 sessions and assigned to two roles: Person A (endowed with 3 tokens) or Person B (endowed with 5 tokens). The subjects' roles were fixed for the10 periods Decisions made by the two subjects as well as subjects' individual period and cumulative earnings were reported to subjects at the end of each period.

Subjects' earnings were designated in "experimental tokens". They were paid for all periods, and their cumulative token balance was converted to U.S. dollars at a rate of 4 tokens to one dollar for the group treatment and 20 tokens to one dollar for the individual treatment. Sessions with communication typically lasted for 60-75 minutes including instructions, while sessions without communication proceeded more quickly, some as short as 35 minutes. The average per-person earnings are $15 for short sessions and $20 for long sessions.

4. Predictions, Hypotheses and Results

We conducted all sessions with a prize of 18 tokens. This parameter choice generates relatively distinct types of equilibrium. We refer to one equilibrium as Type H to reflect the

[9] A detailed literature review of studies on the general differences in the decisions of individuals and groups is provided in section 4.

higher contribution rates from both groups relative to the other Type L equilibrium. Table 2 presents the theoretical predictions and data in treatment 3x5 NC pooling across sessions.

Table 2: Theoretical predictions and data in treatment 3x5 NC

	Individual Contr. Rate		**P(large wins)**	**P(large ties)**	**P(large loses)**
	Small	**Large**			
3x5 Game Type L Eq.	0.48	0.03	2.0%	17.3%	80.7%
3x5 Game Type H Eq.	0.91	0.74	67.1%	23.4%	9.5%
3x5 NC data	0.62	0.52	50.0%	30.0%	20.0%

As Table 2 shows, in both equilibria, the small group contributes at higher rate than the large group. The large group loses most of the time (80.7%) in Type L equilibria because members of the large group rarely contribute. In Type H equilibria, the groups compete aggressively with individual contribution rates of 0.91 in the small group and 0.74 in the large group. Despite the size advantage, the large group is able to win the competition about 67.1% of the time. The small group still has a 9.5% chance of winning.

The theoretical prediction highlights the fact that small group members contribute more often than large group members. This leads to the following hypothesis.

Hypothesis 1: Without communication (treatment 3x5 NC), the relative individual contribution rate is higher in the small group than in the large group.

Result 1: Hypothesis 1 is partially supported.

The data in treatment 3x5 NC are different from point predictions from both types of equilibrium (Table 2). But if we focus on the contribution rates and the outcomes of the competition, the data are much closer to the type H equilibrium than the type L equilibrium as large groups never contributed 0 tokens. The individual contribution rates are significantly lower than the Nash equilibrium in both groups (Wilcoxon signed-rank test, p-value=0.0273 for small groups, p-value= 0.0269 for large groups).[10] The mean individual contribution rate is higher in the small group than in the large group, but the difference is not statistically significant though

[10] This is somewhat consistent with Levin and Palfrey (2007) which document that the turnout rates for the smallest electorate with one voter in a group and two in the other group are lower than predicted by theory. Yet they also reported that when turnout rates for larger electorates with 9 voters in total (either 3 in one group and 6 in the other or 4 in one group and 5 in the other) are approximately equal to the Nash equilibrium value, whereas turnout rates for the largest electorates with 27 or 51 voters in total are higher than predicted by theory.

(Mann-Whitney test, n=m=6, p-value = 0.6291)[11]. The large group Groups were competing aggressively. Averaging across six sessions, the large group only wins the game half of the time and ties the game 20% of the time.

To form a set of testable hypotheses for the communication treatment, we consider the extreme benchmark where within-group communication completely eliminates the free-riding incentives present in group competition. In this case, members of each group are able to reach an agreement to coordinate their individual choices and act as a single agent and also believe that members of the other group behave in the similar fashion. This implies a restructuring of the group competition into a two-player nonzero-sum game (hereafter, 1x1 game; we refer to the group competition as 3x5 game corresponding to 1x1 game.). A small player endowed with 3 tokens and a large player endowed with 5 tokens decide how many tokens out of their endowments to contribute to a group account. Contributions are not refundable. The player with higher contribution wins a prize of 18 tokens and the player who loses gets no prize. When there is a tie, each player gets 9 tokens. Treatment 1x1 I and treatment 1x1 G are designed based on the 1x1 game. The key difference between these two treatments is whether the two players in the game are two individuals (1x1 I) or two groups of 3 and 5 members each (1x1 G).

Given the payoff structure of the 1x1 game, it is straightforward to solve the mixed strategy Nash equilibria for the 1x1 game. Figure 2 compares the predicted probability mass function of group level contributions in the 3x5 game and in the 1x1 game. [12]

The white bars in Figure 2 display the predictions in the 3x5 game while the black bars represent the predictions in the 1x1 game. In the 1x1 game, the small player should abstain from the competition about 78% of the time. This is quite different from the prediction in the 3x5 game where the most frequent choice for the small group is to contribute 3 tokens 75% of the time. On the other hand, the large player in the 1x1 game should contribute 4 tokens 78% of the time and either 1 token or 3 tokens the rest of the time. By contrast, in the 3x5 game, the distribution of contributions in the large group is much more dispersed. Note that the large group

[11] The parametric t test also indicates no significant difference (two-sided, *p*-value=0.3101). The fact that the turnout rate is lower in small groups, but lack of statistical significance is consistent with Schram and Sonnemans (2001a).

[12] The proof of the Nash equilibria can be found in the appendix I. In the 1x1 game, there are two sets of mixed strategy Nash equilibria for the small player. They are very similar and behaviorally indistinguishable. We only present one of them in figure 2. The mixed strategy Nash equilibrium for the large player is unique as shown in figure 2. The frequency of contributions in the 3x5 game is calculated using the type H equilibrium value. As we documented earlier, the data are completely at odds with the type L equilibrium. Thus we focus on examining the type H equilibrium here.

is expected to contribute 5 tokens about 22% of the time, yet, only four tokens are needed for the large group to beat the small group. This highlights the fact that miscoordination within the large group causes inefficiency.

Figure 2: Theoretical comparison between the 3x5 Game and 1x1 Game

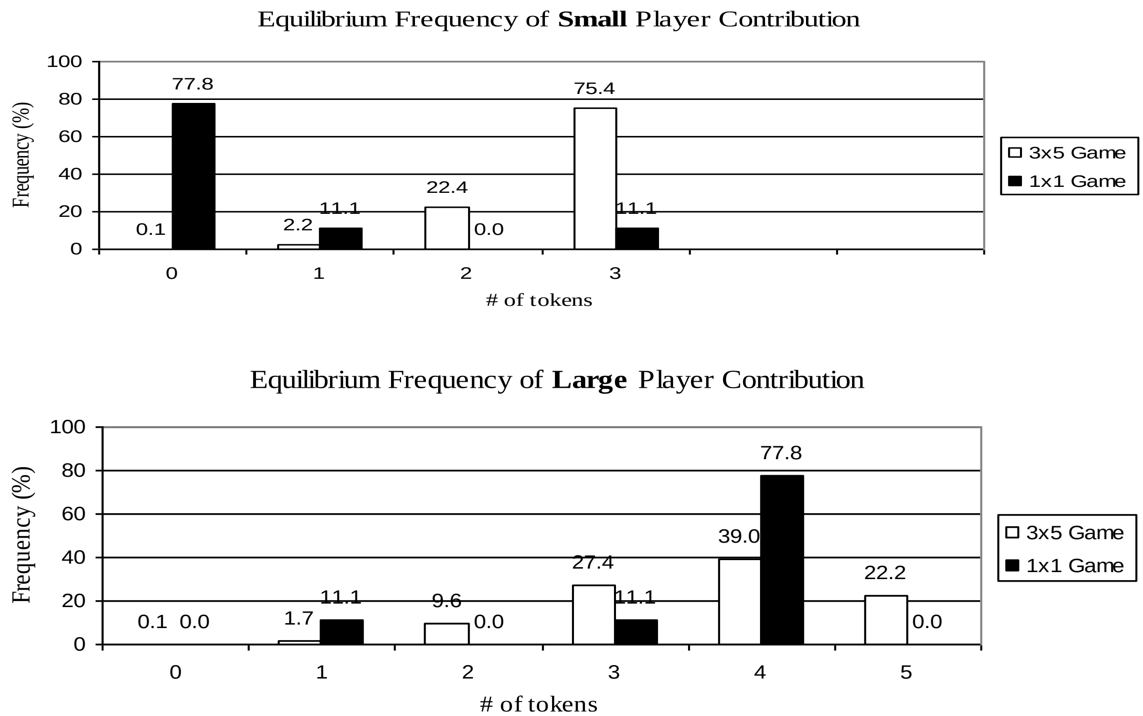


Table 3 presents the predicted average group contributions, average group earnings and the probability the large group wins, ties and loses the game in the 3x5 game and the 1x1 game along with the data we observed in four treatments. Both the Kruskal Wallis test on the equality of medians and the F test on the equality of means indicate that there is a statistically significant difference across all four treatments in both groups.

Recall that the 1x1 game is structured as the extreme benchmark where within-group communication completely eliminates the free-riding and miscoordination problems. Based on the theoretical comparison between the 3x5 game and the 1x1 game, we form the following hypotheses:

Hypothesis 2: Within-group communication (treatment 3x5 C) helps to reduce free-riding and miscoordination. The small group abstains from contributing quite often and the large group is able to win the game most of the time. This leads to relatively higher earnings for the large group and lower earnings for the small group compared to the no communication case (treatment 3x5 NC).

Result 2: Hypothesis 2 is supported.

Table 3: Theoretical predictions and observed data

	Average Group Contribution		Average Group Earnings		P(large wins)	P(large ties)	P(large loses)
	Small	Large	Small	Large			
3x5 Game Prediction	2.74	3.68	6.78	15.52	67.1%	9.5%	23.4%
1x1 Game Prediction	0.44	3.56	3.00	19.00	96.3%	1.2%	2.5%
Data: 3X5 NC	1.87	2.62	7.43	14.08	50.0%	30.0%	20.0%
Data: 3x5 C	1.10	3.77	3.10	18.03	91.7%	5.0%	3.3%
Data: 1x1 G	0.77	3.54	3.77	17.91	90.0%	2.9%	7.1%
Data: 1X1 I	1.26	3.51	3.54	17.69	83.8%	12.5%	3.8%
***p*-value:Kruskal Wallis**	0.0001	0.0001	0.0001	0.0001	0.0001	-	-
***p*-value: F test**	0.0000	0.0000	0.0000	0.0000	0.0000	-	-

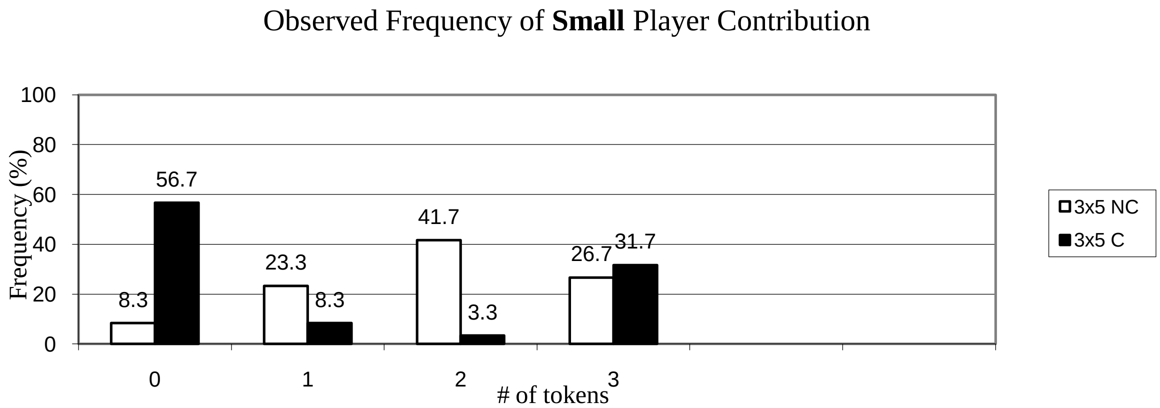
As shown in Table 3, the probability the large group wins the game increases from 50.0% to 91.67% when within-group communication is allowed. Figure 3 reports the observed distributions of contributions in treatment 3x5 NC and treatment 3x5 C. When we permit communication, the most conservative Mann-Whitney test, which takes each session as independent data indicates that: 1) Average group contributions decrease significantly in small groups (n=m=6; p = 0.0534) and increase significantly in large groups (n=m=6; p-value= 0.0038). 2) Average group earnings decrease significantly in small groups (n=m=6; p-value= 0.0039) and increase significantly in large groups (n=m=6; p-value= 0.0039). 3) There is a statistically significant increase in the probability that large groups win the game (n=m=6; p-value= 0.0033).

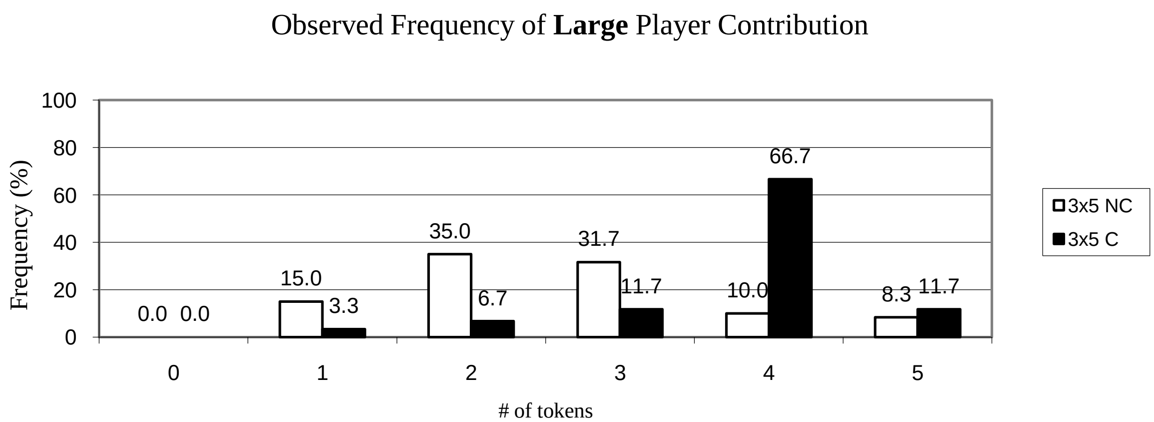
Our extreme benchmark captures the idea that pre-play within-group communication results in a restructuring of the game with members of each group coordinating their individual strategies and acting as a single group. The next hypothesis follows.

Hypothesis 3: Within-group communication leads group members to act as one agent when making decisions. Thus contribution decisions made by groups in treatment 3x5 C are not different from those made in treatment 1x1 G.

Result 3: Hypothesis 3 is supported.

Figure 3: Data comparison between 3x5 NC sessions and 3x5 C sessions

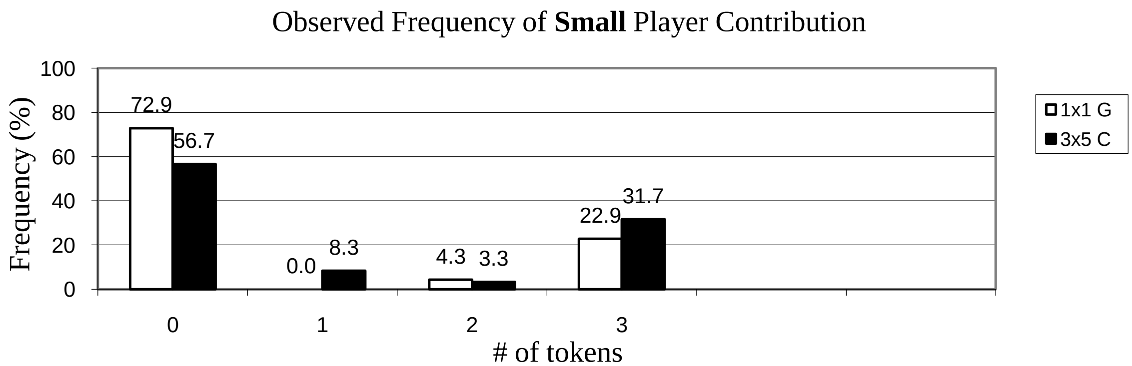


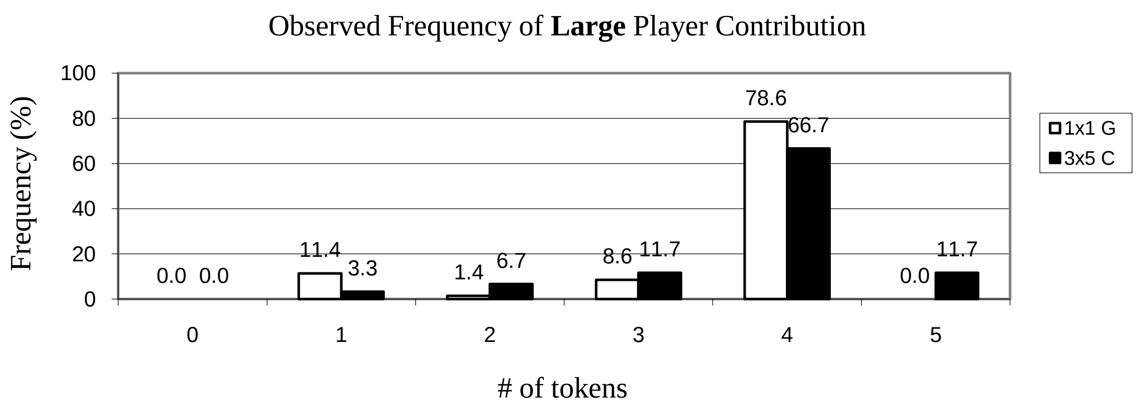


Mann-Whitney tests report no significant difference in average group contributions, average group earnings in both types of groups and the probability that the large group wins the competition.[13] Recall that in treatment 1x1 G, the incentive to free-ride is removed by the structure of the game. Also, the observed distributions of contributions in both groups in treatment 1x1 G and treatment 3x5 C line up closely (Figure 4). Thus this result tells us that group level contributions are not significantly different in the presence or absence of the free-riding incentives as long as groups have the opportunity to communicate.

[13] Mann-Whitney tests, n=7, m=6, *p*-value=0.2201 for small group average contributions, *p*-value=0.3807 for large group average contributions, *p*-value=0.2833 for small group average earnings, *p*-value=0.8277 for large group average earnings, *p*-value=0.8195 for the probability that the large group wins the competition. All the results hold if we use t-tests here.

Figure 4: Data comparison between 1x1 G sessions and 3x5 C sessions





The comparison between treatment 1x1 I and treatment 1x1 G allows us to examine whether groups behave differently from individuals.

Literature in social psychology and economics has provided compelling evidence that group behavior is different from individual behavior.[14] Concerned the performance of groups in inter-group competitions, psychologists report that inter-group relations tend to be highly competitive

[14] For example, in the games with no strategic interactions, groups are just as quick as individuals to reach decisions and require no more information than the individuals before coming to a decision (Blinder and Morgan, 2005); groups gain higher expected payoffs at a significant lower risk in investment games (Rockenbach, et al., 2007) or at a constant level of risk in lottery choices (Sutter, 2007). In the strategically interactive games, groups demand more in the role of proposers and accept lower offers in the role of responders in the ultimatum game (Bornstein and Yaniv, 1998); groups exit the centipede game earlier (Bornstein, et al. 2004); groups exert less efforts as second movers in a gift-exchange game (Kocher and Sutter, 2007); groups play more strategically in signaling game (Cooper and Kagel, 2005); groups perform better in terms of payoffs in beauty-contest game (Kocher and Sutter, 2005). In the trust game, Cox (2002) observes that groups return less in the role of responders but reports no differences in the role of senders; By contrast, Kugler et al. (2007) find that returns of groups and individuals are not significantly different but groups send smaller amounts than individuals. Experimentalists also report inconsistent results in the dictator game. Cason and Mui (1997) find groups behave more altruistically than individuals whereas Luhan, Kocher and Sutter (2007) show that group decisions are more selfish and less altruistic than individual decisions.

as compared to individual relations under the same functional conditions (Tajfel, 1982; McCallum et al., 1985; Insko et al., 1987). Evidence supporting this observation has also been reported by economists. Cox and Hayne (2006) find that groups bid more competitively than individuals when they have more information about the value of the auctioned item, leading to more overbidding and less profit than individuals in a common value auction game.

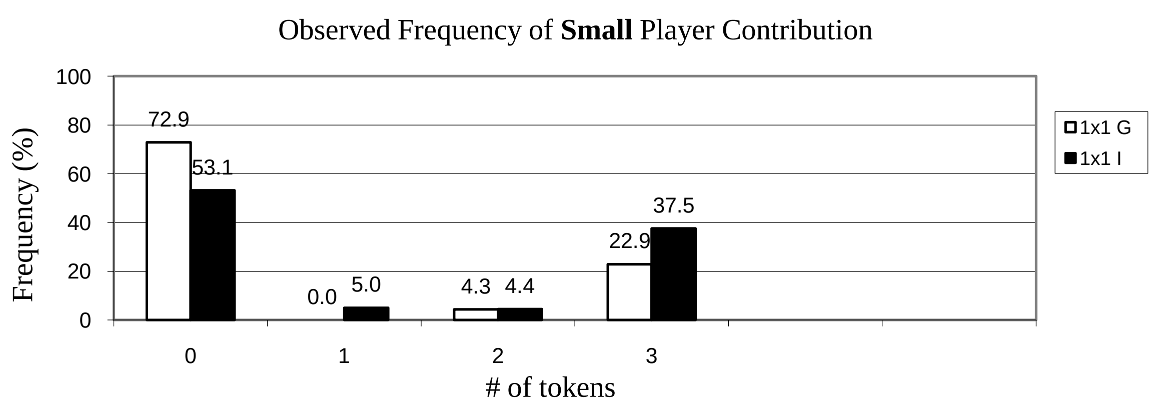
Based on these findings, we form the last hypothesis:

Hypothesis 5: Contribution decisions made by groups in treatment 1x1 G are different from those made by individuals in treatment 1x1 I since groups perceive the situation more competitively than individuals.

Result 5: Hypothesis 5 is not supported.

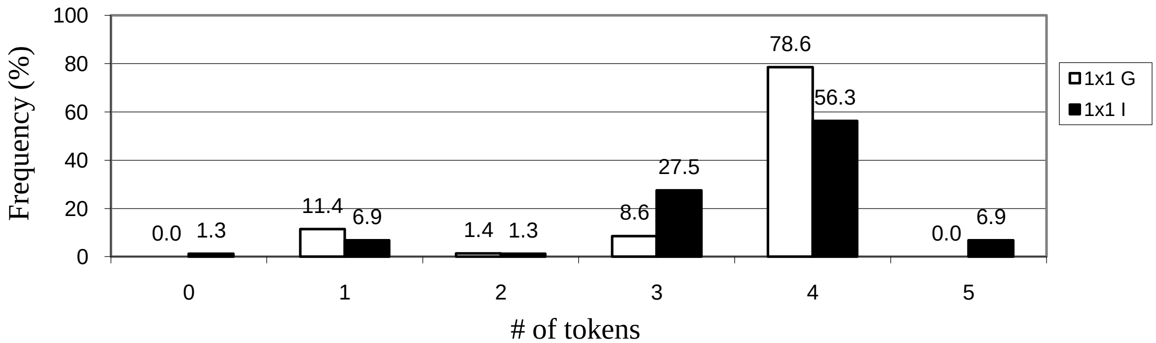
On average, small groups in treatment 1x1 G contributed significantly more than the counterpart individuals in treatment 1x1 I (Mann-Whitney test, n=16, m=7, *p*-value= 0.0472) while no difference was observed in large group contributions (Mann-Whitney test, n=16, m=7, *p*-value= 0.7868). The difference in earnings in neither groups is significant (Mann-Whitney, n=16, m=7, *p*-value= 0.7125 for small group earnings, *p*-value= 0.8405 for large group earnings) and nor is the outcome of the game (*p*-value= 0.4470 for the probability that the large group wins).[15] Small groups behaved more aggressively in treatment 1x1 G than their individual counterparts in treatment 1x1 I. The comparison of the frequencies of contribution in the two treatments (Figure 5) also supports this conclusion.

Figure 5: Data comparison between 1x1 G sessions and 1x1 I sessions



[15] Results hold if we use parametric t tests here.

Observed Frequency of **Large** Player Contribution



5. Content Analysis

At this point we know that communication reduces free-riding behavior and leads group members to act as one agent in making decisions. This brings us to the heart of the matter: what kinds of messages are linked to this effect? We use content analysis to answer this question.

We used the following procedure to systematically quantify the recorded messages. First, we randomly selected a test sample from the pilot sessions to develop a coding scheme which classifies messages into different categories. Second, we employed two undergraduate coders, trained separately, to independently read and classify all messages according to the coding scheme. They were not informed about any of the hypotheses of the study.[16] We implemented binary coding—a message is coded as a 1 if it is deemed to contain the relevant category of content and 0 otherwise. Each message can be coded under as many or few categories as the coders deem appropriate. Category1 has six sub-categories. Coders are free to code a message under as many or few sub-categories as they desire.

Cohen's Kappa K is used to measure coders' agreement which follows the conceptual formula:

Chance-corrected agreement = $\frac{P_a - P_c}{1 - P_c}$

where P_a is the proportion of messages that both coders agree on and P_c is the proportion of agreements expected by chance. The denominator quantifies the difference between perfect agreement and expected chance agreement. The numerator quantifies the difference between the observed agreement and the expected chance agreement. Thus, this measure quantifies agreement as the proportion of the difference attained between perfect agreement and chance

[16] The instructions for coders are attached in appendix III.

agreement. If $P_a = P_c$ agreement and therefore reliability equals zero. Reliability is greater than zero only if the proportion of agreements exceeds the proportion of agreement expected by chance (i.e., $P_a > P_c$). It is possible for reliability to be less than zero if the coders agree less than expected by chance (i.e., $P_a < P_c$). In that case, reliability should be treated as zero. For reliability of quantitative measurements, 0.7 is generally acceptable (Neuendorf, 2005). But for chance corrected measures of agreement, we should be more lenient in our definition of acceptability because correction for chance sometimes makes it nearly impossible to achieve agreement above 0.7 (Hayes, 2005). The general conventions regarding the interpretation of other values are: $0 < K \leq 0.20$ is poor agreement, $0.20 < K \leq 0.40$ is fair agreement, $0.40 < K \leq 0.60$ is moderate agreement, $0.60 < K \leq 0.80$ is good agreement and $K > 0.80$ is very good agreement (Neuendorf, 2005).For the vast majority of our main categories, K indicates a good agreement. Moderate agreements are found in a few of the categories.[17]

Table 5 reports the frequency of codings under each category in the two treatments. All discussions of codings hereafter are based on the average of the two independent codings, unless otherwise stated. It also reports the ratios of coding frequencies between small and large groups across the two treatments as well as the ratio of coding frequencies between the two treatments.

The most frequently coded category is category 1 in both treatments. It codes messages that coordinate individual choices by some specified decision rules, occurring for more than 35% of the time in both types of groups. The six sub-categories under category 1 help us to identify the different strategies groups adopt to coordinate their members' behavior. In treatment 1x1 G, the large group used majority rule to reach the unanimous decision as shown in the following messages: "group strategy proposal: if our decision is not agreed on the first round, we do NOT want to get caught with our pants down voting "0" because of disagreement…. so if somebody disagrees, go to the most voted number." Thus, we observe more messages falling into category 1d (Agree with group members' proposals on the contribution level) and category 1f (Push for consensus on the contribution level) in treatment 1x1 G relative to treatment 3x5 C. On the other hand, in treatment 3x5 C, the large groups came up with a rotation strategy where the member with the same ID number as the period number was designated as the non-contributor in that period. The following messages were sent in a large group: "if one of us holds individual we will

[17] Table A1 in appendix II displays the coding scheme along with the reliability indexes Cohen's Kappa K for the two treatments.

maximize what we can make cause they can't get more than 3, take turns according to rounds and don't be selfish; member 1 hold everyone else group, we will rotate to 2 next time and so on". This strategy was followed from period 1 to period 4. In period 5 some new ideas came into the large group: "hey…for this round only 1 person should put it into the group account…everyone else the other…coz they are always 0". The large group formed the strategy of contributing 1 token as a group instead of contributing 4 to optimize group earnings. And they actually rotated to be the non-contributor to equalize individual earnings. By contrast, the small group rarely rotated or explicitly designated contributors or non-contributors. The small group members' strategy was typically to contribute either everything (57% of the time) or nothing (32% of the time).

Another common strategy adopted by both types of groups is to fool the other group across periods. A typical quote from the large group in treatment 3x5 C is "We need to bet 4 for several rounds to make them confident we won't budge, and then while they are betting zero, we'll bet 1 for 1 round and get lots of earnings, and then go back to betting 4. So let's start off doing 4 for the first several rounds. We need to get them to establish a solid few sets of zeros." A quote from the small group is "that's why if we are going to do it [everyone contributes] we have to be completely random." These messages fall into category 2. This indicates that subjects understand the essence of mixed strategy equilibrium and try to implement their decisions in an unpredictable way across periods.

To decide the contribution level, groups spent a fair amount of time on reasoning from the other group's point of view in both treatments. For example, in treatment 1x1 G, after observing a previous "1 token" choice of the small group, one member in the large group said "ok they are going for a 0 now sure, let us go for 1" Another member responded: "Remember!: they are thinking the exact same thing we are, 4 is our only guarantee. They [small] think we think they're gonna put 0, so they'll try 3, let's just stick with 4." Thus category 3 reveals the strategic sophistication of the subjects. It provides evidence for the Level-K thinking model (Crawford and Iriberri, 2007).

Discussions about monetary benefits were coded under category 4 and 5. For the majority of the time, group members focused on their own group benefits. They specified payoffs associated with all potential strategies. For example, messages sent out by the members of the large group in treatment 1x1 G: "so if do 1 and win we get 4.4, if we 4 & win we get 3.8 & if we do 1 & lose we get .6”; “if we choose 3 and win, we get an extra nickel, if we choose 3 and tie, we lose 80 cents.” This suggests that reinforcement learning model which assumes subjects know absolutely nothing about the forgone or historical payoffs from strategies they did not choose is a poor model by itself of group learning (Erev, I. and Roth, A., 1998).

Table 5: Comparison of Frequencies across Treatments and across Group types[18]

Code	Coding Category Description	1X1 G		3x5 C	
		Large	**Small**	**Large**	**Small**
1	Coordination on the contribution level for the current period	45%	36%	56%	46%
1a	Propose a specific contribution level	8%	9%	4%	14%
1b	Ask for the opinions of other group members (should not specifically refer to a contribution level)	2%	2%	4%	5%
1c	Disagree with group members' proposals	4%	2%	1%	3%
1d	Agree with group members' proposals on the contribution level	29%	20%	17%	22%
1e	Propose to rotate or explicitly designate contributors and (or) non-contributors	N/A	N/A	29%	1%
1f	Push for consensus on the contribution level	3%	3%	1%	2%
2	Appeal to fool the other group across periods (be unpredictable, to trick others, pretend to be predictable)	7%	9%	8%	8%
3	Make choices by reasoning from the other group's point of view	8%	12%	4%	15%
4	Discussion about benefits for own group	9%	8%	6%	6%
5	Discussion about benefits for the other group	2%	2%	1%	2%
6	Reference to the previous choices of the other group	3%	5%	1%	6%
7	Reference to the previous choices of own group	3%	4%	7%	4%
8	Reference about the size asymmetry	5%	2%	4%	2%
9	Appeal to play safe	2%	4%	3%	5%
10	Appeal to take risks	1%	0%	1%	1%
11	Other Messages	23%	31%	14%	16%
Number of Observations		1559	1005	951	712

Moreover, the reference to the previous choices made by the other group suggests that subjects update beliefs about what other group would do based on history and use those beliefs to determine which strategies are the best. Typical quotes in the large group falling into this

[18] In treatment 1x1 G, category 1 refers to "Propose how many tokens to contribute as a group" while in treatment 3x5 C, it refers to "Propose how many people contribute to the group account and/or keep to the individual account". Subcategory 1e and subcategory 1f only apply to treatment 3x5 C. Messages that appeal to play safe under category 10 are associated with contributing 0 tokens in the small group and contributing 4 tokens in the large group. By contrast, messages which appeal to take risks under category 10 mean to increase contributions in the small group and decrease contributions in the large group.

category are: “they never did 3 or 0 three times a row before.”; “last time we did 1 they tried beating us for like 5 rounds after.” A Belief-based learning model seems to better capture the data, given this direct evidence that players look back at what other players have done previously and also give weights to forgone payoffs from un-chosen strategies (Crawford, 1995).

Groups referred to their own choices in the previous rounds much more often in treatment 1x1 G than in treatment 3x5 C. They either cheered for their success, “our group rocks” or regretted the choices, “Damn it, I told you guys 1 wouldn’t work, stick with 4.” This reflects strong group identity in treatment 1x1 G due to the absence of the free-riding incentive.

Just because a category of message is used frequently doesn’t necessarily mean it accomplishes much. Table 6 reports the results of robit regressions on the contribution decisions made in the large group across treatments. The dependent variable is whether or not the large group contributed 4 tokens in a given period. Table 7 reports the results of the probit regressions on the contribution decisions made in the small group across treatments. The dependent variable is whether or not the small group contributed 0 tokens in a given period (Model 1) or whether or not the small group contributed 3 tokens in a given period (Model 2). The independent variables are the numbers of messages coded under each category in a given period. Specifically, the value of the codings is treated as 1 if two coders agreed that a message belongs to a given category, 0 if the two coders agreed that a message does not belong to a given category, and 0.5 if two coders disagreed with each other. We also include three lag dummies to control for any effects from observing last period outcome. They are whether large group contributed 4 tokens in the last period, whether small group contributed 3 tokens in the last period and whether small group contributed 0 tokens in the last period. Also, messages in category 1e “Propose to rotate or explicitly designate contributors and (or) non-contributors” and category 2 “Appeal to fool the other group across periods” may affect contribution decisions over a few periods as they are often referring to multi-period strategies. We thus include up to 3-period lag of relevant variables in regressions. All models include dummies to capture the differences among sessions and a time trend variable (expressed as 1/period) as well. Standard errors are corrected for clustering at the group level.

Table 6: Probit regressions on large group contribution decisions

	Dependent variables: **1= the large group contributed 4 tokens in a given period, 0= otherwise**	**Treatment 1x1 G**	**Treatment 3x5 C**
	Independent variables: *(coding categories)*		
1a	Propose how many people to contribute to the group account	-0.031	0.185*
		(0.071)	(0.110)
1b	Ask for the opinions of other group members		-0.150*
			(0.078)
1c	Disagree with group members' proposals	-0.052**	-0.102**
		(0.024)	(0.044)
1d	Agree with group members' proposals on the contribution level	-0.017	-0.058
		(0.034)	(0.055)
1e	Propose to rotate or explicitly designate contributors		0.067***
			(0.016)
1f	Push for consensus on the contribution level	0.188**	-0.253*
		(0.078)	(0.135)
2	Appeal to fool the other group across periods (e.g., be unpredictable)	0.027**	0.026
		(0.014)	(0.042)
3	Make choices by reasoning from the other group's point of view	-0.112	0.041
		(0.099)	(0.079)
4	Discussion about benefits for own group	0.034	-0.051
		(0.042)	(0.048)
6	Reference to previous choices for the other group	0.011	-0.116**
		(0.032)	(0.056)
7	Reference to the previous choices of own group	0.104	-0.030
		(0.147)	(0.040)
8	Reference about the size asymmetry	-0.050	0.329***
		(0.068)	(0.080)
9	Reference to the game rules	-0.007	
		(0.011)	
10	Appeal to play safe	0.116	0.386***
		(0.091)	(0.086)
	1/period	-0.250	-1.706
		(0.748)	(2.117)
	Lag1 dummy (1 if large group contributed 4 tokens in the last period)		-0.274***
		0.244	(0.020)
	Lag1 dummy (1 if small group contributed 3 tokens in the last period)	(0.286)	0.172
		-0.070	(0.119)
	Lag1 dummy (1 if small group contributed 0 tokens in the last period)	(0.108)	0.317
		0.001	(0.208)
	Lag 1: Propose to rotate or explicitly designate contributors	(0.114)	0.018
			(0.013)
	Lag 1: Appeal to fool the other group across periods		-0.080**
		0.004	(0.032)
	Lag 2: Propose to rotate or explicitly designate contributors	(0.009)	0.008
			(0.016)
	Lag 2: Appeal to fool the other group across periods		-0.148***
		-0.007	(0.035)
	Lag 3: Propose to rotate or explicitly designate contributors	(0.010)	0.038**
			(0.019)
	Lag 3: Appeal to fool the other group across periods	0.022	-0.065***
		(0.014)	(0.019)
	Number of observations	66.00	68.00
	Log likelihood	-19.82	-20.86

Notes: marginal effects; Robust standard errors in parentheses, clusters on groups.
*Statistical significance *** p<0.01, ** p<0.05, * p<0.1.*

Now let us discuss the marginal effects of the messages exchanged upon the large groups' contribution decisions of 4 tokens. In treatment 1x1 G, communication significantly improves coordination in two ways: through communication, group members are able to push for a consensus of contributing 4 tokens (category 1f); also, communication enables them to coordinate across periods and strategize unpredictable decisions. This in turn reduces free-riding behavior that is due to the uncertainty about other group members' intentions across periods (category 2). In treatment 3x5 coordination through the rotation strategy (category 1e) is effective in reducing free-riding and making groups act as one agent. Messages about being random to fool the other group across periods (category 2) significantly affect group decisions up to 3 periods. One typical quote from the large group can explain the positive effect in the current period and the negative effects in lag periods: "let us do 4 for 2 to 3 rounds and then drop to 1."

Table 7 reports the marginal effects of messages on the small groups' contributions of 0 tokens and 3 tokens. We observe similar effects of category 2 in small group decisions. Messages about making choices by reasoning from the other group's point of view (category 3) make the small group to contribute 0 tokens less often and 3 tokens more often. This is clear when we look at a typical message under this category: "they [large group] will get greedy and go down soon after a few 4." Another interesting finding from lag variables is that small groups understand that large groups are trying to be unpredictable. If the large group contributed 4 tokens in the last period, it is unlikely that they would reduce contribution to 1 in the consecutive period. Thus, to best respond to that, small groups keep contributing 0 in the current period.

Several other categories of messages have significant effects on groups' decisions across treatments. In large groups, playing safe means to contribute 4 tokens to ensure a win in large groups and taking risks means to contribute less. By contrast, in small groups, playing safe means to contribute 0 tokens to save the endowment and taking risks means to contribute more. Our regressions correctly capture these effects as can be seen from the coefficients on categories 10 and 11 in Tables 6 and 7. Also, messages about the size asymmetry (category 8) increase large groups' contributions but decrease small groups' contribution. Lastly, discussions about benefits for own group (category 4) increases small groups' contributions. This is because these discussions emphasized the fact that the individual share of the prize in the small group is more than in the large group.

Table 7: Probit regressions on small group contribution decisions

	Dependent variables: **Model 1: 1= the small group contributed 0 tokens in a given period, 0= otherwise** **Model 2: 1= the small group contributed 3 tokens in a given period, 0= otherwise**	**Treatment 1x1 G** **Model 1 (0 tokens)**	**Treatment 3x5 C** **Model 1 (0 tokens)**	**Treatment 1x1 G** **Model 2 (3 tokens)**	**Treatment 3x5 C** **Model 2 (3 tokens)**
	Independent variables *Coding categories*				
1a	Propose how many people to contribute to the group account	-0.197	0.124	0.168***	0.022
		(0.303)	(0.297)	(0.044)	(0.095)
1b	Ask for the opinions of other group members	0.269	0.100	-0.040	-0.008
		(0.231)	(0.165)	(0.115)	(0.129)
1c	Disagree with group members' proposals	0.100	-0.098	-0.191***	-0.111
		(0.093)	(0.152)	(0.035)	(0.075)
1d	Agree with group members' proposals on the contribution level	-0.127***	-0.139***	0.083***	0.106***
		(0.033)	(0.044)	(0.018)	(0.018)
1e	Push for consensus on the contribution level		-0.140*		-0.028
			(0.082)		(0.072)
2	Appeal to fool the other group across periods	-0.321***	-0.121***	0.080	0.167***
		(0.053)	(0.014)	(0.058)	(0.065)
3	Make choices by reasoning from the other group's point of view	-0.532***	-0.125***	0.159***	0.256***
		(0.112)	(0.048)	(0.054)	(0.061)
4	Discussion about benefits for own group	-0.197***	-0.058**	0.279***	0.024
		(0.028)	(0.017)	(0.020)	(0.028)
6	Reference to previous choices for the other group	-0.106**	-0.004	0.018	-0.029
		(0.050)	(0.101)	(0.025)	(0.043)
7	Reference to the previous choices of own group	-0.104	-0.005	0.278***	0.014
		(0.597)	(0.042)	(0.076)	(0.030)
8	Reference about the size asymmetry	-0.027	0.142	-0.023*	-0.141**
		(0.081)	(0.092)	(0.013)	(0.065)
9	Reference to the game rules	0.005	-0.065	-0.008	-0.003
		(0.014)	(0.040)	(0.016)	(0.022)
10	Appeal to play safe	0.222		-0.128**	
		(0.136)		(0.055)	
11	Appeal to take risks	-0.300	-0.242**	-0.005	0.196***
		(0.525)	(0.098)	(0.239)	(0.056)
	1/period	-2.815	-2.553**	0.190	0.383
		(2.385)	(1.040)	(1.237)	(0.588)
	Lag1 dummy (1 if small group contributed 0 tokens in the last period)	0.441**	0.224	-0.149	-0.143
		(0.223)	(0.153)	(0.141)	(0.251)
	Lag1 dummy (1 if small group contributed 3 tokens in the last period)	-0.261	-0.288	0.030	-0.033
		(0.305)	(0.274)	(0.124)	(0.099)
	Lag1 dummy (1 if large group contributed 4 tokens in the last period)	0.554***	0.394***	-0.305***	-0.268**
		(0.077)	(0.065)	(0.096)	(0.129)
	Lag 1: Appeal to fool the other group across periods	-0.004	-0.250	-0.008	0.072
		(0.082)	(0.165)	(0.028)	(0.078)
	Lag 2: Appeal to fool the other group across periods	0.038	-0.006	-0.047***	0.026
		(0.067)	(0.078)	(0.011)	(0.023)
	Lag 3: Appeal to fool the other group across periods	0.269**	0.080		0.015
		(0.105)	(0.056)		(0.028)
	Number of observations	67.00	68.00	71.00	68.00
	Log likelihood	-19.90	-23.53	-19.89	-21.01

Notes: marginal effects; Robust standard errors in parentheses, clusters on groups.
*Statistical significance *** p<0.01, ** p<0.05, * p<0.1.*

6. Conclusions

This paper conducts an experimental study on the effects of communication in a competition between two unequal sized groups over a public good. When group members make a binary decision on whether or not to contribute, we find that communication significantly increases contributions in the large group and deters contributions in the small group. This is because communication makes group members act as one agent in their strategic interactions. Moreover, group level contributions are not significantly different in the presence or absence of free-riding incentives as long as groups have the opportunity to communicate. Integrating research methods drawn from sociology and economics, we analyze the content of the group communication to provide insights into behavior, as subjects articulate their strategies in the chat. We find that the categories of messages that help groups to achieve the group optimal outcome and avoid free-riding include messages proposing to rotate or explicitly designating contributors; messages appealing to fool the other group across periods and messages regarding making choices by reasoning from the other group's point of view.

We focus on binary decisions on whether or not to contribute in this study. Yet, the option of lowering the level of contributions, but not necessarily to zero can only be observed when a continuous strategy space is allowed. We report the effects of communication in a more general form of intergroup competition in Zhang (2009). Group members are asked to make a continuous contribution decision on how much to contribute and an all-pay auction contest success function is used to determine the winner group. Besides documenting similar effects of communication on group contribution decisions, we find that both groups on average contribute less and earn more when they decide how much to contribute rather than whether or not to contribute.

Another interesting extension to explore is how much communication is needed to achieve and maintain coordination in the inter-group competition. Cason and Khan (1999) report that face to face communication dramatically improves subjects' ability to efficiently provide the public good in a single group. They focus on examining the impact of imperfect monitoring in both communication and non-communication settings where subjects can't learn others' public goods contributions instantaneously but every six periods. They show that contributions are increased by communication even with imperfect monitoring. However, improved contribution monitoring alone cannot increase contributions without communication. Also, adding *between-group communication* would be a natural extension of our study. Bornstein et al. (1992)

investigate between-group communication in a one-shot inter-group public goods game played between two 3-player groups. They show that the possibility of communication with out-group members considerably lowers the in-group member's ability to solve the internal free rider problems. Sutter and Strassmair (2008) examine the effects of communication on effort-choices in team tournaments. The tournament is repeated for 10 rounds with fixed groups. They find that in the case of between-group communication where any messages are public to both groups, there is significant decrease in effort levels due to collusion, relative to effort levels when within-group communication is allowed. It would be interesting to see how individual and group decisions would alter according to within and between group communication infrastructure implemented in our games.

References

Blinder, A. S. and Morgan, J. (2005). Are Two Heads Better than One? An Experimental Analysis of Group versus Individual Decision-making. *Journal of Money, Credit and Banking*, 37(5), 789-811.

Bochet, O., Page, T. and Putterman, L. (2006). Communication and Punishment in Voluntary Contribution Experiments, *Journal of Economic Behavior & Organization*, 60(1), 11-26.

Bornstein, G., Kugler, T. and Ziegelmeyer, A. (2004). Individual and Group Behavior in the Centipede Game: Are Groups More "Rational" Players? *Journal of Experimental Social Psychology*, 40, 599-605.

Bornstein, G. and Yaniv, I. (1998). Individual and Group Behavior in the Ultimatum Game: Are Groups More "Rational" Players? *Experimental Economics*, 1, 109-118.

Brandts, J. and Cooper, D. (2007). It's What You Say not What You Pay: An Experimental Study of Manager-Employee Relationships in Overcoming Coordination Failure. *Journal of the European Economic Association*, forthcoming.

Camerer, C. (2003). Behavioral Game Theory: *Experiments in Strategic Interaction*, Princeton University Press, Princeton, New Jersey.

Cason, T. N. and Khan, F. U. (1999). A Laboratory Study of Voluntary Public Goods Provision with Imperfect Monitoring and Communication. *Journal of Development Economics*, 58 (2), 533-552.

Cason, T. N. and V.-L. Mui (1997). A Laboratory Study of Group Polarization in the Team Dictator Game. *The Economic Journal*, 107, 1465-1483.

Cason, T. N. and V.-L. Mui (2005). Uncertainty and Resistance to Reform in Laboratory Participation Games. *European Journal of Political Economy*, 21(3), 708-737.

Charness, G. and Dufwenberg, M. (2006). Promises and Partnership. *Econometrica*, 74(6), 1579-1601.

Cooper, D. J. and Kagel, J. H. (2005). Are Two Heads Better than One? Team versus Individual Play in Signaling Games. *The American Economic Review*, 95(33), 477-509.

Cox, J. C. (2002). Trust, Reciprocity, and Other-regarding Preferences: Groups versus Individuals and Males versus Females. In (Eds.), *Advances in experimental business research*. Kluwer Academic Publishers.

Cox, J.C. and Hayne, S. C. (2006). Barking Up the Right Tree: Are Small Groups Rational Agents? *Experimental Economics*, 9(3), 209-222.

Crawford, V. (1998). A Survey of Experiments on Communication via Cheap Talk, *Journal of Economic Theory*, 78, 286-298.

Crawford, V. and Iriberri, N. (2007). Level-K Auctions: Can a Nonequilibrium Model of Strategic Thinking Explain The Winner's Curse and Overbidding in Private-Value Auctions? *Econometrica*, 75, 1721-1770.

Crawford, V. and Iriberri, N. (2007). Fatal Attraction: Salience, Naivete, and Sophistication in Experimental Hide-and-Seek Games, *American Economic Review*, 97, in press.

Fischabbcher, U. (2007). z-Tree-Zurich Toolbox for Readymade Economic Experiments. *Experimental Economics*, 10 (2), 171-178.

Hackett, S., Schlager, E. and Walker, J. (1994). The Role of Communication in Resolving Commons Dilemmas: Experimental Evidence with Heterogenous Appropriators. *Journal of Environmental Economics and Management*, 27, 99-126.

Hayes, A. F. (2005). *Statistical Methods for Communication Science*, Mahwah, NJ: Erlbaum.

Hennig-Schmidt, H., Li, Z.Y. and Yang, CH. (2007). Why People Reject Advantageous Offers – Non-monotone Strategies in Ultimatum Bargaining. *Journal of Economic Behavior and Organization*, forthcoming.

Himmelweit, H. T., Biberian, M. J., and Stockdale, J. (1978). Memory for Past Vote: Implications of a Study of Bias in Recall. *British Journal of Political Science*, 8, 365-375.

Hoffman, Elizabeth, McCabe, K., Schachat, K. and Smith, V. (1994). Preferences, Property Rights and Anonymity in Bargaining Games. *Games and Economic Behavior*, 7(3), 346-380.

Insko, C. A., Pinkley, R. L., Hoyle, R. H., Dalton, B., Hong, G. and Slim, R. M., et. al. (1987). Individual versus Group Discontinuity: The Role of Intergroup Contact. *Journal of Experimental Social Psychology*, 23, 250-267.

Isaac, R. M. and Walker, J. M. (1985). Information and Conspiracy in Sealed Bid Auctions. *Journal of Economic Behavior and Organization*, 1985(6), 139-159.

Isaac, R. M. and Walker, J. M. (1988a). Group Size Effects in Public Goods Provision: The Voluntary Contributions Mechanism. *The Quarterly Journal of Economic*, 103, 180-199.

Isaac, R. M. and Walker, J. M. (1988b). Communication and Free-Riding Behavior: The Voluntary Contribution Mechanism. *Economic Inquiry*, 26 (4), 585-608.

Kocher, M. G. and Sutter, M. (2005). The Decision Maker Matters: Individual versus Group Behavior in Experimental Beauty-Contest Games. *Economic Journal*, 115(500), 200-223.

Kocher, M. G. and Sutter, M. (2007). Individual versus Group Behavior and the Role of the Decision Making Procedure in Gift-exchange Experiments. *Empirica* 31, 63-88.

Krippendorf, K. (2004). *Content Analysis: An Introduction to Its Methodology*. 2nd edition, Thousand Oaks, CA: Sage.

Kugler, T., Bornstein, G., Kocher, M. and Sutter, M. (2007) Trust between Individuals and Groups: Groups are Less Trusting than Individuals but just as Trustworthy. *Journal of Economic Psychology*, 28(1), 69-78.

Levin, D. K., and Palfrey, T. R. (2007). The Paradox of Voter Participation? A Laboratory Study. *American Political Science Review*, 101, 143-58

Luhan, W. J., Kocher, M. G. and Sutter, M. (2007). Group Polarization in the Team Dictator Game. *Experimental Economics*, forthcoming.

McCallum, D. M., Harring, K., Gilmore, R., Drenan, S., Chase, J. P., Insko, C. A., et al. (1985). Competition and Cooperation between Groups and between Individuals. *Journal of Experimental Social Psychology*, 21, 301-320.

Ostrom, E., Gardner, R and Walker, J. (1994). Rules, Games and Common-Pool Resources. Ann Arbor: The University of Michigan Press.

Palfrey, T. R. and Rosenthal, H. (1983). A Strategic Calculus of Voting. *Public Choice*, 1983(41), 7-53.

Rapoport, A. and Bornstein, G. (1987). Intergroup Competition for the Provision of Binary Public Goods. *Psychological Review*, 94, 291-299.

Rapoport, A. and Bornstein, G. (1989). Solving Public Goods Problems in Competition between Equal and Unequal Size Groups. *Journal of Conflict Resolution*, 33, 460-479.

Rockenbach, B., Sadrieh, A. and Mathauschek, B. (2007). Teams Take the Better Risks. *Journal of Economic Behavior and Organization*, 63 (3), 412-422.

Sally, D. (1995). Conversation and Cooperation in Social Dilemmas: A Meta-Analysis of Experiments from 1958 to 1992. *Rationality and Society*, 7 (1), 58-92.

Schram, A. and Sonnemans, J. (1996a). Voter Turnout as a Participation Game: An Experimental Investigation. *International Journal of Game Theory*, 25, 385-406.

Schram, A. and Sonnemans, J. (1996b). Why People Vote: Experimental Evidence. *Journal of Economic Psychology*, 17, 417-442.

Schram, A. and van Winden, F. (1991). Why People Vote: Free Riding and the Production and Consumption of Social Pressure. *Journal of Economic Psychology*, 12, 575-620.

Sutter, M. (2007). Are Teams Prone to Myopic Loss Aversion? An Experimental Study on Individual versus Team Investment Behavior. *Economics Letters*, forthcoming.

Sutter, M. and Strassmair, C. (2009). Communication, Cooperation and Collusion in Team Tournaments - An Experimental Study. *Games and Economic Behavior*, 66 (1), 506-525.

Tajfel, H. (1982). Social Psychology of Intergroup Relations. *Annual Review of Psychology*, 33, 1-39.

Wichman, H. (1972). Effects of Isolation and Communication on Cooperation in a Two-person Game. In L. S. Wrightsman, J. O'Connor, and N. J. Baker (Eds.), *Cooperation and Competition: Readings on Mixed-motive Games*, 197-206. Belmont, CA: Brooks/Cole Publishing Company.

Zhang (2009). The Impact of Communication in Inter-Group Competition over Public Goods: Effects of Strategy Spaces and Contest Rules, working paper, McMaster University

Appendix I: Expected Payoffs in 3x5 Game

The expected payoff of contributing $EV_{\mathrm{i}}^{A}(Contribute)$ for any player i in Group A is:

$$EV_{\mathrm{i}}^{A}(Contribute) = \frac{\mathrm{r}_A}{2}\sum_{j=0}^{\mathrm{n}_A-1}\binom{\mathrm{n}_A-1}{\mathrm{j}}\mathrm{p}^{\mathrm{j}}(1-\mathrm{p})^{\mathrm{n}_A-\mathrm{j}-1}\binom{\mathrm{n}_\mathrm{B}}{\mathrm{j}+1}\mathrm{q}^{\mathrm{j}+1}(1-\mathrm{q})^{\mathrm{n}_B-\mathrm{j}-1}$$

$$+\mathrm{r}_A\sum_{j=0}^{\mathrm{n}_A-1}\binom{\mathrm{n}_A-1}{\mathrm{j}}\mathrm{p}^{\mathrm{j}}(1-\mathrm{p})^{\mathrm{n}_A-\mathrm{j}-1}\binom{\mathrm{n}_\mathrm{B}}{\mathrm{j}}\mathrm{q}^{\mathrm{j}}(1-\mathrm{q})^{\mathrm{n}_B-\mathrm{j}}$$

$$+\mathrm{r}_A\sum_{j=1}^{\mathrm{n}_A-1}\sum_{k=0}^{\mathrm{j}-1}\binom{\mathrm{n}_A-1}{\mathrm{j}}\mathrm{p}^{\mathrm{j}}(1-\mathrm{p})^{\mathrm{n}_A-\mathrm{j}-1}\binom{\mathrm{n}_\mathrm{B}}{\mathrm{k}}\mathrm{q}^{\mathrm{k}}(1-\mathrm{q})^{\mathrm{n}_B-\mathrm{k}}$$

This expression is the sum of three components. The first component is the expected payoff associated with a tie, i.e., by contributing, player i will change a losing situation into a tie and get $\frac{\mathrm{r}_A}{2}$; the second is the expected payoff associated with winning the contest, i.e., by contributing, player i can break the tie and lead his or her group to a victory and get r_A units of rewards; and the third is the expected payoff associated with a wasted contribution, i.e., excluding player i, the number of contributors in Group A has already exceeded the number of contributors in Group B. Player i's decision of contributing or not will have no effect on the outcome of the contest.

The expected payoff of NOT contributing $EV_{\mathrm{i}}^{A}(Not\ to\ Contribute)$ for any player in Group A is:

$$EV_{\mathrm{i}}^{A}(Not\ to\ Contribute) = \mathrm{e}\sum_{j=0}^{\mathrm{n}_A-1}\sum_{k=j+2}^{\mathrm{n}_B}\binom{\mathrm{n}_A-1}{\mathrm{j}}\mathrm{p}^{\mathrm{j}}(1-\mathrm{p})^{\mathrm{n}_A-\mathrm{j}-1}\binom{\mathrm{n}_\mathrm{B}}{\mathrm{k}}\mathrm{q}^{\mathrm{k}}(1-\mathrm{q})^{\mathrm{n}_B-\mathrm{k}}$$

$$+\mathrm{e}\sum_{j=0}^{\mathrm{n}_A-1}\binom{\mathrm{n}_A-1}{\mathrm{j}}\mathrm{p}^{\mathrm{j}}(1-\mathrm{p})^{\mathrm{n}_A-\mathrm{j}-1}\binom{\mathrm{n}_\mathrm{B}}{\mathrm{j}+1}\mathrm{q}^{\mathrm{j}+1}(1-\mathrm{q})^{\mathrm{n}_B-\mathrm{j}-1}$$

$$+\left(\mathrm{e}+\frac{\mathrm{r}_A}{2}\right)\sum_{j=0}^{\mathrm{n}_A-1}\binom{\mathrm{n}_A-1}{\mathrm{j}}\mathrm{p}^{\mathrm{j}}(1-\mathrm{p})^{\mathrm{n}_A-\mathrm{j}-1}\binom{\mathrm{n}_\mathrm{B}}{\mathrm{j}}\mathrm{q}^{\mathrm{j}}(1-\mathrm{q})^{\mathrm{n}_B-\mathrm{j}}$$

$$+(\mathrm{e}+\mathrm{r}_A)\sum_{j=1}^{\mathrm{n}_A-1}\sum_{k=0}^{\mathrm{j}-1}\binom{\mathrm{n}_A-1}{\mathrm{j}}\mathrm{p}^{\mathrm{j}}(1-\mathrm{p})^{\mathrm{n}_A-\mathrm{j}-1}\binom{\mathrm{n}_\mathrm{B}}{\mathrm{k}}\mathrm{q}^{\mathrm{k}}(1-\mathrm{q})^{\mathrm{n}_B-\mathrm{k}}$$

This expression is the sum of four components. The first two components are the expected payoff associated with a loss when player i chooses not to contribute: in the first case, Group A will lose the contest even with player i's input; in the second case, player i will miss the opportunity to tie the game if he or she chooses not to contribute. The third component is the expected payoff associated with the case when excluding player i, the number of contributors in Group A has already tied the number of contributors in Group B. By not contributing, player i saves his endowment e and gets to share half of the prize $\frac{r_A}{2}$ for a tie. The last component is the expected payoff associated with the case when player i avoids wasting his endowment by not contributing because excluding player i the number of contributors in Group A has already exceeded the number of contributors in Group B.

Similarly, we can get another function of p, q for players in Group B such that $EV_i^B(Contribute) - EV_i^B(Not\ to\ Contribute) = 0$, where the expected payoff of contributing $EV_i^B(Contribute)$ for any player i in Group B is:

$$EV_i^B(Contribute) = \frac{r_B}{2}\sum_{j=0}^{n_B-1}\binom{n_B-1}{j}q^j(1-q)^{n_B-j-1}\binom{n_A}{j+1}p^{j+1}(1-p)^{n_A-j-1}$$

$$+r_B\sum_{j=0}^{n_B-1}\binom{n_B-1}{j}q^j(1-q)^{n_B-j-1}\binom{n_A}{j}p^j(1-p)^{n_A-j}$$

$$+r_B\sum_{j=1}^{n_B-1}\sum_{k=0}^{j-1}\binom{n_B-1}{j}q^j(1-q)^{n_B-j-1}\binom{n_A}{k}p^k(1-p)^{n_A-k}$$

And the expected payoff of NOT contributing $EV_i^B(Not\ to\ Contribute)$ for any player i in Group B is:

$$EV_i^B(Not\ to\ Contribute) = e\sum_{j=0}^{n_B-1}\sum_{k=j+2}^{n_A}\binom{n_B-1}{j}q^j(1-q)^{n_B-j-1}\binom{n_A}{k}p^k(1-p)^{n_A-k}$$

$$+e\sum_{j=0}^{n_B-1}\binom{n_B-1}{j}q^j(1-q)^{n_B-j-1}\binom{n_A}{j+1}p^{j+1}(1-p)^{n_A-j-1}$$

$$+\left(e+\frac{r_B}{2}\right)\sum_{j=0}^{n_B-1}\binom{n_B-1}{j}q^j(1-q)^{n_B-j-1}\binom{n_A}{j}p^j(1-p)^{n_A-j}$$

$$+(e+r_B)\sum_{j=1}^{n_B-1}\sum_{k=0}^{j-1}\binom{n_B-1}{j}q^j(1-q)^{n_B-j-1}\binom{n_A}{k}p^k(1-p)^{n_A-k}$$

With two functions and two unknowns, we can numerically solve the mixed strategy equilibria.

Appendix II: Proof of the Nash equilibria in 1x1 Game

In the case of two-person nonzero-sum game,

	Person B	q_0	q_1	q_2	q_3	q_4	q_5
Person A	Strategies	**0**	**1**	**2**	**3**	**4**	**5**
p_0	**0**	12,14	3,22	3,21	3,20	3,19	3,18
p_1	**1**	20,5	11,13	2,21	2,20	2,19	2,18
p_2	**2**	19,5	19,4	10,12	1,20	1,19	1,18
p_3	**3**	18,5	18,4	18,3	9,11	0,19	0,18

Note for Person B, action q_5 is strictly dominated by q_4 **.** Strictly dominated action cannot be part of Nash equilibrium. Therefore, probability of playing q_5 is equal to zero. Note also that action q_0 is strictly dominated by q_3 and q_4 and thus by the same logic cannot be a part of Nash equilibrium.

By elimination of the strictly dominated strategies, we have reduced our problem to a simple 4 by 4 game.

	Person B	q_1	q_2	q_3	q_4
Person A	Strategies	**1**	**2**	**3**	**4**
p_0	**0**	3,22	3,21	3,20	3,19
p_1	**1**	11,13	2,21	2,20	2,19
p_2	**2**	19,4	10,12	1,20	1,19
p_3	**3**	18,4	18,3	9,11	0,19

To make Person A be indifferent among all the actions of Person B, Person B should set the probabilities so that ${E^A}_0 = {E^A}_1 = {E^A}_2 = {E^A}_3$ where ${E^A}_i$ is the expected payoff for Person A to choose ${Strategy^A}_i$.

$${E^A}_0 = 3q_1 + 3q_2 + 3q_3 + 3q_4$$
$${E^A}_1 = 11q_1 + 2q_2 + 2q_3 + 2q_4$$
$${E^A}_2 = 19q_1 + 10q_2 + q_3 + q_4$$
$${E^A}_3 = 18q_1 + 18q_2 + 9q_3$$

By equalizing the above 4 equations, we can solve 4 unknowns. Thus the equilibrium mixed strategies for Person B is to play each strategy at the following probabilities:
$q_0 = 0, q_1 = 0.111, q_2 = 0, q_3 = 0.778, q_4 = 0, q_5 = 0$

Similarly, to make Person B be indifferent among all the actions of Person A, Person A should set the probabilities so that ${E^B}_1 = {E^B}_2 = {E^B}_3 = {E^B}_4$ where ${E^B}_i$ is the expected payoff for Person B to choose ${Strategy^B}_i$.

$E^{B}{}_{1} = 22p_0 + 13p_1 + 4p_2 + 4p_3$
$E^{B}{}_{2} = 21p_0 + 21p_1 + 12p_2 + 3p_3$
$E^{B}{}_{3} = 20p_0 + 20p_1 + 20p_2 + 11p_3$
$E^{B}{}_{4} = 19p_0 + 19p_1 + 19p_2 + 19p_3$

By equalizing the above 4 equations, we can solve 4 unknowns. We get two sets of mixed strategies for Person A: $p_0 = 0.778, p_1 = 0.111, p_2 = 0, p_3 = 0.111$ or $p_0 = 0.833, p_1 = 0, p_2 = 0.056, p_3 = 0.111$.

Mixed Strategy NE		Person B	0	0.111	0	0.111	0.778	0
Person A (1)	Person A (2)	# of tokens contributed	0	1	2	3	4	5
0.778	0.833	0	12,14	3,22	3,21	3,20	3,19	3,18
0.111	0	1	20,5	11,13	2,21	2,20	2,19	2,18
0	0.056	2	19,5	19,4	10,12	1,20	1,19	1,18
0.111	0.111	3	18,5	18,4	18,3	9,11	0,19	0,18

Plug the equilibrium probabilities into the expected payoffs, we get
$E^{A}{}_{0} = E^{A}{}_{1} = E^{A}{}_{2} = E^{A}{}_{3} = 3$ for Person A.

For Person B, if we consider the first set of mixed strategies where Person A plays
$p_0 = 0.778, p_1 = 0.111, p_2 = 0, p_3 = 0.111$, $E^{B}{}_{1} = E^{B}{}_{2} = E^{B}{}_{3} = E^{B}{}_{4} = 19$

Yet, for the second set of mixed strategies where Person A plays $p_0 = 0.833, p_1 = 0, p_2 = 0.056, p_3 = 0.111$, we get $E^{B}{}_{1} = E^{B}{}_{3} = E^{B}{}_{4} = 19, E^{B}{}_{2} = 18.5$. Person B gets lower payoffs by contributing 2 tokens. This is why Person B never contributes 2 tokens in equilibrium.

Appendix III

Table A1: Coding Table and Reliability Indexes

Code	Coding Category Description	Reliability (Cohen's Kappa K) 1x1 G Large	1x1 G Small	3x5 C Large	3x5 C Small
1	Coordination on the contribution level for the current period	0.87	0.89	0.70	0.74
1a	Propose a specific contribution level	0.65	0.76	0.42	0.55
1b	Ask for the opinions of other group members (should not specifically refer to a contribution level)	0.55	0.69	0.56	0.58
1c	Disagree with group members' proposals	0.70	0.80	0.63	0.76
1d	Agree with group members' proposals on the contribution level	0.82	0.83	0.61	0.67
1e	Propose to rotate or explicitly designate contributors and (or) non-contributors	N/A	N/A	0.56	0.66
1f	Push for concensus on the contribution level	0.82	0.66	0.84	0.80
2	Appeal to fool the other group across periods (be unpredictable, to trick them, pretend to be predictable)	0.79	0.70	0.50	0.58
3	Make choices by reasoning from the other group's point of view	0.87	0.86	0.79	0.66
4	Discussion about benefits for own group	0.71	0.60	0.58	0.61
5	Discussion about benefits for the other group	0.70	0.79	0.40	0.63
6	Reference to the previous choices of the other group	0.73	0.71	0.41	0.60
7	Reference to the previous choices of own group	0.79	0.76	0.67	0.83
8	Reference about the size asymmetry	0.74	0.52	0.86	0.68
9	Appeal to play safe	0.71	0.79	0.77	0.68
10	Appeal to take risks	0.80	0.60	0.50	0.54
11	Other	0.82	0.74	0.64	0.57