Group Size and Sincere Communication in Experimental Social Dilemmas

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Abstract

This paper makes two contributions to the research on cooperation in experimental social dilemmas. First, we demonstrate an interaction between group size and communication in which the effectiveness of communication in promoting cooperation declines as group size increases. Second, we corroborate some previous research showing the positive effect of communication is due to sincere signaling of cooperative intentions. The experimental data comes from 289 undergraduate student subjects playing public goods games over a computer network. These findings suggest that large group size opens up a niche for the evolution of institutions for collective action.

Key Words

Cooperation, institutions, communication, social dilemma, public goods

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June 2008, under review, *Rationality and Society*

This paper makes two contributions to the research on cooperation in experimental social dilemmas. First, we demonstrate an interaction between group size and communication in which the effectiveness of communication in promoting cooperation declines as group size increases. Second, we corroborate some previous research that suggests the positive effect of communication is due to sincere signaling of cooperative intentions.

In the theoretical and empirical literature on cooperation, the ideas that group size decreases cooperation and communication enhances cooperation have virtually become received wisdom. The group size hypothesis is most famously stated by Olson (1970), who argued that large groups are less likely to provide collective goods because the per capita benefits of collective action decline with group size. While game theoretic analyses of this hypothesis show that it depends on the structure of the public goods production function (Chamberlin 1974; Sandler 1992), the proposition has received a good deal of empirical support especially in experimental findings. Isaac and Walker (1988) and Brewer and Kramer (1986) both found that levels of cooperation decline when group size leads to a decrease in the marginal returns from collective goods. Kerr (1989) has shown that individuals in larger groups are less likely to believe they can effectively influence levels of cooperation. Sally's (1995) meta-analysis of over 100 experimental social dilemmas from 1958-1992 shows that group size significantly decreases the rate of cooperation in most experiments.

The positive effect of communication has received even stronger support in the experimental literature, despite the game theoretic prediction that communication is merely cheap talk and should not affect equilibrium behavior. Sally’s (1995) meta-analysis confirms the numerous studies that have found communication to be a strong and consistent accelerator of cooperation. Investigations of why communication has this effect have focused on implicit promises and signaling of cooperative intentions (Dawes et al. 1977; Isaac 1988; Orbell et al. 1988). This evidence is consistent with the idea that people tend to apply evolved strategies of conditional cooperation to experiments with repeated games (Fehr and Gachter 2002). Communication thus gives them an opportunity to signal what type of strategy they will employ, and allows others to conditionally cooperate.

Despite the huge number of social dilemma experiments—Axelrod (1980) declared the Prisoner's Dilemma the *E. coli* of social psychology—our extensive literature review found that nobody has examined the interaction between group size and communication. A straightforward information economics hypothesis suggests that the marginal value of communication decreases as group size increases. While a signal of cooperative intentions might be useful for a single partner, the usefulness and credibility of the signal declines for multiple receivers. Because each message sent entails some cost, communication also becomes more costly as group size increases. The content of messages also tends to become distorted as information disperses through social networks (Mesoudi and Whiten 2004, 2006). Hence, our experiments test the simple hypothesis of a negative interaction between communication frequency and group size.

In addition to exploring the communication/group size interaction, our experiments feature repeated communication with messages sent via computer that can be content coded to analyze how different types of messages affect cooperation. The experimental design can thus corroborate some of the earlier work on how signaling cooperative intentions affects behavior (Kerr and Kaufman-Gilliland 1994; Wilson and Sell 1997). We are additionally interested in whether communication is sincere in the sense that cooperative signals are correlated with cooperative behavior, or strategic in the sense that cooperative signals persuade other players to cooperate while the message sender free-rides.

Experimental Design

The experiment was a repeated public goods game in which each player could contribute between 0 and 20 experimental tokens per round. The contributions were multiplied by a factor of 1.6 and redistributed equally to all group members regardless of contribution amount. All tokens not contributed were kept by the individual. The experiment represents a pure public good, and the Nash equilibrium in a single round of play is to contribute zero. Each experimental token was worth 2 cents such that subjects earned on average $15 for a one-hour session. Subjects were paid anonymously in cash at the end of the session. The game lasted 10 rounds, and players were informed of this in the instructions at the beginning of the session. The players were all undergraduate students at UC Davis recruited through classroom communication and advertisements in student newspapers. All interactions were anonymous such that no individual could connect another player's comments or contributions with a real participant. Participants were advised that there would be no deception involved in the experiment. Full instructions were provided to the participants at the beginning of the experiment, and the participants were required to correctly answer a set of questions that demonstrated their understanding of the game choices and payoffs.

There were two communication conditions: one-shot and repeated. Messages were sent via computer in both conditions, and all messages were public knowledge because they could be viewed by all the members of the group. There were no private, peer-to-peer messages. In the one-shot condition, the subjects were allowed to send one message only prior to the first round of the game. In the repeated condition, the subjects could send one message prior to each round, for a total of ten messages. The subjects did not have to send a message if they did not want to. In each round, the contribution decision was made after the communication round, so the following analyses do not need to consider simultaneous causality.

Group size ranged from three to sixteen, and was manipulated by inviting different numbers of players to each experimental session, although when some of the players did not show up, group size was adjusted accordingly. The resulting distribution of group sizes reported in Table 1 provides enough variance in group size within both communication conditions to analyze the hypothesized interaction.

[Insert Table 1 about here]

Results: Group Size, Communication, and Cooperation

Table 2 shows the average contribution by round for all groups, large groups, and small groups for each communication condition. As seen in numerous previous experiments, the contribution levels start off reasonably high and decline towards the end of the game. End-game effects are the typical explanation for this drop-off, but there is certainly more cooperation than would be expected from a pure rational choice analysis of this game, which would suggest backwards induction leading to non-cooperation. Table 2 also shows that while on average repeated communication leads to higher contributions, the difference between repeated and one-shot communication is much greater in small groups compared to large groups (see Figure 1). This is initial evidence for the interaction between group size and communication, and indeed a standard three-factor ANOVA analysis shows a significant three-way interaction between group size, round, and repeated cooperation ($F=1.37$, $p<.05$). The ANOVA also has significant main effects for group size ($F=32.42$, $p<.05$), round ($F=16.12$, $p<.05$), repeated communication ($F=56.20$, $p<.05$), and significant two-way interactions between round and group size ($F=1.65$, p<.05), round and repeated communication (F=2.37, p<.05), and repeated communication and group size (F=28.46, p<.05).

[Insert Table 2 about here]

To get a more systematic understanding of the dynamics of cooperation, we follow the method of Chaudhuri et al. (2006) and estimate random effects tobit models. Random effects tobit models take into account the bounded nature of the dependent variable, and also assume there is some unobserved heterogeneity for each subject that is not captured by the independent variables. The independent variables in the model are 1/round (inverse of time), group size, a dummy variable for repeated communication, and an interaction term between group size and communication. Following Chaudhuri et al., the lagged contribution(t-1) and lagged deviation from average contribution (individual contribution minus group average) are also included as independent variables. The main hypothesis is a negative slope coefficient for the interaction effect between group size and repeated communication.

Table 3 reports the results of the tobit analysis; the first model includes the lagged contribution and deviance variables and the second model examines only the game-level variables. The results in both models confirm prior research: contributions are lower in later rounds of the game and higher on average in the repeated communication condition. In addition, there is a positive relationship between contributions in the previous round and current contributions, and lagged contributions in the previous round greater than the group average were followed by a decrease in current contributions.

[Insert Table 3 about here]

Most importantly, in both models there is a negative interaction between group size and repeated communication although the interaction is only significantly different from zero (and much larger) in the model excluding the lagged variables. As shown by Achen (2000, see also Keele and Kelly 2006), lagged dependent variables suppress the explanatory power of other independent variables because in the presence of autocorrelated errors, lagged dependent variables act as a proxy that picks up the effect of other independent variables. This effect can be seen in the general increase in the size of the coefficients of all the independent variables for the model without lagged variables compared with the model with the lagged variables. Furthermore, the next section analyzes only the repeated game players and shows a negative coefficient for group size even with the lagged variables (see Table 5). The coefficient for group size is always very close to zero in the one-shot communication. Thus the bulk of statistical evidence supports the hypothesized negative interaction.

While the lagged variables disguise some of the effects of the experimental conditions, they are important for showing how the mix of strategies in a given group has consequences for overall levels of cooperation. The mix of strategies in a particular group has the potential to overcome conditions unfavorable to cooperation, such as a large group. While the average level of cooperation is lower in unfavorable situations, groups in which members are playing more cooperative strategies can overcome these challenges at least in the short run. However, to the extent that these strategies rely on conditional cooperation, the increased costs of communication and observation in large groups may lead to a decline in cooperation in the long-run (e.g., longer than the 10-round experiment) without some other type of institutional intervention.

Results: The Content of Communication

This section focuses on results with repeated communication. Even though the effectiveness of repeated communication declined with group size, it still produced an overall increase in cooperation compared with one-shot communication. Since much previous research has focused on signaling of cooperative intentions as an explanation for the effect of communication, we tested this idea further by coding each message sent into the following five categories:

1. Group building: Statements explicitly or implicitly emphasizing group solidarity. Examples: "We're on a roll! Woot! Woot!" “Let’s be sure to work together here so that we all win” “This is not me vs. you it’s us vs. them so all give 20 and we can walk away with 18+dollars.” “Hello Team – let’s work cooperatively =).”
2. Cooperative intentions: Statements encouraging cooperation or indicating an intention to cooperate, sometimes with specific mention of amounts. Examples: "Go ALL IN and be happy." "I propose that everyone put in all 20 tokens. If everyone puts in 20 tokens, we all get 32 tokens at the end of the round." “So it seems like the best way for us all to earn more money is to all contribute. We all walk out of here with 20 dollars – it’d be nice.”
3. Irrelevant: Game-irrelevant communication. Examples: "Do you like cheese? Why yes I do…my favorite is Gouda." "In Kentucky there's a law against having ice cream in your back pocket. I wonder why that is."
4. Positive moral statements: Positively framed statements attributing moral significance to the decision. Examples: "The fair thing to do is max out." "Cooperation breeds happiness." "Get good karma and put in 20; we're all poor." “Put a fair share people.”
5. Negative moral statements: Negatively framed statements attributing moral significance to the decision. Examples: "One bad apple turned the whole group greedy. Such is the way of the world I guess. Losers!" "Three of you are here to cheat us out—that's wrong!" "Voodoo curses on all y'all!"

Each message sent could have multiple phrases and thus might be coded in more than one category. The coding scheme is best conceptualized as quantifying different "bits" of each message.

[Insert Table 4 about here]

Table 4 shows the proportion of players sending each type of message by round for the repeated communication games. The most frequently sent messages were cooperative intentions, group building, and irrelevant messages; about one third of the players sent these types of messages throughout the game. Positive moral statements were used the least frequently, while negative moral statements increased in frequency after the first round. The increasing use of negative moral statements is reminiscent of the use of material punishments and strategies of strong reciprocity (Fehr and Gachter 2000; Fehr and Gachter 2002). The frequencies in round one of the repeated communication game are virtually identical to the frequencies of round one of the one-shot game (not shown).

[Insert Table 5 about here]

Table 5 shows the random effects tobit models with and without lags, where the messages received by each player are included as independent variables. Because individual players received messages from the entire group, the messages received variables were calculated by subtracting the message sent by the individual player from the overall group totals for each type of communication. The models in Table 5 do not include a dummy variable for repeated communication because only the repeated communication games were analyzed. The results clearly show that group building, cooperative intentions, and positive moral statements have the strongest positive effect on cooperation, with group building being most effective. Negative moral statements also increase cooperation, but not as effectively as positive moral statements, despite the increasing use of negative moral statements in middle rounds of the game and the effectiveness of negative sanctions found in other experiments.

Table 6 uses probit models with robust standard errors to analyze messages sent as a function of lagged contributions and lagged deviance. The pattern of coefficients for all three types of effective messages—positive moral statements, group building, and cooperative intentions—is consistent with sincere signaling of cooperative intentions. Higher previous contributions increase the use of all three types of messages, and higher deviations from the group average decrease the use of positive moral statements. Since Table 3 shows that lagged deviations from the mean decreased subsequent contributions, players that are most likely to decrease their contributions are also less likely to send positive moral statements. On average, the messages being sent are not strategic; players intending to free-ride are not sending messages that encourage cooperation. However, some individual players within the population do engage in such "self-interest with guile" (Williamson 1985) and those strategies can severely degrade cooperation.

Conclusion: A Niche for Institutional Evolution?

The analysis demonstrates two simple conclusions: the effectiveness of communication declines with group size, and communication mostly consists of sincere signaling of cooperative intentions. Although these findings are important for combining two of the major hypotheses about cooperation, what do they mean for the broader topic of the evolution of cooperation?

The history of how this specific experiment evolved in the context of our experimental lab helps answer this question. To some extent, this experiment is a consequence of serendipity as much as design. The authors' lab group is developing experiments that allow for the evolution of cooperation and institutions over multiple generations, similar to the work of

Chaudhuri et. al.(2006). As part of this work, we were searching for a combination of group size and communication that would allow for the evolution of cooperation sometimes, but not always. We noticed that communication was generally effective in small groups, but less effective in large groups, and so proceeded to systematically investigate this pattern in order to produce the results of this paper.

What this suggests is that in groups where communication fails, there is an opportunity for alternative types of institutions to emerge with the potential to increase cooperation. In the real world, social groups turn to many different types of institutions to organize cooperation. These institutions typically include some mixture of communication, sanctions, and rewards. As Ostrom (2005) notes, diversity is the defining feature of real-world institutions; multiple institutional and cooperative equilibria are possible. Understanding this diversity is a major challenge for future research on cooperation. The negative interaction between group size and communication suggests communication can be a very effective and efficient institution for small groups. Increasing group size creates a niche for the emergence of new institutions, and future experiments will examine how these alternative institutions emerge in multi-generation laboratory micro-societies.

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Table 1: Distribution of Group Sizes by Communication Condition

Group Size	Repeated Communication	One-Shot Communication
3	2	4
4	1	9
5	1	8
6	3	2
7	1	1
8	2	2
9	2	0
11	2	1
14	1	1
15	1	0
16	0	1
Total	16 Groups 125 subjects	29 Groups 164 subjects

Table 2: Average Contribution by Round and Communication Condition

All Groups			Small Groups (Less than six subjects; 25th percentile of group size)		Large Groups (More than 10 subjects; 75th percentile of group size)	
Round	One-Shot	Repeated	One-Shot	Repeated	One-Shot	Repeated
1	11.8	9.8	10.4	14.2	12.6	9.0
2	9.3	9.3	8.2	13.9	8.3	9.2
3	7.0	9.5	6.6	12.9	5.4	8.8
4	6.0	8.5	5.9	9.3	4.8	8.4
5	4.9	8.9	5.3	12.3	3.4	7.9
6	4.3	8.5	4.3	11.1	4.3	7.7
7	4.5	7.6	4.7	12.7	4.0	7.3
8	4.6	6.7	4.4	11.4	4.3	6.0
9	5.2	6.7	5.3	9.8	4.6	6.8
10	4.2	6.2	4.5	10.1	3.5	6.2

Table 3: Random Effect Tobit Models for Contributions

	Model with Lagged Contribution Variables		*Model Without Lagged Contribution Variables*	
Independent Variables	Coefficient(S.E)	Z-Score	Coefficient(S.E)	Z-Score
1/Round	7.24 (1.63)	4.44**	12.67(.75)	16.81**
Repeated Communication	2.16(1.14)	1.89*	5.41(1.18)	4.59**
Group Size	.022(.076)	0.29	.06 (.07)	0.79
Repeated Communication X Group Size	-.13(.12)	-1.06	-.39(.12)	-3.14**
Lag Contribution	.99(.05)	20.32**	---	---
Lag Deviation from Average	-.76 (.06)	-13.14**	---	---
Constant	-3.26 (.76)	-4.30**	1.82(.68)	2.66**
Rho (Residual/Intraclass Correlation)	.42(.02)		.54 (.02)	
Log Likelihood	-5409.48		-6412.22	
Wald Chi-Square	600.93**		306.14**	

Notes: Cell entries are random effect tobit slope coefficient estimates with standard errors in parentheses and associated z-scores in adjacent column. Reject hypotheses of parameter=0, *p<.10; **p<.05

Table 4: Proportion of Players Sending Messages by Round for Repeated Communication Games

Round	Irrelevant	Group Building	Positive Moral Statement	Negative Moral Statement	Cooperative Intentions
1	.20	.22	.02	.01	.28
2	.16	.17	.06	.12	.31
3	.13	.17	.06	.14	.38
4	.17	.30	.12	.17	.36
5	.20	.22	.06	.21	.36
6	.16	.22	.07	.21	.49
7	.15	.20	.08	.21	.26
8	.23	.21	.11	.14	.30
9	.22	.19	.07	.20	.26
10	.19	.13	.11	.13	.30

Table 5: The Effect of Messages Received on Contributions

	Model with Lagged Contribution Variables		*Model Without Lagged Contribution Variables*	
Game-Related Independent Variables	Coefficient (S.E.)	Z-Score	Coefficient(S.E)	Z-Score
1/Round	6.77 (2.63)	2.58**	10.20(1.28)	7.94**
Group Size	-.22 (.20)	-1.10	-.44(.22)	-1.98**
Lag Contribution	1.27 (.10)	12.74**	---	---
Lag Deviation from Average	-1.03(.11)	-9.16**	---	---
Group Messages Sent				
Group Building	4.02(.85)	4.74**	4.15(.84)	4.95**
Cooperative Intentions	.62(.22)	2.88**	1.13(.21)	5.25**
Irrelevant	.14(.32)	.44	-.45(.32)	-1.38
Positive Moral Statement	.61(.43)	1.43	2.11(.42)	5.02**
Negative Moral Statement	.27 (.28)	.95	.50(.29)	1.73*
Constant	-6.65(1.87)	-3.55**	3.89(1.84)	2.10**
Rho (Residual/Intraclass Correlation)	.25(.04)		.45(.04)	
Log-Likelihood	-2479.35		-2891.10	
Wald Chi-Square	279.53**		150.90**	

Notes: Cell entries are random effect tobit slope coefficient estimates with standard errors in parentheses and associated z-scores in adjacent column. Reject hypotheses of parameter=0, *p<.10; **p<.05

Table 6: Probit Models for Sent Messages

Independent Variables	*Irrelevant*	*Group Building*	*Positive Moral Statement*	*Negative Moral Statement*	*Cooperative Intentions*
1/Round	-.21(.37)	-.21(.35)	-.84(.52)	-.57(.40)	.16(.31)
Group Size	-.01(.03)	-.04(.02)**	-.03(.02)*	.001(.01)	-.008(.02)
Lag Contribution	-.05(.01)**	.02(.01)**	.07(.01)**	.01(.01)	.02(.01)**
Lag Deviation From Average	.05(.02)**	-.01(.01)	-.08(.01)**	.01(.01)	-.02(.01)
Constant	-.38(.28)	-.57(.20)**	-1.60(.26)**	-.96(.21)**	-.58(.22)**
Pseudo R^2	.03	.02	.10	.01	.01
Log Likelihood	-514.03	-500.80	-293.63	-500.79	-703.78
Wald Chi-Square	19.06**	12.08**	39.84**	7.28	5.43

Notes: Cell entries are probit slope coefficient estimates with robust standard errors clustered by player in parentheses. Each column shows coefficients for player sending different type of message. Reject hypotheses of parameter=0, *p<.10; **p<.05

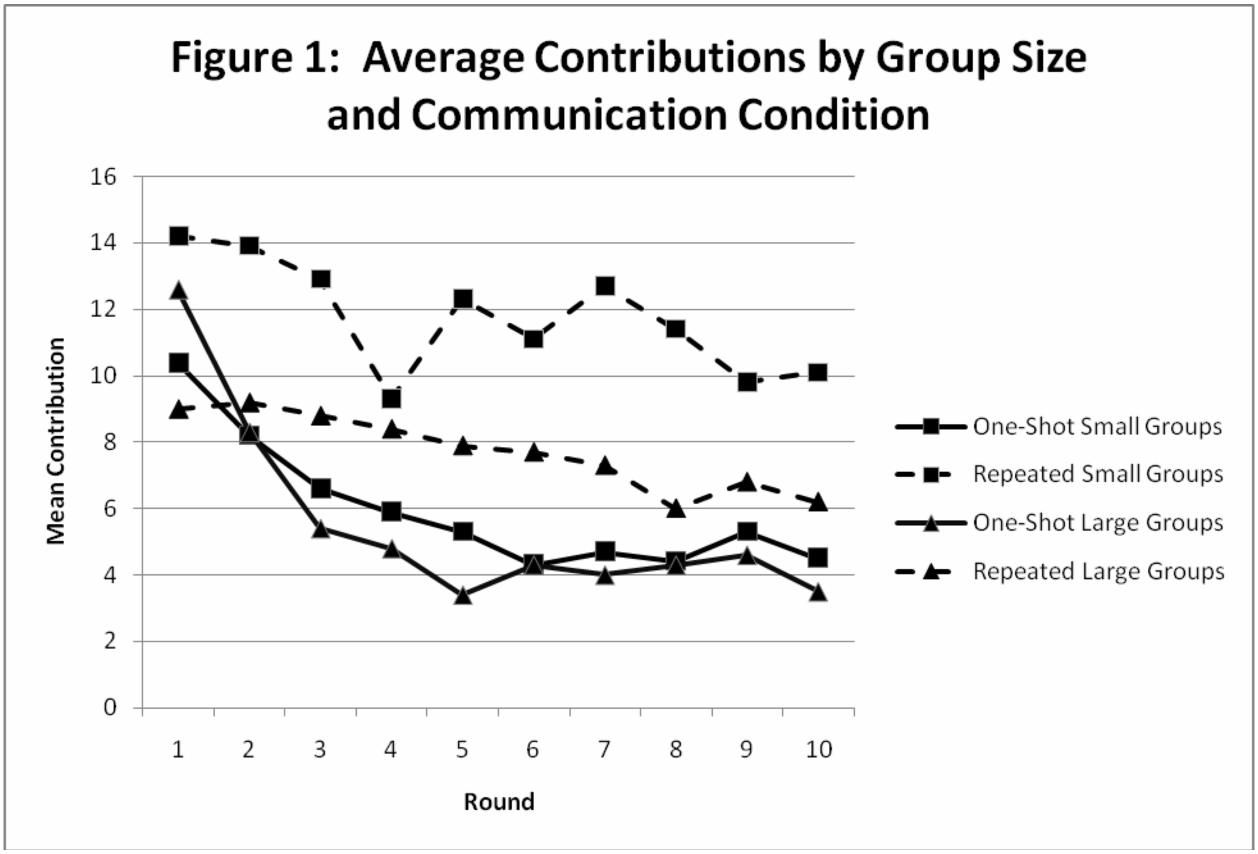
Figure 1: Average Contributions by Group Size
and Communication Condition
16
14
12
10
8
6
4
2
0
Mean Contribution
1
2
3
4
5
6
7
8
9
10
Round
One-Shot Small Groups
Repeated Small Groups
One-Shot Large Groups
Repeated Large Groups