Strategic Behavior and Learning in Repeated Voluntary-Contribution Experiments[1]

by

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Abstract
Voluntary contribution experiments systematically find that contributions decline over time. We use a two-stage voluntary contribution game to investigate whether this decrease is caused by learning or strategic behavior. Using a strategy method we find a robust pattern of declining contributions: contributions in stage two are 45% lower than in stage one. Repeating the game five times we find that experience generates a smaller decline in contributions: stage one contributions decrease by around 7% per game. Finally we find no significant differences between the strategy and direct response method, which suggest that our results help explain behavior in the latter.

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1. Introduction

A robust finding in experimental studies of voluntary contribution games is that cooperation decreases with repeated interaction. Two explanations have been provided for this result. One is that strategies initially are well-defined, but that they depend on the history of play, and therefore may cause players to change their actions over the course of the game. Another is that participants slowly begin to understand the game and refine their strategies accordingly. While both of these explanations are convincing, limited work has been done to directly determine the role played by each. The purpose of this study is to provide such an examination.

To determine the extent to which decreasing contributions arise as a result of history-dependent strategies we need to identify the participants' strategies in a multi-stage voluntary contribution game. To do so we apply the strategy method (Selten, 1967) to a two-stage voluntary-contribution game. Participants submit a plan of action for the two-stage game, specifying a stage-one contribution and a stage-two response to any possible number of aggregate stage-one contributions by other group members. The plan is then matched with that of two other participants, and actions are taken in accordance with the participant's strategy. An advantage of the strategy method is that participants make a decision for every possible history of aggregate contributions, not just those reached in the course of actual play. Thus participants indicate how they would respond to different contributions, making it straightforward to identify strategies. We find that the pattern of contributions is comparable to the results from previous repeated voluntary-contribution experiments in that the elicited strategies imply declining average contributions. The elicited strategies cause contributions to decline by an average of 45% within the two-stage games.

To examine the potential role played by learning we have participants play a sequence of five two-stage games, playing against a new set of people in each game. This allows us to examine whether experience with the game leads to a modification of strategies, and whether such modifications decrease contributions. We find that individuals do modify their strategies across games, and as a result contributions in stage one sometimes increase and sometimes decrease across successive games. On average stage-one contributions decrease by 7% per game. Stage two contributions decrease more reliably across games, but the average decrease is still only 14% per game. Thus experience with the game leads to an erratic and less pronounced deterioration in contributions, compared with the systematic and substantial deterioration generated by submitted strategies.

We observe, as in previous studies, considerable heterogeneity in submitted strategies. Following Fischbacher et al. (2001), we classify participants on the basis of the strategies they submit, and in any game most participants are classified as “free-riders” (participants who contribute nothing in stage two), or “conditional cooperators” (contributors whose stage-two contribution increases with other group members’ stage-one contribution). Individual strategies are not stable across games, as many participants switch from one class to another across successive games. While a potential interpretation is that these participants do not have stable preferences, we cannot rule out that participants nonetheless have well-defined preferences over the outcome of the two-stage game. The reason is that experience may help participants better understand the game, and may cause them to update their prior on the strategies others use when playing the game. Thus participants may be uncertain of what strategies best serve their interests and revise strategies as they learn how their own strategies influence outcomes. While participants often change their strategies from game to game, the *distribution* of strategies is quite stable: the proportions of different types do not change much from game to game.

A potential disadvantage of the strategy method is that it may elicit strategies that differ from those used by participants in a traditional experiment based on a 'direct-response' method. The direct-response method, applied to this game, would have participants make simultaneous stage-one contributions, and then, after observing aggregate stage-one contributions, participants would make simultaneous stage-two contributions. For our strategy-method examination to shed light on the decrease in contributions observed in direct-response games it is necessary that the elicited behavior is similar across the two elicitations. Although the two methods are equivalent from a standard theoretical point of view, there are plausible behavioral reasons why differences may emerge (see the discussions in Roth, 1995, or Brandts and Charness, 2000). For example, eliciting a strategy for the two-stage game encourages subjects to consider stage two when making their stage-one decision; if the two stages were played out in sequence a subject might make a stage-one decision without giving any consideration to stage two. If behavior under the direct-response method differs from that under the strategy method, then it is unreasonable to argue that we can use elicited strategies to shed light on the decrease in contributions observed in the direct-response interaction.

Previous research delivers mixed evidence on whether people behave differently according to whether the strategy or direct-response method is used. Brandts and

Charness (2000) examined Sequential Prisoners' Dilemma and Sequential Chicken games, and found no significant differences between outcomes elicited by direct-response and strategy-method approaches. They carefully conclude: "in games of low complexity, the strategy method may be a valid technique for collecting a rich data set without affecting participants' decisions significantly." However, other studies provide evidence of significant differences between direct-response and strategy-method approaches. For example, Güth et al. (2001) compare alternative versions of a mini-ultimatum game – they find significant differences when the direct-response method is used, but not when a strategy method is used; Brandts and Charness (2003) study a game with pre-play communication in which players can punish opponents who send misleading messages – they find that under a direct-response method punishment rates are significantly higher than under a strategy method; Burton et al. (2005) study coordination games with pre-play communication – they find that under a direct-response method coordination on the efficient equilibrium was significantly lower than under a strategy method.

Thus, equivalence between the two elicitation procedures cannot be taken for granted, and so to test the validity of the strategy-method implementation of our game we also run a direct-response version of the game, where participants simultaneously choose contributions for the first stage, are informed of stage-one contributions, and then play the second stage. Our results reveal that the contributions elicited by the strategy method are no different from those of our control, direct-response, treatment. Thus the behavior that results from the elicited strategies is consistent with that of the direct-response games.

The remainder of the paper is organized as follows. In Section 2 we review the related literature. We then describe our experimental design and procedures in Section 3. The results are presented in Section 4, and we conclude in Section 5.

2. Literature Review

A number of studies have examined contributions in a repeated voluntary contribution game. Among the first is Isaac and Walker (1988) who in a series of repeated linear public goods games find that repetition causes free riding to increase and contributions to 'decay.' With ten repetitions of the game contributions tend to start out at about half the endowment and decrease to about 15-25% of the endowment in round ten. The two most common arguments for this decrease in contributions are that as the game is repeated errors diminish as participants learn to free ride, and that with repetitions participants can play history-dependent strategies potentially causing both conditional cooperators and free riders to decrease their contributions over the course of the game.

A number of studies have used indirect tests to determine whether the 'learning' or the 'strategies' hypothesis is the likely cause of the decay in contributions. To examine if participants at the end of the repeated game have learned to free ride, Isaac and Walker (1988) invited past participants back to the laboratory to determine if their contribution rates differed from that of inexperienced participants. In contrast to the learning hypothesis and in support for the strategies hypothesis, behavior of experienced and inexperienced participants is practically the same. Initial contributions are high and then decrease as the game is repeated.

Andreoni (1988) uses a different approach to examine the two hypotheses. He argues that if the decay in cooperation is caused by state-contingent strategies then contributions should be larger when participants play in a finitely repeated game (partners), than when they are randomly paired with new participants after every repetition of the game (strangers). To further test the learning hypothesis he also examines the effect of restarting the game after ten periods. If the decay in contributions is caused by participants learning to free-ride, then contributions should be unaffected by the restart. His study provides evidence against both hypotheses. First, in contrast to the learning hypothesis, restarting the experiment causes a significant increase in contributions in the partner treatment. Second, in every round of the game contributions are larger in the stranger than partner treatment, suggesting that the decay in contributions cannot be caused by strategic play alone.[2]

Other researchers have subsequently used Andreoni's design to compare the behavior of partners versus strangers. While these have succeeded in replicating the restart effect, the evidence is mixed when replicating higher contributions in the stranger treatment.[3] Andreoni and Croson (2002) summarize these mixed findings and conclude, along the lines of Palfrey and Prisbrey (1996), that the reason why contributions in the stranger treatments sometimes are larger and sometimes smaller than in the partner treatment, is that confusion or errors seem to be larger in the stranger treatment. In addition to errors differing between the two treatments it has also been noted that both the

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[2] Andreoni and Croson (2002) argue that "...with plenty of experience in a number of finitely repeated games, subjects will learn the benefits of reputation building. In a single finitely repeated game, such as these public goods experiments, these results indicate that subjects are unlikely to have learned the sophisticated strategy of reputation building (p. 7)."

[3] See e.g. Croson (1996).

decision-making process and the manner in which one learns across games can differ substantially between the two treatments. Thus it is not clear that by comparing contributions in the partners versus strangers treatments we can determine what causes the decay in contributions in the partner treatments.[4]

This paper uses a different approach to distinguish between the two hypotheses. First our learning hypothesis is broader, as we do not focus solely on learning as a process that teaches participants to free ride over time, rather we examine a repeated public good game multiple times, and we attribute any modification of strategies and resulting changes in contributions between supergames as being due to learning.[5] Second, in determining the role of strategic play we directly elicit the participants' strategies in the repeated public good game. Thus we do not try to infer the strategies by comparing behavior in two different treatments. While others previously have applied the strategy method to public good games, our approach is unique in that we elicit strategies over the entire repeated public good game and use these strategies to determine whether the decrease in contributions is due to learning or state-contingent strategies.

For example, Fischbacher et al. (2001) apply a strategy method to a sequential voluntary-contributions game where three group members first make simultaneous contributions, and then after observing their total contribution a fourth group member makes her contribution. In their experiment the fourth group member indicates a contribution for each possible average contribution by the other three. Thus they can

[4] Along the lines of the learning hypothesis a series of other studies have argued that the decay in contributions in the strangers environment primarily is caused by a decrease in errors (see e.g., Andreoni (1995), Palfrey and Prisbrey (1996), and Houser and Kurzban (2002)).
[5] Note that this can include learning in terms of developing an improved understanding of the game, as well as learning in terms of updating priors on the anticipated strategies of opponents.

determine whether behavior in sequential public goods games depends on the contributions made by others and classify the strategies that participants use. 50% of their participants are classified as “conditional cooperators” – participants whose contribution in the role of fourth group member is increasing in others’ contributions – and 30% are classified as free riders – participants whose contribution in the role of fourth group member always is zero. Fischbacher and Gächter (2006) extend this elicitation procedure to a two-part experiment. In one part they classify people in the sequential public good game, and in the second part participants play a 10-period repeated simultaneous-move public good game in a stranger environment with random rematching after every game. The distribution of types is similar to that of Fischbacher et al. (2001), and these type classifications are found to be a good predictor of behavior in the repeated public good experiment. They argue that preference heterogeneity in the sequential public good game can be used to better understand the dynamics of simultaneous-move voluntary contributions games in the strangers environment.

To the best of our knowledge Keser (2000) is the only study that elicits strategies for a repeated simultaneous-move public good game and allows participants to experience their submitted strategies. Using a rather special participant pool she asked 50 academic economists to submit strategies for playing a 25-period repetition of a voluntary-contributions game. Strategies were then translated into computer code and matched with one another in every possible group of four, generating average payoffs for each strategy. Participants received feedback about payoffs, and could then revise and resubmit strategies for a second, then a third simulation. She found that in all three simulations, strategies typically consisted of high initial contributions, followed by a phase of reciprocation, and then by a very pronounced endgame effect. With each simulation initial contributions increased, and endgame effects occurred earlier. The endgame effects she observes are stronger than in most standard experiments, perhaps because her participants are more sophisticated, or more familiar with public goods experiments, or because their motivations differed from those of typical experimental participants.[6]

As we focus specifically on the role played by learning and state-contingent strategies in decreasing contributions in the standard repeated simultaneous-move public good game our approach differs from that of the earlier studies. Using a standard experimental subject pool we eliminate all possibilities of repeated interaction across games as participants only are matched with another participant for one supergame. Furthermore, to check that the elicited strategies match those of actual play of a repeated simultaneous-move game we conducted some control sessions with new subjects, where subjects played an identical direct-response version of the game.

3. Experimental Procedures

The experiment was conducted at the University of Nottingham in Spring 2001. We ran four sessions of a direct-response treatment and four sessions of a strategy-method treatment, with 15 participants in each session, for a total of 120 participants. Participants were recruited from a pool of undergraduate students at the University, and randomly

[6] Her participants were informed that after each simulation one participant would be randomly selected to be paid their earnings, and also that after the experiment participants' strategies, payoffs, and identities would be publicly revealed. In this latter respect her study is somewhat similar to the repeated prisoner's dilemma tournaments reported in Axelrod (1984).

assigned to a treatment. No participant participated in more than one session of the experiment.

All sessions used an identical protocol. Upon arrival, participants were seated at computer terminals and given a set of instructions, which the experimenter then read aloud (Appendix A contains the instructions). As part of the instructional phase of the session participants completed a computerized quiz that tested their understanding of the game. When all participants had completed the quiz correctly the experimenter continued with the instructions.

The decision-making phase of the session then began with a practice two-stage game, in which the participants played against the computer for hypothetical payoffs. The practice game was used simply to familiarize participants with their task and the computer screens. Participants then played five two-stage games in which they were randomly and anonymously matched into groups of three, no participant ever being matched with another participant more than once. Participants were endowed with 2 tokens in each stage of the game and had to decide how many tokens to place in a group account and how many to place in a private account. For each token an individual placed in the private account, that individual received £1.50, and for each token placed in the group account by any individual all three group members received £1. Denoting subject *j*'s contribution in stage *t* by x_{jt}, participant *i*'s payoff from a two-stage game is:

$$\pi_i = 1.5(2 - x_{i1}) + \sum x_{j1} + 1.5(2 - x_{i2}) + \sum x_{j2} \qquad i=1,..,3$$

where summations are taken over all three group members. At the end of the experiment one of the five two-stage games was selected at random, and the participant was paid her earnings from that game. These monetary incentives imply that to maximize group earnings participants should contribute all tokens to the group account in all stages, whereas the standard game-theoretic prediction, based on own-earnings maximization, dictates zero contributions.

In our direct-response treatment each participant was informed of the total contributions to the group account in stage one by the other two group members, and then made a stage-two decision. In our strategy-method treatment, each participant completed a strategy for the two-stage game, which consisted of a stage-one contribution, and a stage-two contribution conditional on total stage-one contributions by the other group members.[7] At the end of the game participants were informed of own-contributions, total contributions by other group members, and their payoff, and they recorded this information on a record sheet.

Throughout the session participants were only allowed to ask questions by raising their hand and speaking to the experimenter in private. Participants were not allowed to communicate with one another throughout the session, except via the decisions they entered on their terminal. At the end of the experiment participants were paid their earnings in private. All sessions lasted less than an hour and participants earned an average of £7.83 (with a minimum of £4.50 and a maximum of £12.00).

[7] With this strategy-method design the strategy space grows geometrically as stages are added. For example, a three-stage game would require participants to complete a matrix of conditional contributions. Thus, submitting strategies becomes much more cognitively demanding, and time-consuming, as the number of stages grows, and we therefore focus on the simple two-stage games. Likewise, we restricted the endowment space to 0, 1 or 2 tokens, and group sizes to three, to reproduce a voluntary-contributions game structure while maintaining a relatively simple task.

4. Results

Our analysis of the data starts with a brief overview. We first confirm that the behavior derived from the strategy method is consistent with that of the direct-response game, and we determine the extent to which these strategies cause contributions to decrease over the repeated public good game. Second, we then classify the elicited strategies, examine the distribution of types, and how these change with repetition. These changes in strategies help us assess the extent to which learning is responsible for decreasing contributions in the repeated public good game.

4.1 Overview

Average contributions are similar in our direct-response and strategy-method treatments: averaging over all games of the direct-response (strategy-method) treatment, participants contribute 37% (41%) of their endowment in stage one and 23% (23%) in stage two. Moreover, the time-series of contributions in the two treatments track each other closely, as shown in Figure 1.[8]

--- Figure 1 here ---

Formal statistical tests fail to reject the hypothesis that the two elicitation methods induce the same contribution behavior. Using two-sided Wilcoxon rank-sum tests applied to session-level data from all games we find no significant difference across treatments for either stage-one contributions (p = 0.561) or stage-two contributions (p = 0.773). We also find no significant differences in contributions if we focus on any given game.[9] All of these tests compare two sets of four observations, a rather conservative use of the data.

[8] Average contributions for each stage of each session are tabulated in Appendix B.

[9] The p-values are 0.363 (game 1), 0.883 (game 2), 0.307 (game 3), 0.549 (game 4) and 0.309 (game 5) for comparisons using stage-one contributions. The corresponding p-values using stage-two contributions are 0.243, 0.468, 0.773, 0.554, and 0.885.

We also made the same comparisons using individual-level data, i.e., comparing two sets of 60 observations. Although this procedure is biased toward finding significant differences, because it overstates the number of independent observations, we still fail to find any significant differences between elicitation methods.[10]

We also examined changes in contributions between stages one and two. Using a two-sided Wilcoxon rank-sum test applied to session-level data from all games we again find no significant difference between the two elicitation methods (p = 0.468), and with one exception for the case of game 1, we also find no significant differences between treatments if we focus on a given game or use individual-level data.[11] The overall message is that our strategy-method treatment generates behavior remarkably consistent with that of a direct-response method.

The time-series displayed in Figure 1 are similar to those from previous experiments, in that contributions decline within each two-stage game. In game one for example, contributions decrease from 45% to 32% of token endowments (averaging over all eight sessions). Moreover, the same pattern is seen in subsequent games: contributions fall from 36% to 26%, 39% to 23%, 41% to 18%, and 31% to 14% in games two through five respectively.[12] Thus, on average, contribution rates decrease by 16 percentage points between stage one and two, this corresponds to an average decrease of contributions of 41%. Similar decreases are observed in each treatment (38% and 45% for the direct-

[10] The p-values are 0.280 (game 1), 0.966 (game 2), 0.575 (game 3), 0.915 (game 4), 0.335 (game 5) and 0.448 (overall) for comparisons using stage-one contributions. The corresponding p-values using stage-two contributions are 0.281, 0.441, 1.000, 0.628, and 0.837.

[11] Based on session-level data the p-values are 0.020 (game 1), 0.307 (game 2), 0.884 (game 3), 0.559 (game 4), 0.147 (game 5) and 0.468 (overall). The corresponding p-values using individual-level data are 0.056, 0.577, 0.567, 0.661, 0.245, and 0.433.

[12] While end-game contributions are quite similar to that of Isaac and Walker, stage-one contributions of the two-stage game tend to lie below stage-one contributions of the ten-stage game.

response and strategy-method treatments respectively). Indeed, average stage-two contributions are lower than average stage-one contributions in all eight sessions, thus stage-two contributions are significantly lower than stage-one contributions (using a one-sided Wilcoxon matched-pairs signed-ranks test, $n = 8$, $p < 0.005$).

Figure 1 exhibits substantial ‘restart effects,’ that is, after contributions decline within a game, they restart at a higher level at the beginning of the next game. While this effect is not significant for the first restart, i.e., the transition from game one to game two, (p-value = 0.6367 using a one-sided Binomial test), it is significant for the other three (p-value = 0.035 for the second restart, and p-value = 0.0039 for the third and fourth restarts).[13]

4.2 Individual Strategies – Game One

Next we analyze the strategies elicited in the first game. With four strategy-method sessions, each involving fifteen participants, we elicited strategies from sixty participants. Figure 2 presents the strategies initially submitted for the second stage by each participant, demonstrating substantial heterogeneity across participants. Following Fischbacher et al. (2001) we classify participants into four categories. Of our sixty participants, 35% contribute nothing independent of the contributions of others (free-riders), while the contribution schedules are increasing for 38% (conditional cooperators), hump-shaped for 15%, and cannot easily be classified for the remaining 12%.[14]

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[13] The restart observed here differs slightly from that of Andreoni (1988) and Croson (1996), as they focus on the cases where participants either continue with the same group of people before as after the restart, or are rematched with new people after every decision in the game.

[14] The corresponding percentages in the four person sequential public good game reported by Fischbacher et al. (2001) were 30%, 50%, 14%, and 7%, and by Fischbacher and Gächter (2006) were 23%, 55%, 12%, and 10%. They use a slightly different classification procedure based on Spearman rank correlation statistics (see their paper for details).

--- Figure 2 here ---

In examining how our participants' stage-one decisions relate to their stage-two decisions, we observe some consistency. There is a systematic relation between stage-one decision and the type-classification based on stage-two decisions, and we reject the hypothesis that the distribution of types is independent of stage-one decisions ($\chi^2(6) = 13.46$, p-value = 0.036). As can be seen in Table 1, of the eighteen participants who contributed zero in stage one 67% were classified as free-riders and 22% were classified as conditional cooperators, while of the seventeen participants who contributed two tokens 24% were classified as free-riders and 53% as conditional cooperators. Thus, our results mirror Brandts and Charness (2000) and Fischbacher et al. (2001), in that stage-one contributors are more likely to be conditional cooperators.[15] Table 1 also reveals that almost half of the participants who free ride in the second stage nonetheless made a positive contribution in the first stage. Thus free riders too cause contributions to decrease with repetition.

--- Table 1 here ---

The notion of consistency addressed by these data is quite limited. An own-earnings maximizer may either contribute or not in stage one depending on their beliefs about how other participants respond in stage two. Similarly, a participant who prefers to contribute, but only so long as others also contribute, may either contribute or not in stage

[15] Brandts and Charness (2000) had participants play two games, once as first-mover and once as second-mover (against different opponents, and with no feedback between the two games). This allowed them to note a certain consistency in participants' decision rules in the two roles: when making decisions as second-movers, first-mover cooperators were much more likely to respond positively to a cooperative move than first-mover defectors. Fischbacher et al. (2001) also require participants to make decisions in two roles, and note a similar consistency across decisions in each role. Conditional cooperators contribute 42% of their endowment, on average, when they make an unconditional decision, while free riders contribute 10%.

one, depending on their beliefs about other participants' contributions in stage one. In the next sub-section we will examine a different notion of consistency by studying how participants' strategies develop across games.

The predominance of free-riding and conditionally cooperative strategies imply that on average stage-two contributions increase with stage-one contributions, albeit with a rather shallow slope. At best contributing one additional token in stage one increases the stage-two contribution by each of the other group members by 0.25 tokens.[16] Fitting a line through the conditional contribution schedules using a simple OLS approximation for game one yields

stage-two contribution = 0.29 + 0.16*(aggregate stage-one contributions by other group members).

Thus, by contributing an additional token in stage one a participant induces other group members to increase their stage-two contributions by 0.16 tokens each, on average; as this is not sufficient to cover the £0.50 contribution cost it is not worthwhile for an own-earnings maximizer to contribute in stage one.[17] Given this relationship between stage-two contributions and stage-one contributions, stage-two contributions will be below stage-one contributions as long as stage-one contributions exceed 21% of endowments – in fact stage-one contribution rates were 45%, easily exceeding this threshold.[18]

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[16] The marginal increase in tokens by other group members depend on the initial contribution level. Increasing the contribution by other group members from 0 to 1 or from 1 to 2 tokens will on average increase the contribution by each of the other group members by 0.25, going from 2 to 3 it increases 0.1, and from 3 to 4 it increases 0.03. The average stage-one contribution by other members is 1.97 in game one.

[17] This result is based on the submitted strategies, if we instead look at the actual responses that were carried out, the corresponding coefficient on contributing would be 0.18.

[18] That is, denoting average stage-two contribution by s_2 and average stage-one contribution by s_1, since aggregate stage 1 contribution by others equals $2s_1$ we can see that $s_2 < s_1 \Leftrightarrow 0.29 + 0.16 * 2 * s_1 < s_1 \Leftrightarrow s_1 > 0.42$. 0.42 tokens represent 21% of the endowment.

4.3 Individual Strategies – Development across Games

Next we examine how learning influences behavior, that is how behavior changes across the five repetitions of the games. Twenty-two of our sixty participants submitted the same type of strategy in every game. Thirteen of these submitted free-riding strategies in every game, and seven submitted conditionally cooperative strategies in every game. This leaves almost two-thirds of our participants whose strategy classification varies from game to game.

With sixty participants, each having four opportunities to revise their strategies, there are 240 opportunities for participant-strategies to change. Table 2 presents a transition matrix indicating the transition rates from each class. For example, 92 free-riding strategies were observed in the first four games, and in 80% of these cases the participant remained in the free-riding category in the next game. Similarly, participants classified as conditional cooperators usually remain in the same category in the next game. In contrast, participants in the "hump-shaped" or "other" category usually transit to a different category.

--- Table 2 here ---

Transitions from one category to another occur throughout the experiment: of sixty subjects 20 are classified differently in games one and two, 24 in games two and three, 21 in games three and four, and 15 in games four and five. A variety of explanations may account for these transitions. One possibility is that a participant whose behavior changes across games does not have stable preferences, while another possibility is that the participant is aware of what outcomes they prefer, but is learning how best to achieve them. This suggests caution should be used when interpreting strategies and their development over time. First, if participants do have stable preferences, elicited strategies do not map onto these in a direct way. Second, if we interpret changes in behavior from game to game as ‘learning,’ many of the observed transitions suggest that this goes beyond simply learning how best to maximize own-payoff.

Figure 3 shows the distribution of strategy-types across the five games. Depending on the game, free-riding strategies account for between 33% (game two) and 45% (game five) of submitted strategies, while conditionally-cooperative strategies account for between 35% (game four) and 42% (game two) of submitted strategies. What is clear from Figure 3 is that together, free riding and conditionally cooperative strategies predominate throughout the experiment. We also see that the distribution of types is fairly stable over the course of the experiment.

--- Figure 3 here ---

The implication of these distributions of strategy-types for the average response function is shown in Figure 4. The presence of conditionally cooperative strategies generates a response function that increases in others’ stage-one contributions, but the rate of increase is dampened by the presence of free-riding strategies.

--- Figure 4 here ---

From Figure 4 it appears that the average response function is approximately an increasing linear function that shifts downward from game to game. Table 3 reports the results of using simple OLS to approximate the average response function by a straight line. The slopes vary from 0.14 to 0.17, indicating that if a participant were to increase their stage-one contribution by a token, the aggregate contributions made by others in stage two would, on average, increase by between 0.28 and 0.34 tokens. Thus, the degree of responsiveness, as measured by this slope, does not vary much, and is never strong enough to make it worthwhile for an own-earnings maximizer to contribute in stage one.[19] The more apparent change over time is with respect to the intercept of the response function, which falls steadily across games. Thus participants respond less generously to a given level of others' stage-one contributions as games progress. A linear average response function with a slope less than ½ implies that if stage-one contribution rates exceed some critical percentage of endowments then average stage-two contributions will be lower than average stage-one contributions. Given the estimated response functions presented in Table 3, these critical percentages are 21%, 20%, 17%, 12%, and 10% for games one through five respectively. Note that these critical percentages all are far below the contribution rates observed in the experiment.

--- Table 3 here ---

The actual dynamic pattern of contributions depends on how stage-one decisions and the stage-two response function develop over games. As seen in Figure 1, contributions in stage one and two appear to be lower in game five than game one. Wilcoxon matched-pairs signed-ranks tests support this impression: stage-one contributions are significantly lower in game five than game one ($n = 8$, one-sided $p < 0.01$), as are stage-two contributions ($n = 8$, one-sided $p < 0.005$). However, the effect of experience is quite erratic from one game to the next; for example, stage-one

[19] If we instead use actual behavior to estimate the marginal increase in contributions we find coefficients ranging from 0.14 - 0.22. Alternatively we may look at the average marginal response at each contribution level in each of the five games, doing so we find marginal responses ranging from 0.03-0.25. Thus, at best a contributor will break even by contributing in stage 1, and with the exception of the first game her monetary return is always strictly lower from contributing in stage 1 (the largest marginal return is 0.19 in the remaining games).

contributions actually increase between games 2 and 3, and between games 3 and 4. Stage-two contributions show a more regular pattern of decrease across games. Overall, both stage-one and stage-two contribution rates vary quite widely around an average decrease of 4 percentage points per game. This corresponds to an average decrease in contributions in stage one of 7% and in stage two of 16%. Thus the decay in contributions from one game to the next (for a given stage) is lower and less stable than the decay from the first to the second stage (for a given game).

5. Conclusion

Previous experiments where participants repeatedly make voluntary contributions to public goods consistently result in a declining pattern of contributions. The existing literature has discussed two mechanisms that can lead to this pattern. One is that declining contributions are the result of reduced confusion as participants gain experience with the game. The other is that declining contributions results from the interaction of agents with heterogeneous motivations, and reflects deliberate strategies whereby some participants condition their contributions on past contributions by others. In one of our experimental treatments participants submit strategies for playing a two-stage game, and repeat this process five times, against new opponents each time. This treatment allows for a direct comparison of the effects of strategic responses and learning.

As in previous studies that elicit strategies in social dilemma experiments, most strategies can be classified as either free-riding – contributing nothing in the second stage of our game, regardless of others' contributions in the first stage, – or conditionally cooperative – where stage-two contribution is increasing in others' stage-one contributions. The observed distribution of submitted strategies is robust across the five repetitions and results in declining contributions within our two-stage voluntary contribution games: on average, stage-two contributions are 45% lower than stage-one contributions. Thus, deliberate strategic choices made by heterogeneous agents generate a substantial decrease in contributions.

However, for almost two-thirds of our participants the elicited strategy type falls in different classes in different games. This suggests caution be exercised in interpreting someone who uses a ‘conditionally cooperative strategy’ as a ‘conditionally cooperative person.’ We suggest that, as in many other experiments, these changes in behavior over time reflect some type of learning. Participants in our experiment are not able to dictate the outcome of a game, and so even if they have well-defined preferences over the outcome of the two-stage game they may not necessarily know what strategy best serves these interests. The changes in strategy may then reflect the attempts of participants to find the strategies that best work for them. Under this interpretation it is important to point out that transitions from one class of strategy to another are not always in the direction that serves the interests of selfish participants. Thus, participants are not simply learning how to maximize own payoff.

Indeed, although individuals switch between strategy-classes throughout the experiment, the *distribution* of strategy-types is quite stable, and so experience has a relatively small effect on average contributions. On average, stage-one contributions fall by about 7% each time the two-stage game is repeated.

This direct approach to testing the ‘strategy’ and ‘learning’ hypotheses leads us to conclude that strategic responses have a more pronounced and systematic effect than learning. The decline in contributions is much greater and more reliable across the two stages of a given game than across a given stage of successive games. In extrapolating this conclusion to the causes of declining contributions in other experiments two further comments are in order.

First, we focus on a game that is simpler in many respects than that used in more conventional public goods experiments. Our game consists of three players (compared with four players in the "small" group treatments of Isaac and Walker, 1988); each player decides how to allocate a two-token endowment (compared with at least a ten-token endowment in Isaac and Walker) in each of two stages (compared with ten stages in Isaac and Walker). These differences between our game and the more conventional one were dictated by our implementation of the strategy method, and whether the dynamics in contribution behavior differs according to these variables is an open question.

Second, a possible way to account for our results is that our strategy-method approach encourages participants to think about the two-stage game in a way that they would not if they were playing the two stages in sequence. If this were the case, then our strategy-method results may have little to say about the declining pattern of contributions in other experiments, where subjects are not required to submit strategies for playing the entire game. However, our results from a control treatment using a direct-response method do not square with this account. In our direct-response treatment subjects contribute 37% of their endowments in stage one (compared with 41% in the strategy-method treatment), and 23% in stage two (compared with 23% in the strategy-method treatment). The similarity between contributions under the two elicitation methods, make us confident that our results are not an artifact of the strategy method.

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Figures

Figure 1. **Average Contributions by Game (Note: The left end of each line indicates the mean contribution in stage one, and the right end indicates the mean in stage two).**

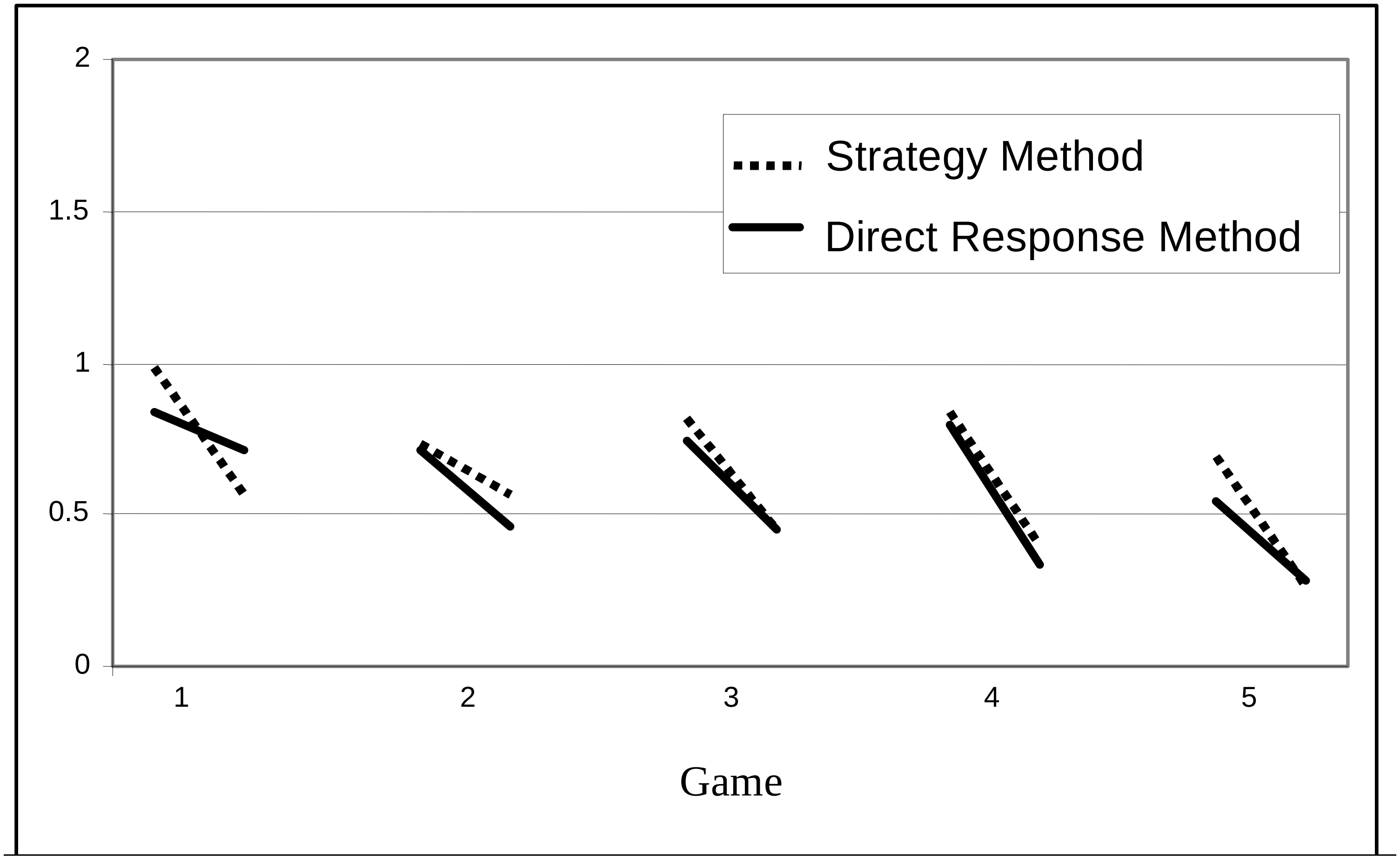


Figure 2: Stage-Two Strategies in Game One (Note: x-axis measures the aggregate stage-one contribution by other group members, y-axis measures the participant's conditional stage-two response. A panel represents one participant).

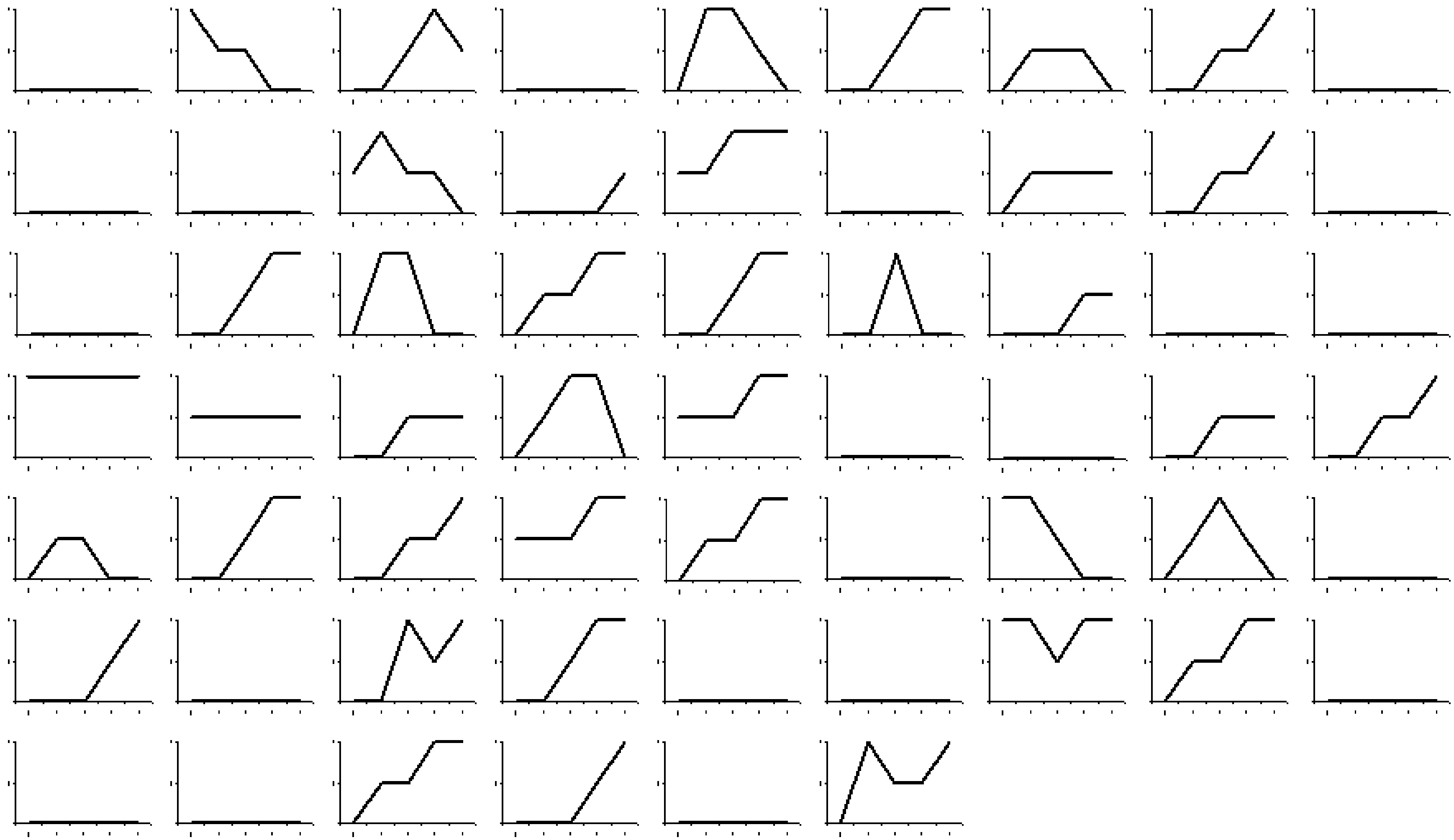


Figure 3. Distribution of Strategy Types across Games

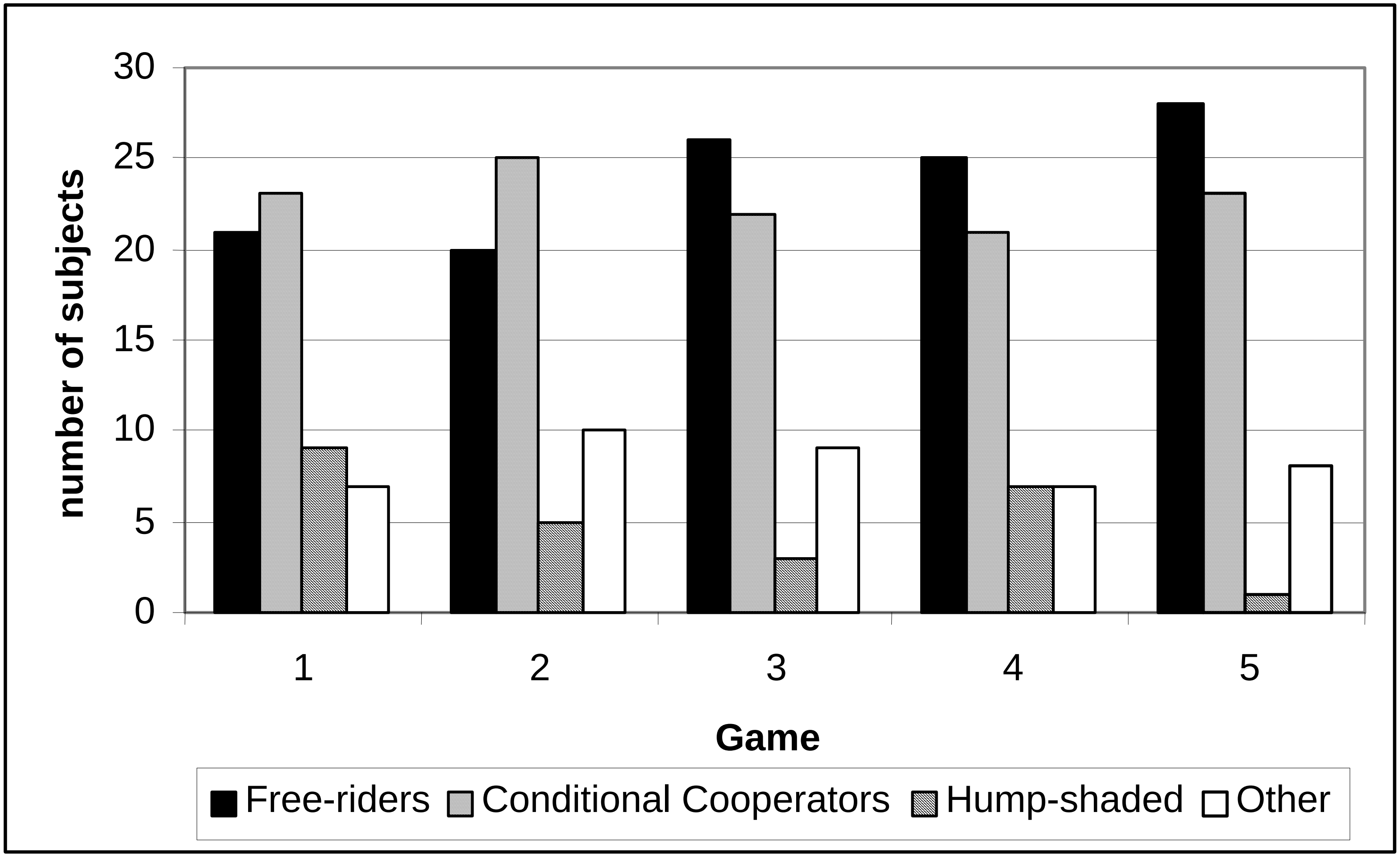
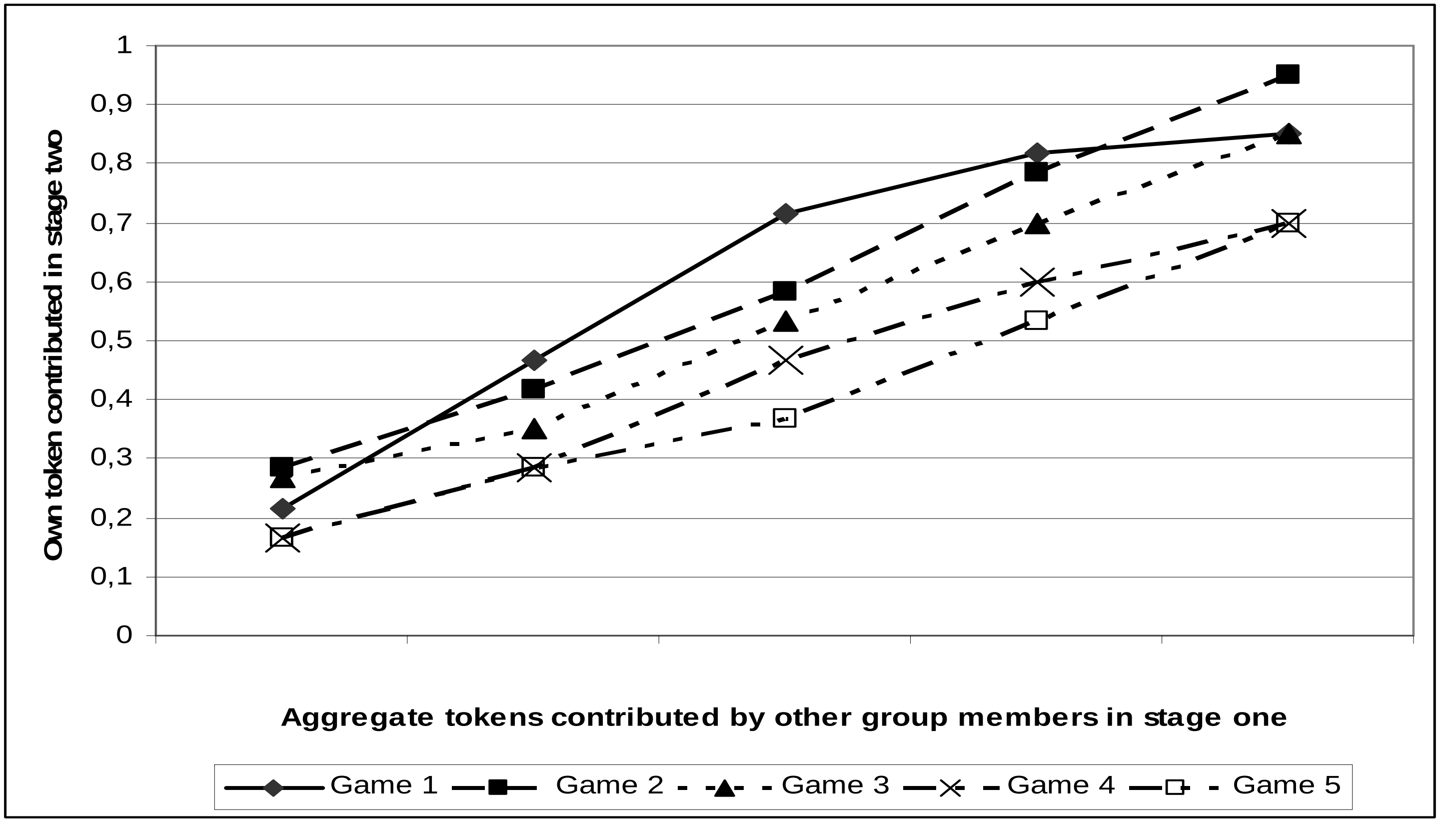


Figure 4. Strategy Method: Stage-Two Average Contribution Schedule



Tables

Table 1. Distribution of types by stage-one contribution				
	Fraction (percentage) of			
contribution in stage one	Conditional Cooperators	Free-riders	Hump-shaped	Other
0	3/18 (17%)	12/18 (67%)	2/18 (11%)	1/18 (5%)
1	11/25 (44%)	5/25 (20%)	4/25 (16%)	5/25 (20%)
2	9/17 (53%)	4/17 (24%)	3/17 (18%)	1/17 (6%)

Table 2. Transitions between types across games					
category	number observed in any of the first four games	percentage categorized in the following game as:			
		Free Rider	Conditional Cooperator	Hump-shaped	Other
Free Rider	92	80	12	2	6
Conditional Cooperator	91	17	69	2	12
Hump-shaped	24	12	25	42	21
Other	33	21	33	6	40

Table 3. Linear approximations to stage-two conditional response schedule					
	game				
	1	2	3	4	5
intercept	0.29	0.26	0.24	0.17	0.15
slope	0.16	0.17	0.15	0.14	0.13

Appendix A. Instructions

Introduction

This is an experiment about decision-making. There are other people in this room who are also participating in this experiment. You must not talk to them or communicate with them in any way during the experiment. The experiment will take about an hour, and at the end you will be paid in private and in cash. The amount of money you will earn depends on the decisions that you and the other participants make.

In this experiment you will perform a decision task five times. We refer to each decision task as a game. In each game you will be in a group with *two* other people, but you will not know which of the other people in this room are in your group. The decisions made by you and the two other people in your group will determine how much you earn.

Each game you will be matched with two new group members. You will never be matched with the same person more than once. At the end of the experiment the computer will randomly choose one of the five games and you will be paid your earnings for that game. Since you don't know which game will be chosen, the best thing to do when asked to make a decision is to assume that this is the game for which you will be paid.

The Decision Task

Each game consists of two stages. In the first stage you will have 2 tokens which you can place in your private account or in a shared group account. The other members of your group will also have two tokens each, and can place them in either their own private accounts or the shared group account. Your earnings depend on how much you place in your private account and the total amount placed in the group account by you and the other group members.

For each token you place in your *private account* you will receive £1.50. For each token you place in the *group account* all three members of the group, including yourself, will receive £1 each. Likewise, if another member of your group places a token in their own private account, that person will receive £1.50, and for each token that person places in the group account all three members of your group will receive £1 each.

Suppose for example in stage 1, Person A places one token in the group account and the other token in his or her private account. Suppose also that the other two group members place a total of 2 tokens in the group account. This means that there are a total of 3 tokens in the group account. Thus, Person A will earn £3 from the group account (3 tokens × £1 per token) plus £1.50 from the private account (1× £1.50 per token) for a total of £4.50. The other two group members' earnings will be calculated in a similar way.

At the end of stage 1 everyone will be informed of the total number of tokens in the group account and of their earnings. Stage 2 will be identical to stage 1. Each group member will have two tokens to allocate between the group account and their private account. Earnings are calculated in the same way as in stage 1.

To make sure everyone understands how earnings in a stage are calculated, we are going to ask you to complete a short quiz. Once everyone has completed the quiz correctly we will continue with the instructions. If you finish the quiz early please be patient.

How you enter your decisions [STRATEGY TREATMENT]

You will make your decisions by completing a plan for the entire game. The plan will specify your stage one decision, and also a stage two decision that can depend on what the other group members did in stage one. At the beginning of the game you will see a screen like the one below:

PARTICIPANT xx GAME x

STAGE ONE DECISION

I place ____ token(s) in the group account

CHOOSE 0, 1 or 2

PRESS TAB KEY TO MOVE TO STAGE TWO DECISION

WHEN YOU HAVE COMPLETED YOUR PLAN FOR BOTH STAGES PRESS THE ENTER KEY

This screen is for your **stage one decision**. Here you will indicate how many tokens you wish to place in the group account in stage one. You can choose 0, 1 or 2. When you have typed your decision you should press the Tab key.

You will then see the following screen:

PARTICIPANT xx GAME x

STAGE TWO DECISION

Number of tokens placed in group account by other two group members in stage ONE	Number of tokens I place in the group account in stage TWO
0	___
1	___
2	___
3	___
4	___

IN EACH SPACE CHOOSE 0, 1 or 2. USE ARROW KEYS TO MOVE FROM SPACE TO SPACE

PRESS TAB KEY TO MOVE TO STAGE ONE DECISION

WHEN YOU HAVE COMPLETED YOUR PLAN FOR BOTH STAGES PRESS THE ENTER KEY

This screen is for your **stage two decision**. The first column lists the possible number of tokens placed in the group account by the other group members in stage one. For each possibility you must type the number of tokens you place in the group account in stage two. Once again you must type 0, 1, or 2 into each blank. You can use the arrow keys to move from one row to another.

At any time you can use the Tab key to move between the two screens. If you want to modify your plan you can do so using the 0, 1, 2, Tab, and arrow keys.

When you have filled in the blanks in both screens, you should press the Enter key. Then the computer shows you your plan on a single screen, and asks you whether you want to submit the plan. If you want to change your plan you should type N. If you are satisfied with your plan you should type Y. After you have typed Y your plan cannot be changed.

When all participants in the experiment have submitted their plans, the computer will calculate the number of tokens placed in the group account by each group member in each stage, and will inform you of your earnings. You should record this information on your record sheet.

The actual number of tokens a group member places in the group account in stage one is simply the number of tokens that person indicated in their stage one decision. The actual number of tokens a group member places in the group account in stage two will depend on that person's stage two decision, and the stage one decisions of the other two group members.

Suppose for example that the other two group members placed a total of three tokens in the group account in stage one. Then the first result screen will look like the one below (except the x's will be replaced with the numbers that you chose):

PARTICIPANT xx GAME x

STAGE ONE DECISION

I place x token(s) in the group account

STAGE TWO DECISION

Number of tokens placed in group account by other two group members in stage ONE	Number of tokens I place in the group account in stage TWO
0	x
1	x
2	x
3	x
4	x

THIS WAS YOUR PLAN. ACTUAL DECISIONS ARE HIGHLIGHTED.
PRESS TAB KEY TO CONTINUE

In this screen your actual choices are highlighted. The first highlighted number is the number of tokens you placed in the group account in **stage one**. Now look at the **stage two** decision. Since, in this example, the other two group members placed a total of 3 tokens in the group account in stage one, the number of tokens you placed in the group account in stage two is the number you entered in the highlighted row.

How you enter your decisions [DIRECT TREATMENT]

You will enter your decisions one stage at a time. At the beginning of the game you will see a screen like the one below:

PARTICIPANT x GAME xx

STAGE ONE DECISION

I place _____ token(s) in the group account

CHOOSE 0, 1 or 2
WHEN YOU HAVE TYPED YOUR DECISION PRESS THE ENTER KEY

This screen is for your **stage one decision**. Here you will indicate how many tokens you wish to place in the group account in stage one. You can choose 0, 1 or 2. When you have typed your decision, you should press the Enter key. Then the computer shows you your decision, and asks you whether you want to submit the decision. If you want to change your decision you should type N. If you are satisfied with your decision you should type Y. After you have typed Y your decision cannot be changed.

When all participants in the experiment have submitted their stage one decisions, the computer will calculate the number of tokens placed in each group account, and will inform you of the number of tokens in your private and group account, as well as of your earnings. You should record this information on your record sheet.

You will then be presented with a screen for your stage two decision. This screen will be identical to that of your stage one decision. Remember you are matched with the same group of people during stage one and stage two. After you have finished both stage one and stage two you will be informed of your total earnings from this game. You should record this information on your record sheet.

Practice Game

To illustrate how you enter your decisions and how earnings are determined we will go through a practice game. Nothing you do in the practice game will affect your payment in this experiment. For this practice game the decisions of the other two group members have been made by the computer. In the practice game the other two members of your group placed a total of 1 token in the group account in stage one and 3 tokens in stage two. These decisions were randomly chosen before the experiment, and are for illustrative purposes only.

Remember this is just a practice game and will not affect your final payment. It does not matter what you enter in the practice game. When everyone has finished the practice game we will continue with the instructions.

A Brief Review of the Experiment

Before we start the actual experiment we will briefly review the instructions.

1. You will be asked to perform the decision task five times. We refer to each decision task as a game.

2. You will be paired with two new participants in each game.

3. Each game will consist of two stages.

4. In each stage you will be given 2 tokens. You must place these tokens in either your private account or the group account. For each token you place in your private account you will receive £1.50. For each token you place in the group account all three members of the group will receive £1.

5. At the end of the experiment one game will be chosen at random and you will be paid in cash for your earnings in that game.

Now we are ready to begin game one. From now on you will be matched with real people and the decisions you make may influence your earnings. If you have a question at any time, raise your hand and a monitor will come to where you are sitting and answer it.

Appendix B. Data: Average contributions by treatment, session, game and stage.

		Strategy				Direct			
Game	Stage	Session 1	Session 2	Session 3	Session 4	Session 1	Session 2	Session 3	Session 4
1	1	1.00	1.00	0.93	1.00	0.93	0.93	1.13	0.33
	2	0.53	0.60	0.60	0.53	0.73	0.67	1.00	0.47
2	1	0.93	0.60	0.93	0.47	0.67	0.80	0.80	0.60
	2	0.73	0.53	0.60	0.40	0.20	0.47	0.40	0.80
3	1	0.80	0.87	0.87	0.73	1.00	0.67	0.73	0.60
	2	0.33	0.27	0.67	0.53	0.60	0.07	0.40	0.73
4	1	0.60	0.87	0.93	0.93	0.93	0.80	0.60	0.87
	2	0.27	0.27	0.67	0.40	0.33	0.27	0.53	0.20
5	1	0.47	0.80	1.00	0.53	0.47	0.73	0.67	0.33
	2	0.07	0.20	0.53	0.27	0.33	0.20	0.47	0.13

Average conditional contributions in strategy treatment. (2_0 indicates contribution in stage 2 if other group members contribute 0 in stage 1, etc.)

Game	Stage	Session 1	Session 2	Session 3	Session 4	Average
1	1	1.00	1.00	0.93	1.00	0.98
	2_0	0.27	0.20	0.27	0.13	0.22
	2_1	0.47	0.47	0.53	0.40	0.47
	2_2	0.67	0.87	0.87	0.47	0.72
	2_3	0.67	0.87	0.93	0.80	0.82
	2_4	0.53	0.93	0.87	1.07	0.85
2	1	0.93	0.60	0.93	0.47	0.73
	2_0	0.40	0.07	0.33	0.33	0.28
	2_1	0.40	0.33	0.67	0.27	0.42
	2_2	0.67	0.60	0.67	0.40	0.59
	2_3	0.87	0.67	0.87	0.73	0.79
	2_4	1.00	0.80	1.00	1.00	0.95
3	1	0.80	0.87	0.87	0.73	0.82
	2_0	0.13	0.27	0.33	0.33	0.27
	2_1	0.20	0.27	0.53	0.40	0.35
	2_2	0.47	0.47	0.80	0.40	0.54
	2_3	0.47	0.60	1.00	0.73	0.70
	2_4	0.73	0.87	0.87	0.93	0.85
4	1	0.60	0.87	0.93	0.93	0.83
	2_0	0.20	0.00	0.33	0.13	0.17
	2_1	0.40	0.13	0.40	0.20	0.28
	2_2	0.47	0.27	0.73	0.40	0.47
	2_3	0.33	0.53	0.87	0.67	0.60
	2_4	0.53	0.60	0.80	0.87	0.70
5	1	0.47	0.80	1.00	0.53	0.70
	2_0	0.07	0.00	0.33	0.27	0.17
	2_1	0.33	0.13	0.40	0.27	0.28
	2_2	0.40	0.27	0.53	0.27	0.37
	2_3	0.33	0.53	0.80	0.47	0.53
	2_4	0.67	0.73	0.80	0.60	0.70