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ORIGINAL PAPER

Conditional cooperation and group size: experimental evidence from a public good game

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Abstract
Conditional cooperation is the tendency to cooperate if and only if others do so as well. It is the most common behavior in social dilemmas. We study how the incidence of conditional cooperation in the public goods game, the most widely studied social dilemma in experimental economics, varies with group size. In a laboratory experiment, we apply the strategy method to elicit how participants' willingness to contribute to a public good depends on other group members' decisions. A within-subject design allows us to evaluate and compare an individual participant's contribution behavior in different-sized groups. Two main findings emerge. First, the share of players who are conditional cooperators is consistent across group sizes. Second, the strategies chosen imply that conditional cooperators hold a (correct) belief that others are more cooperative in a larger than in a smaller group.

Keywords Conditional cooperation · Public goods · Strategy method · Group size

JEL Classification C9 · H41

1 Introduction

The tension between self-interest and group-interest is at the heart of many situations in the social sciences. In economics, the most common paradigm to measure the extent of each of these motivations is the linear Public Good game. In this game, a group of players each receives an endowment and may contribute any portion of

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the endowment to a public good. The contribution of any one player yields a benefit to each player that is always less than the amount contributed, but the sum of these benefits is greater than the contribution. Thus, the game has the property that an increase in contributions always increases total group earnings, while each player has a dominant strategy to contribute zero. The contribution level of an individual or group can be interpreted as a measure of cooperativeness.

Experiments have shown that a group interacting repeatedly typically makes initial contributions at levels that are intermediate between self-and group-interested levels, but that cooperation decreases over time (Andreoni, 1988; Isaac & Walker, 1988). Allowing individuals to condition their decisions on the average contributions of other members of their group, using a strategy method experimental protocol, has revealed that a plurality of individuals are conditional cooperators (Fischbacher et al., 2001). These individuals contribute more if the average contribution of the rest of the group is higher. Less common are two other contribution patterns, the free-rider (who contributes zero regardless of the behavior of others, demonstrating only self-interested motivation) and the "hump-shaped player' whose contribution increases in the group average up to a certain level, beyond which it decreases in the group average. On average, conditional contributors do not exactly match the average of others, but rather try to get away with contributing somewhat less than the group average. This behavior is referred to as imperfect conditional cooperation (Fischbacher & Gaechter, 2010). With repetition of the game, it is clear that a group of imperfect conditional cooperators experiences a decline in average contributions.

Research on whether the average cooperation level increases or decreases with group size, all else equal, has yielded mixed results (Isaac et al. (1994), Isaac and Walker (Isaac & Walker, 1988), Carpenter (2007), Capraro and Barcelo (2015), Feltovich and Grossman (2015), Nosenzo et al. (2015)). However, no prior study that we are aware of has considered whether group size is a determinant of the propensity to be a conditional cooperator. Is one more likely to reciprocate the cooperative or selfish behavior of one other individual, a small group, or a relatively larger group?

This is the question that we take up in this study. We conduct an experiment in which we test whether conditional cooperation is more common in a group of 2, 4, or 8 individuals. The experimental design has a within-subject structure so that we are able to observe whether specific individuals change their contribution strategy as the size of their group changes. We can also observe the extent to which players are imperfect conditional cooperators.

Our focus is on one-shot games. Andreozzi et al. (2020) show that as the game is repeated, the incidence of conditional cooperators tends to decline while that of pure free-riders increases. We avoid this effect of repetition by not providing any feedback about others' behavior or own payoffs until after all tasks have been completed. This means that decisions cannot be affected by prior experience that might lead strategies to be updated as a consequence. Furthermore, the sequence of group sizes individuals face is counterbalanced in a manner that would nullify any trend in behavior that might occur in the absence of feedback when a comparison is made across conditions.

Observing the rules individuals use when gains from cooperation are possible is important. Previous studies have convincingly shown that conditional cooperation is a mechanism that enables cooperation to occur in social dilemmas. The willingness to cooperate if only if others do so as well creates incentives for others to cooperate and disincentives for them to defect. If the propensity to behave in this manner is greater in larger groups, it would suggest that cooperation is easier to maintain once it has been achieved in large groups than in smaller ones.

As the size of a group increases, a number of other key variables change as well. When the group size is larger, the total benefit of one's own contribution increases proportionately. The effect of a given increase in others' average contribution on one's own earnings also scales up proportionately. The average contribution of others is a complete description of others' behavior in a two-person group but is only a summary statistic for a larger group. In a large group, an individual may believe that some other members of the group contributed considerably more or less than the average and choose cooperation levels on the basis of these beliefs. Any of these forces might affect the incidence of conditional cooperation or free-riding.

We observe that there is less cooperation in the groups of two than in the larger groups, particularly among male participants. Nevertheless, the percentage of individuals classified as conditional cooperators is very similar under the three group sizes. A player's behavioral type tends to be quite stable at the individual level, regardless of group size. That is, a conditional cooperator in a group of four players tends to behave similarly in a group of 2 or 8. However, beliefs about other players seem to be more pessimistic and lead to lower actual observed cooperation in two-person groups.

2 Related Literature

Previous studies report mixed results regarding whether larger groups are more or less cooperative given the same marginal per-capita return from contributions. Isaac et al. (1994), Carpenter (2007), Zhang and Zhu (2011), Diederich et al. (2016), and Pereda et al. (2019) find that cooperation is greater in larger groups. On the other hand, Isaac and Walker (1988), Capraro and Barcelo (2015), Feltovich and Grossman (2015), and Nosenzo et al. (2015) report ambiguous results or no systematic relationship regarding the effect of group size on cooperation. In our view, the prior literature does not give us clear guidance about whether and how we should expect cooperation to depend on group size.

The widespread incidence of conditional cooperation in the Public Goods game has been convincingly demonstrated by Fischbacher et al. (2001) and Fischbacher and Gaechter (2010). These studies apply the strategy method to elicit participants' contingent willingness to contribute given the average contribution from other group members. They classify participants into categories. The two most common are the conditional cooperator, who is willing to contribute more the more other group members contribute; and the free-rider, who does not contribute at all regardless of the behavior of others. In the one-shot game studied by Fischbacher et al. (2001), 50% of participants are conditional cooperators and 30% are free-riders.[1]

If individuals cannot condition their decisions on others' behavior, as in strategy method protocols, conditional cooperators must choose their contribution based on their beliefs about the contribution of other group members. Such beliefs tend to be heterogeneous, even within a group. Kelley and Stahelski (1970) first observe that participants have heterogeneous beliefs about others in Prisoner's Dilemmas. Cooperators are relatively likely to believe that others are cooperative like themselves, while competitive players tend to hold the belief that others are competitive as well. Chaudhuri et al. (2017) use the heterogeneity of initial beliefs about the contributions of others to explain the decay of contributions over time in the public goods game. Ackermann and Murphy (2019) provide evidence that the distributions of preferences, beliefs, and behavior of a group in the first period of a repeated game predict behavior in later periods.

Fischbacher et al. (2001) classify participants into three types: free-riders, conditional cooperators, and "hump-shaped" contributors. With the application of hierarchical cluster analysis, Fallucchi et al. (2017) refine the model to allow for four categories of participants: own (payoff) maximizer, strong conditional cooperator, weak conditional cooperator, and "various". Thöni and Volk (2018) summarize 17 replication studies of Fischbacher et al. (2001) and provide a new classification scheme. They demonstrate that conditional cooperation is the predominant pattern and free-riding is frequent, with non-minimal unconditional cooperation very rare.

The fraction of conditional cooperators reported in a number of studies by various authors has been summarized by Fallucchi et al. (2017) and Thöni and Volk (2018). Fallucchi and al. report percentages of conditional cooperators of between 37.5 and 74.2% in six different studies, with an average across studies of 56.1%. Thöni and Volk consider 18 studies, all of which have group sizes between 3 and 5. They find percentages of conditional cooperators ranging between 40.7 and 77.6% with a mean across studies of 61.7%.

3 Experimental design

The experiment was computerized using the z-Tree software (Fischbacher, 2007). The sessions were conducted in person at the Economic Science Laboratory at the University of Arizona. The 66 participants (44 female, 22 male) were undergraduate students in the laboratory's subject pool who signed up for the sessions. There were 9 sessions and 8 participants per session.[2] A post-experiment questionnaire

[1] Boosey (2017) uses a similar strategy method, but allows players to condition their contributions on the average payoff, rather the average contribution, of other group members. He finds that players who condition on average payoff information about others contribute significantly less than those who condition on average contribution information.

[2] In four of the sessions, fewer than 8 individuals from the participant pool were present. In these sessions, graduate students participated in the session to fill out the groups. The graduate students are not included in our analysis. Since there was no feedback on others' actions before the end of the session and

identified individual characteristics such as gender and major. Participants were paid by Venmo at the end of their session. Earnings averaged $14.91 and sessions took on average 40 min to complete.[3]

In each period, each participant had an endowment of 20 points. The conversion rate was $0.10 for each point. Participants simultaneously chose how much of their endowment to contribute to the public good, referred to in the instructions as "investment" in a "project". The Marginal Per Capita Return (MPCR) was set at 0.7 so that contributing one point to the public good yielded a private marginal return of 0.7 points to each individual (including the contributor) and the marginal social benefit was $0.7n$, where n is the number of players in a group.

Thus, individual's payoff was given by $\pi_i = 20 - g_i + 0.7\Sigma_{j=1}{}^{n}\ g_j$, where g_i is player i's contribution. The value of the public good provided was $0.7\Sigma_{j=1}{}^{n}\ g_j$. The unique Nash equilibrium of this game, under the assumption that all individuals have selfish preferences, is for all group members to contribute nothing, that is, $g_j = 0$ for all j, leading to a socially inefficient outcome. The social optimum is for all individuals to contribute the entirety of their endowments.

After the experimenter read the instructions aloud, with participants following along on their computer screens, they were required to answer eight control questions. The questions involved computing each group member's payoffs for hypothetical examples of contribution profiles. The examples spanned all extremes of the decisions that could be made (0 to maximum possible contributions both for oneself and other group members), so that they would not bias participants toward particular decisions during the experiment. There followed a practice period with four-member groups.

The experiment followed the design in Fischbacher et al. (2001), who applied the strategy method (Selten, 1967) to elicit participants' contribution preferences. All participants played three periods of the experiment. In each period, participants made two decisions, an *Unconditional* and a *Conditional* contribution. The "Unconditional Investment" screen prompted participants to indicate how many points they would like to contribute to the project. They then completed an "Investment Table," in which they indicated how much they wanted to contribute to the public good, conditional on each possible average contribution level of other players in one's group.[4]

Figure 1 shows an example of an "Investment Table". Participants enter their contribution in response to each of 21 possible values (integers from 0 to 20) of the average contribution from the other group members. For instance, in the first space of the first column, participants need to enter the amount they would invest if the average investment of the others in their group was 0. Similarly, in the second space

Footnote 2 (continued)
participants were unaware of the presence of these additional individuals, the data of interest from the undergraduate participants are not affected by the presence of the graduate students.

[3] The study was not preregistered. While we view preregistration as a desirable practice, we believe that it is quite clear what we intended to study with this particular experiment. The data analysis we have conducted is also quite conventional and we report all of the analysis that we have conducted.

[4] In the table, the average contributions were expressed as integers. When the decisions were implemented, the average contribution of others in the group was rounded to the nearest integer.

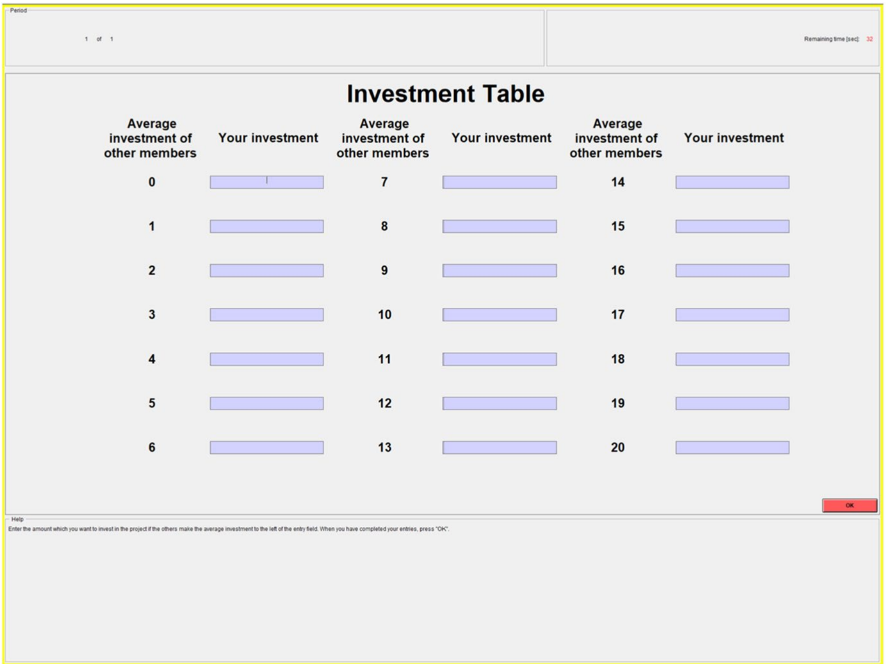

Fig. 1 Investment Table. Notes: Individuals were required to fill in the 21 blue fields. In each field, they indicated how many points they would contribute if the rounded average investment of the others in their group was the quantity indicated in the columns labeled "Average investment of other group members"

of the first column, they indicate their decision if the average of the others' investments was 1, and so on.

Either the unconditional or conditional decision could count toward a player's payoff, so that both decisions were incentivized. For all but one player in the group, the unconditional decision is implemented. The remaining player's conditional decision based on the average unconditional contribution of the other players then becomes operative. The player whose conditional contribution counts is chosen randomly after all players have submitted their decisions.

As an example, suppose that in a four-member group, the unconditional contributions of the four players are 0, 9, 20, and 11 points, respectively. Player 4 is randomly chosen to have her conditional contribution count. The average of the other three players' contributions is $(0+9+20)/3=9.67$ points, which rounds to 10. Suppose that in the row of the contribution table corresponding to 10, player 4 has chosen to contribute 15 points. Then the total amount contributed is $0+9+20+15=44$ points. In that case, each player earns 44×0.7 points, which is \$3.08, from the project. They receive this payment in addition to \$0.10 for each point that they did not invest.[5]

[5] Burton-Chellew et al. (2016) have argued that the strategy method protocol that we are using, though widely employed in the literature, generates confusion on the part of participants. They claim that some of the behavior that is interpreted as conditional cooperation reflects confusion instead. They show that,

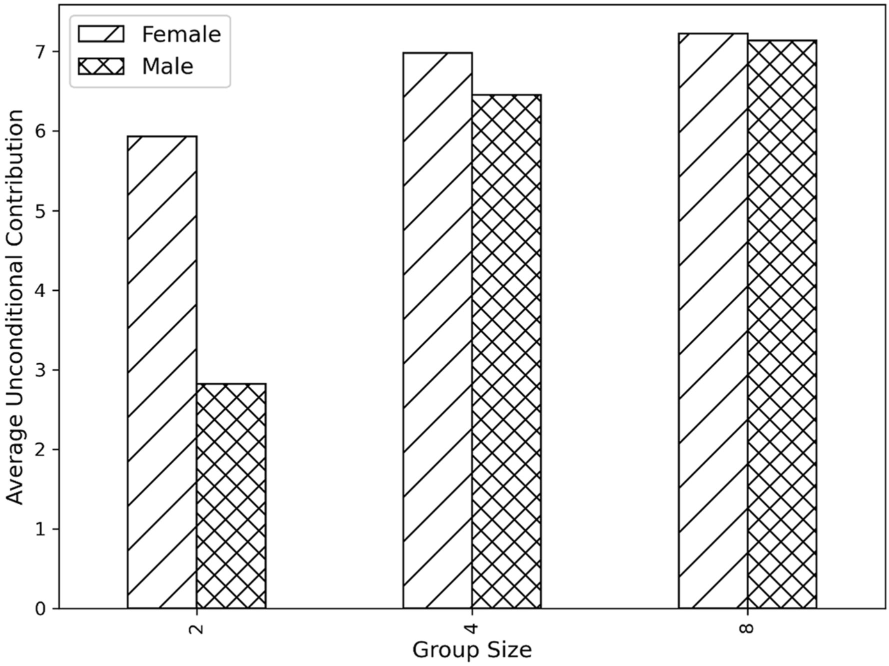

Fig. 2 Average unconditional contribution by group size and by gender

After each period, participants were reshuffled into new groups. Participants did not know who their group members were at any time. The outcome of each period was not released to participants until the end of the last period.

4 Experimental design

The average individual unconditional contribution in the two-, four-, and eight-member groups is 4.9, 6.8, and 7.2 points, respectively. Figure 2 shows the average contribution level in the three conditions, by gender. On average, female participants contribute more than male participants under each group size, though the difference

Footnote 5 (continued)

with a demographically representative sample of the population, many individuals submit increasing contribution functions even when facing computerized players who cannot earn any benefit from their cooperation. Since we use procedures that are standard in the literature, their critique might be applied to our study. However, our participants are undergraduate students who typically have considerable experience with other laboratory experiments, including with complex paradigms such as asset markets, auctions, and transportation route choice experiments. As such, they have considerable sophistication when facing a new experiment. We cannot rule out that some confusion may be present, but we believe that it is at most at a modest level.

Table 1 Distribution of single- and multi-period types by group size

Type	Two-member group	Four-member group	Eight-member group
Single period type			
Free-rider	25.76% ($n=17$)	18.18% ($n=12$)	16.67% ($n=11$)
Conditional cooperator	45.45% ($n=30$)	48.48% ($n=32$)	48.48% ($n=32$)
Hump-shaped	13.64% ($n=9$)	13.64% ($n=9$)	19.7% ($n=13$)
Other	15.16% ($n=10$)	19.7% ($n=13$)	15.16% ($n=10$)
Multiple period type			
Stable	66.67% ($n=44$)		
Switch in	7.58% ($n=5$)		
Switch out	4.55% ($n=3$)		
Other	21.21% ($n=14$)		

Notes: Upper row of data contains percentages of individuals the coders classified as each type in each game. Free-rider contributes 0 regardless of others' behavior. Conditional cooperator contributes more as others contribute more. Hump-shaped has contribution increasing in others' average cooperation level up to a certain level and then decreasing beyond that level. Stable multi-period type indicates an individual with the same single-period type for the three games. Switch-in (out) type is a conditional cooperator in larger (smaller) groups only

is significant only in two-member groups, with a *t* test rejecting the hypothesis that the average contribution of women and men is the same at $p<0.056$.[6]

We follow Fischbacher et al. (2001) and classify each participant's conditional contribution decisions as one of three distinct types: conditional cooperation, free-riding, and hump-shaped contributions. To classify individuals, we recruited three independent coders, who were undergraduate students drawn from the same subject pool as the other participants in the study. We showed each of them a graphic of each participant's conditional contribution function, as displayed in Figs. 4, 5, 6 in Appendix A. The coders were asked to classify each individual as the type that their behavior most closely reflected. If two or more coders agreed with regard to an individual, we classify that individual as the agreed-upon type. The script given to coders is shown here as Appendix C. The category under which each individual was classified is indicated in the captions below Figs. 4, 5, 6 in Appendix A.[7]

Table 1 shows the resulting distribution of types. Fischbacher et al. (2001) observed that half of their participants were conditional contributors. The proportion in our data is very similar. The upper half of the table is the corresponding data from this study. A near-majority of participants (45.45–48.48%) are conditional

[6] In groups of 2, $t=2.112$ and $p=0.0386$. In groups of 4, $t=0.322$ and $p=0.7488$ and in groups of 8, $t=0.05$ and $p=0.96$. The significance of the gender difference for two-player groups does not survive correction for the testing of multiple hypotheses.

[7] An alternative to using coders to classify individuals into types would be the use of a clustering algorithm. While doing so provides in a sense more objectivity, the result is very sensitive to the form of the clustering specified in the algorithm. We are primarily interested in how an individual's strategy is subjectively interpreted by a human observer who could invoke their own impressions about the intent of an individual when choosing their classification.

cooperators, regardless of group size. When the group size increases from 2 to 8, the fraction of free-riders decreases from 25.76 to 16.67% because some free-riders shift to be conditional cooperators or hump-shaped contributors in larger groups. The fraction that are hump-shaped contributors increases from 13.64 to 19.70%. Nevertheless, these differences are small and there are no statistically significant differences in the distribution of types among the three different group sizes. A two-tailed Kolmogorov–Smirnov test yields $D = 0.045$, $p = 1$ for a comparison between two- vs. four-member groups; $D = 0.045$, $p = 1$ for four- vs. eight-member groups; and $D = 0.061$, $p = 1$ for two- vs. eight-member groups.

We now consider how individuals' types respond to changes in group size. We classify individuals into four categories. These are *Stable*, *Switch-in-Cooperation*, *Switch-out-Cooperation* and, if a participant does not satisfy the criteria of any of the three categories, they are assigned to the *Other Pattern* category. A "Stable" type has the same single-period classification under each of the three group sizes. For example, Participant 1 is a Stable Free-Rider. If a participant's decision type changes to conditional cooperation when the group size is larger, the pattern is referred to as "Switch-in Cooperation". Participant 29 is a free-rider in relatively small groups but changes to be a conditional contributor in the eight-member group, and is, therefore, classified as a Switch-in cooperator. Another example is participant 66, who changes from a hump-shaped contributor in their two-member group to a conditional contributor in the eight-member group. On the other hand, "Switch-out Cooperation" describes the behavior of an individual who changes from conditional cooperation to another type when the group size increases. Participant 46 is an example of a Switch-out cooperator.

Forty-four participants (67%) are stable in their behavior. Five participants (8%) are of the "Switch-in-cooperation" type. In their two-member groups, three of them are free-riders and one has a hump-shaped contribution function. They all become conditional cooperators in the eight-member group. The "Switch-out-cooperation" type includes three participants (5%). Their contribution decisions exhibit conditional cooperation in the two-member group but not in larger groups.[8]

Figure 3 displays the average contribution functions of Stable Conditional Contributors. The functions are very close to each other, indicating that individuals' average reaction to their counterpart in a two-member group is very similar to their response to average behavior in a group of 4 or of 8. The slope of the curves is less than 1, which implies that the representative conditional cooperator is imperfect and is seeking to contribute less than the group average. The average conditional contribution functions have slopes of 0.758, 0.783, and 0.800 in two-, four- and eight-member groups respectively. The overall average slope is approximately 0.78.

Since the conditional cooperators typically have strictly monotonic contribution functions, their unconditional contribution decision implies a belief about how much others are contributing. The fact that unconditional cooperation is increasing in group size,

[8] Participants 1, 3–7, 9–17, 19, 20, 24, 25, 28, 30, 31, 35, 37, 39, 40, 42–45, 47, 49, 51–58, and 62–65 are classified as Stable. Participants 8, 29, 36, 60, and 66 are Switch-in Cooperators, while participants 26, 46, and 61 are Switch-out Cooperators. The remaining individuals: 2, 18, 21–23, 27, 32–34, 38, 41, 48, 50, and 59, are classified into the "Other pattern" category.

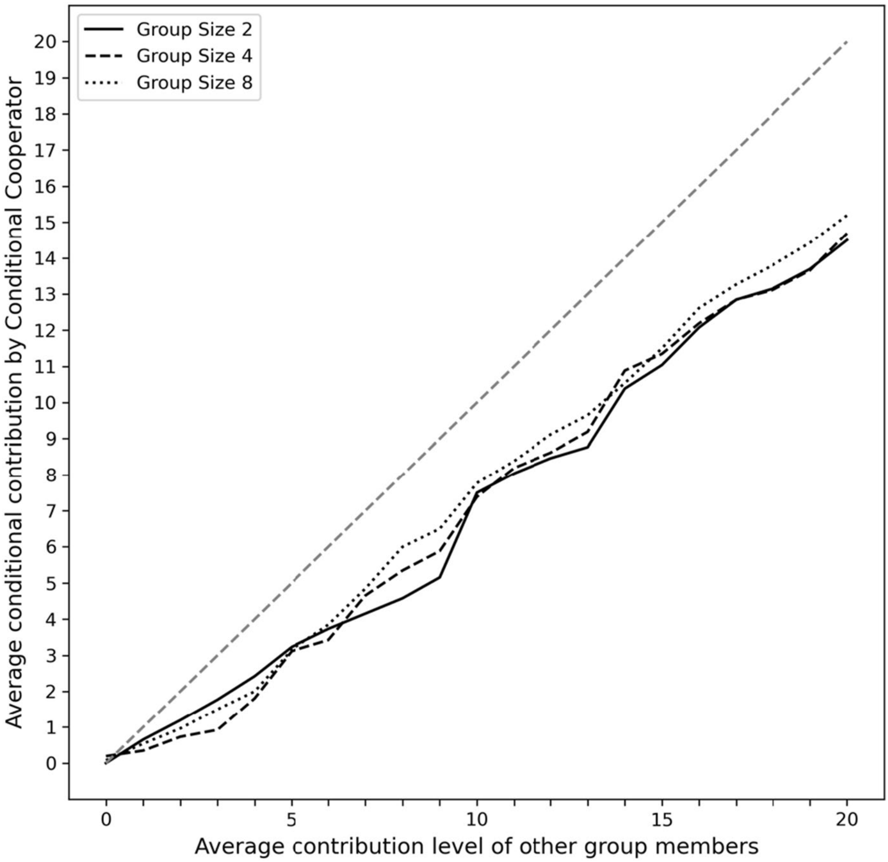

Fig. 3 Average conditional contribution function submitted by stable conditional contributors for each group size

coupled with the fact that conditional contribution functions are similar in the three treatments, suggests that conditional cooperators (correctly) believe that other group members contribute more in larger groups.

5 Conclusion

We find that the incidence of conditionally cooperative behavior does not vary across group sizes. Just under 50% of participants are conditional cooperators in each of the group sizes that we have studied. More generally, there are no significant differences in the distribution of types of strategy across treatments. Moreover, there is strong stability at the level of the individual in that participants keep their contribution functions similar under all three group sizes. On average, these functions tend to exhibit imperfect conditional cooperation, the intention to contribute at a level that is increasing in others' average contribution, but still below the average.

The stability of behavior across groups is not a consequence of the within-subject design of the experiment. Individuals are not using the same strategies because of a failure to recognize that the environment is different under different group sizes. This is clear because the average unconditional contribution is significantly lower in the two-person groups than in the larger groups. This pattern shows that behavior is responsive to group size even if conditional contribution functions are not.

We have shown that conditional cooperation and free-riding are behaviors that are robust to changes in a key parameter of a social dilemma. It remains to be tested whether they are stable over long periods of time and across different games. Indeed, it may be the case that the tendency to be a conditional cooperator or a free-rider is a trait that informs an individual's behavior in a general manner. A design feature of all of the experiments in the literature is that individuals can only condition their contributions on the average contribution of other players. It would be interesting to allow players to condition on the minimum, maximum or median contribution of other players, or indeed to choose which statistic of others contributions to respond to.

Since unconditional contributions are relatively low in two-person groups and conditional contribution functions are consistent across group sizes, it must mean that participants in two-person groups believe that their counterpart is contributing less than the average player in a larger group. This belief turns out to be correct, as unconditional contributions are indeed lowest in two-member groups.

In our environment, the marginal per-capita return is held constant, so that as the number of members in a group increases, so does the total benefit of any given contribution by a group member. This feature of the environment characterizes some public goods in the field. An example is the cleaning up of a public park: the benefit of the cleaning increases the greater the number of visitors to the park. A related environment that might lead to different outcomes is one in which the total benefit of an individual's contribution is independent of the number of recipients. In this environment, the marginal per-capita return decreases as the group size grows. This situation describes, for example, a fixed cash donation to a charity: as the number of beneficiaries increases, the donation is divided among a greater number of people and each individual receives less. It may be the case that in such an environment, the incidence of conditional cooperation changes with group size. This question would be an interesting one for future study.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40881-023-00152-4.

Data availability The replication material for the study is available at https://doi.org/10.17605/OSF.IO/AJZBE.

Appendix

A: Figures

See Figures 4, 5, 6

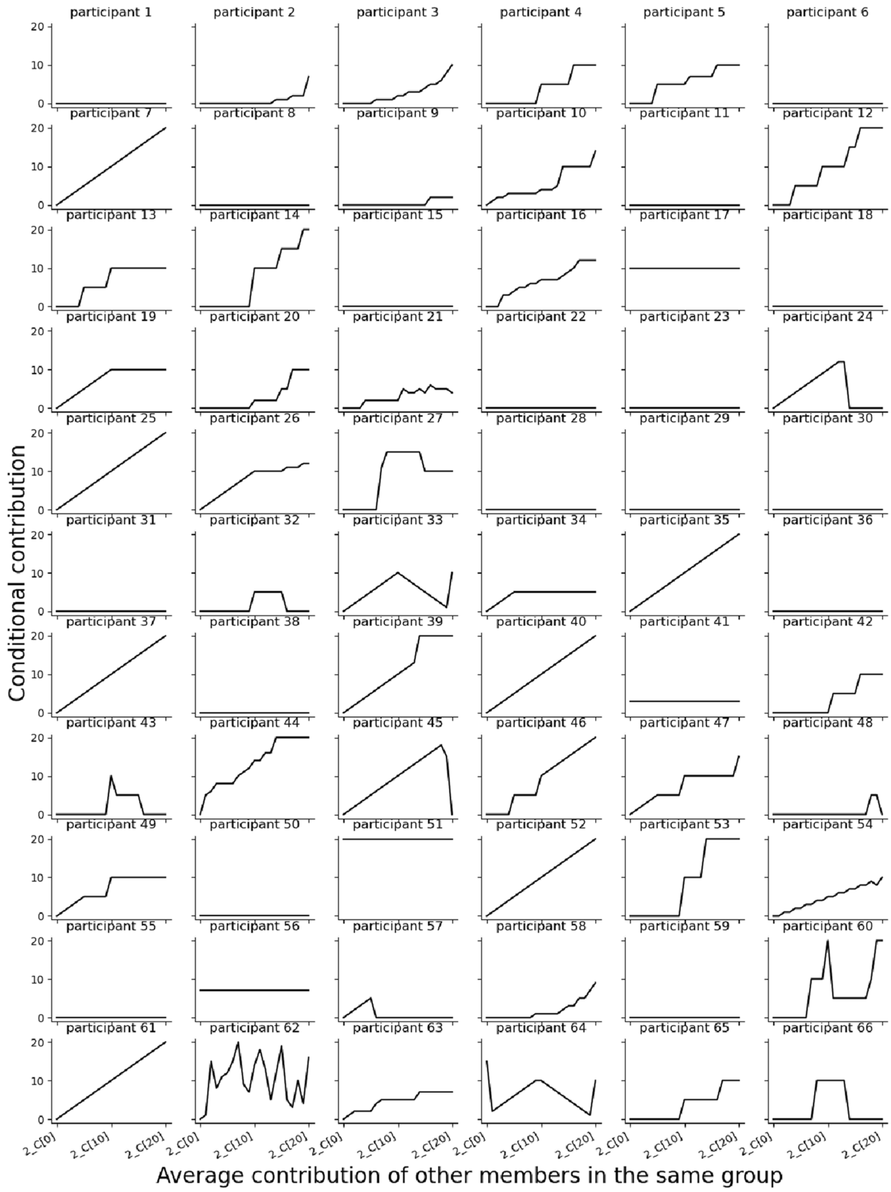

Fig. 4 Individual conditional contribution functions in two-member groups. Free-riders: Participant No. 1, 6, 8, 11, 15, 18, 22, 23, 28–31, 36, 38, 50, 55, 59. Conditional cooperators: Participant No. 2–5, 7, 10, 12–14, 16, 19, 20, 25, 26, 35, 37, 39, 40, 42, 44, 46, 47, 49, 52–54, 58, 61, 63, 65."Hump-shaped": 21, 24, 27, 32, 43, 45, 48, 57, 66 Other patterns: Participant No. 9, 17, 33, 34, 41, 51, 56, 60, 62, 64

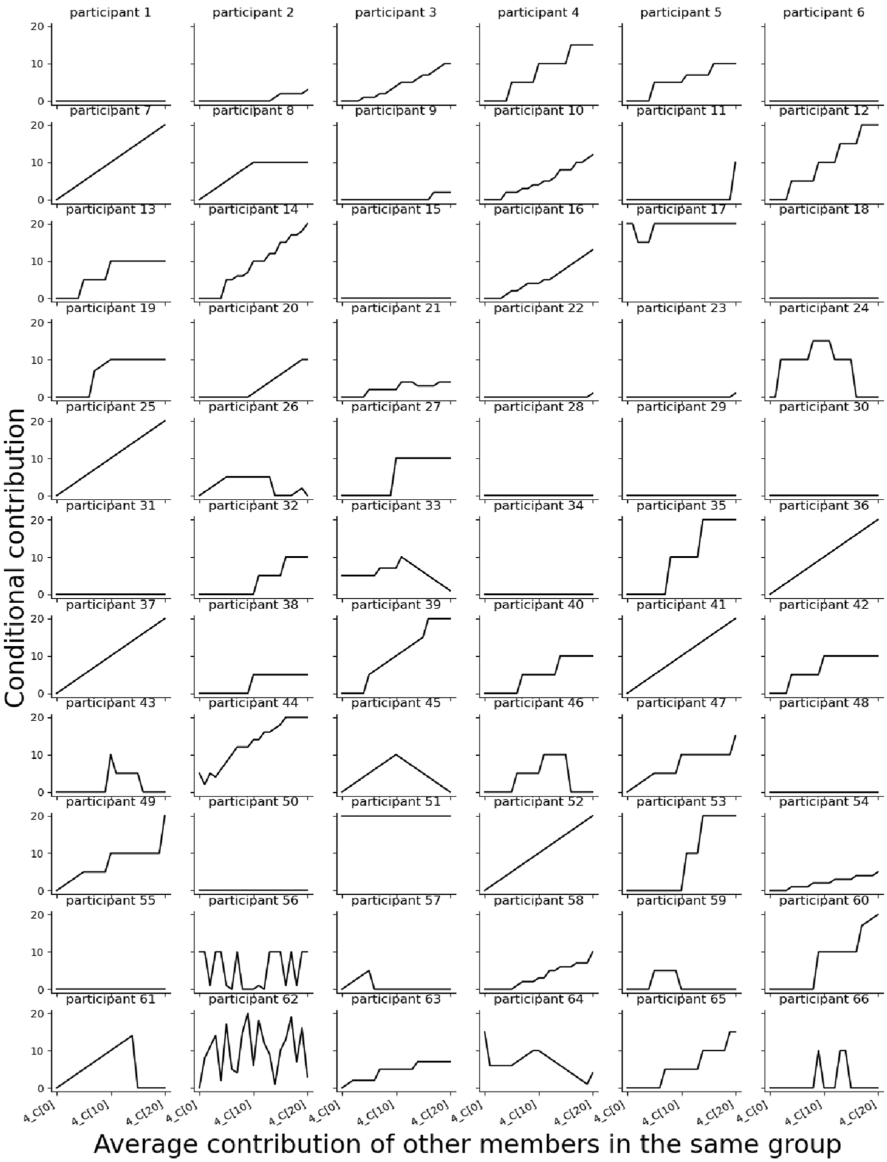

Fig. 5 Individual conditional contribution functions in four-member group. Free-riders: Participant No. 1, 6, 15, 18, 28–31, 34, 48, 50, 55. Conditional cooperators: Participant No. 3–5, 7, 10, 12–14, 16, 19–21, 25, 27, 32, 35–37, 39–42, 44, 47, 49, 52–54, 58, 60, 63, 65."Hump-shaped": 24, 26, 33, 43, 45, 46, 57, 59, 61. Other patterns: Participant No. 2, 8, 9, 11, 17, 22, 23, 38, 51, 56, 62, 64, 66

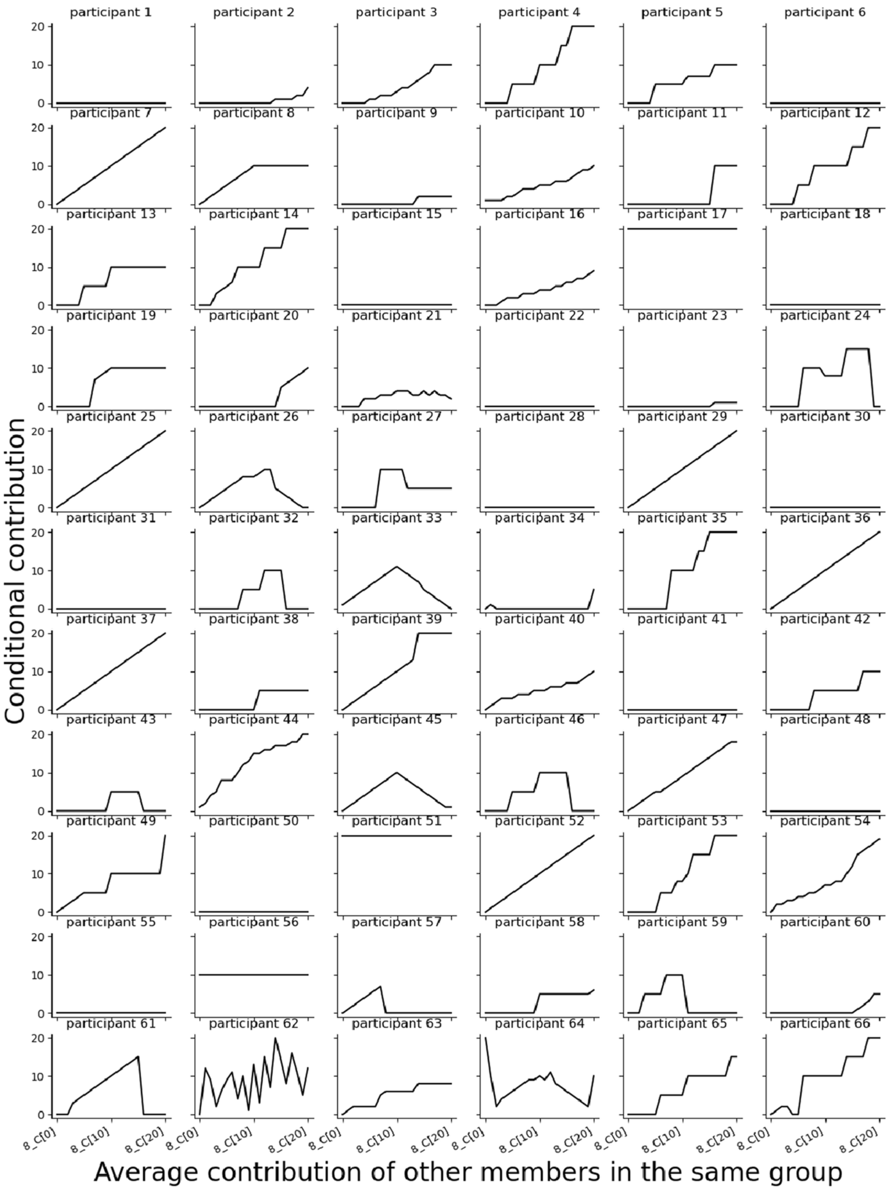

Fig. 6 Individual conditional contribution functions in eight-member groups. Free-riders: Participant No. 1, 6, 15, 18, 22, 28, 30, 31, 41, 48, 55. Conditional cooperators: Participant No. 2–5, 7, 8, 10, 12–14, 16, 19, 20, 25, 29, 35–37, 39, 40, 42, 44, 47, 49, 52–54, 58, 60, 63, 65, 66."Hump-shaped": 21, 24, 26, 27, 32, 33, 43, 45, 46, 50, 57, 59, 61. Other patterns: Participant No. 9, 11, 17, 23, 34, 38, 51, 56, 62, 64

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