



Public good provision by large groups – the logic of collective action revisited

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ABSTRACT

The organization of collective action is extremely important for societies. A main reason is that many of the key problems societies face are public good problems. We present results from a series of laboratory experiments with large groups of up to 100 subjects. Our results demonstrate that large groups, in which the impact of an individual contribution (*MPCR*) is almost negligible, are able to provide a public good in the same way as small groups in which the impact of an individual contribution is much higher. Nevertheless, we find that small variations in *MPCR* in large groups have a strong effect on contributions. We develop a hypothesis concerning the *interplay* between *MPCR* and group size, which is based on the assumption that the saliency of the advantages of mutual cooperation plays a decisive role. This hypothesis is successfully tested in a second series of experiments. Since Mancur Olson's "Logic of collective action" it is a commonly held belief that in large groups the prospects of a successful organization of collective actions are rather bad. Our results, however, suggest that the chance to successfully organize collective action of large groups and to solve important public good problems is much higher than previously thought.

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1. Introduction

The organization of collective action is extremely important for societies. A main reason is that many of the key problems societies face are public good problems. Let us consider two prominent examples. In many cases, solving environmental problems requires collective action, because environmental goods are often public goods. When environmental problems are international, such as the climate problem, national government interventions are not enough. What is needed is cooperation by large groups of people. This is also the basis for producing another, highly important public good: democracy. A

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functioning democracy requires that a large group of citizens does not only make use of their right to vote, but is also prepared to inform themselves about politically relevant issues and to participate in the process of democratic decision-making. Expressed in the terms of contemporary experimental research on public good provision, these kinds of problems concern large groups with a low marginal per capita return (*MPCR*) on contributions to the public good. There is a very large body of literature dealing with public good experiments.¹ But due to capacity limits (e.g., lab space and number of subjects available) and budget constraints, nearly all of these experiments are conducted with small groups and high *MPCR*. In this paper, we report a series of laboratory experiments with large groups of up to 100 subjects, in which the impact of an individual contribution is almost negligible. We provide the first systematic investigation of public good problems with large groups with low *MPCRs* based on a design that is comparable to that employed in the many previous experiments investigating small groups.

The first question we investigate is based on Mancur Olson's book "The logic of collective action", published in 1965. Mancur Olson's theory has had a decisive influence on the scientific understanding of the public good problem – not only in economics. His main hypothesis concerns large groups. In large, latent groups, the contribution that an individual can make to the public good is so small that it is hardly noticed by the other group members. Olson concludes that cooperative behavior in large groups is therefore not rational – not even for people with altruistic preferences.² Olson's conclusion is therefore: "The larger a group is, the farther it will fall short of obtaining an optimal supply of any collective good, and the less likely that it will act to obtain even a minimal amount of such a good. In short, the larger the group, the less it will further its common interest." (p. 36) In this paper, we report on the results of two experimental research projects. In the first project, we particularly focus on what we call the "Olson hypothesis":

"Large groups with a very low *MPCR* close to zero are unlikely to provide the public good."

This hypothesis has far-reaching implications. It suggests, that problems of the kind mentioned above will be exceedingly difficult to solve, if not insurmountable. If Olson's logic of collective action holds, significant contributions to a public good are unlikely to occur in large groups.

We ask whether this hypothesis is correct and conduct experiments with large groups of 60 and 100 and very low *MPCRs* of 0.02 and 0.04. We develop a new connected-lab design, which allows running the experiment under laboratory conditions with subjects interacting simultaneously in real time. We find that the Olson hypothesis cannot be confirmed. Large groups of 60 or 100 members and with low *MPCR* are able to create a public good in the same way as small groups with high *MPCR*.

One may argue that experiments with small groups with rather high *MPCRs* of around 0.4 already provide a test of Olson's theory³. After all, theory predicts that any group with an *MPCR* smaller than one will not provide the public good. But, although experiments with small groups have shown that the Nash-equilibrium of no cooperation cannot be observed, this does not rule out that the Nash-equilibrium will be observed in large groups with low *MPCR*. The Olson hypothesis aims exactly at this combination of group size and *MPCR* value. In our view, this reflects the most common interpretation of Olson's work.

Two studies, namely by Isaac et al. (1994) and Diederich et al. (2016), already consider public good games with large groups with 60 or more members. But their *MPCRs* of 0.30 and 0.75, respectively, are rather high. Diederich et al. (2016) explicitly compare the cooperation of small and large groups using an internet-based design. They find a positive group size effect. Larger groups reach higher degrees of efficiency. Although this is a very interesting finding (which is confirmed in this study), their experiment is not designed to test the Olson hypothesis because the *MPCR* is too high. Isaac et al. (1994) implemented one treatment in which seven groups of 40 faced a very low *MPCR* of 0.03. Six of these groups participated in a multiple-session design (in which the ten rounds were played over several days) and were incentivized by extra credits while one group participated in a single-session design (in which the ten rounds were played "over a relatively brief time span", p. 5) and was paid out in cash. The behavioral patterns observed by Isaac et al. (1994) for this treatment are generally in line with the patterns found in small groups: average first-round contributions are larger than zero and average contributions fall with repetition.⁴ However, compared to treatments with equal group size but much higher *MPCRs* (0.30 or 0.75), they find a lower initial average contribution and a much faster decay of average contributions. In the one group with a single-session design, cooperation decreases to about 5% in round 5 and to 0% in the final 10th round. This latter observation seems to be in line with Olson's hypothesis, but is restricted to one group only. Furthermore, Schumacher et al. (2017) also use large groups (up to 32 subjects) but investigate a different research question. In their experiment, a subject could decide whether a good is provided that benefits himself or one other person but creates costs for a group of people. The size of this group is varied.

The second question we address in this paper is about the determinants of cooperation behavior of large groups: When does the organization of a collective interest succeed? The answer to this question is of eminent importance for modern societies, because it provides the basis for potential solutions for public good problems.

¹ For an early overview see Ledyard (1995) and for a more recent selective survey see Chaudhuri (2011).

² "Selfless behavior that has no perceptible effect is sometimes not even considered praiseworthy. A man who tried to hold back a flood with a pail would probably be considered more of a crank than a saint, ..." (Olson 1965, p. 64).

³ We thank an anonymous referee for pointing this out.

⁴ This particularly holds for the six groups of the multi-session treatment who were incentivized by extra credits.

The results of our first project not only reveal that large groups are just as capable of providing public goods as small groups. They also show that with a given *MPCR* the group effect is positive⁵ (i.e., the groups of 100 make higher average contributions than the groups of 60) and that very small changes in the *MPCR* (i.e., the reduction from 4 cents per Euro investment to 2 cents per Euro) have large negative effects on contributions. These findings suggest that neither the group size alone nor the *MPCR* alone determines the contribution behavior. Rather, it depends on the interaction of both variables.

In the second project we present, we derive a hypothesis, on how this interaction could look like. Based on the observations of the first project, we develop the thesis that the provision of public goods is driven by the *salience* of the mutual advantage of cooperation.⁶ Our experimental findings suggest the *MPCR*-distance as a proxy for salience. The *MPCR*-distance is the difference between the *MPCR* used in the experiment and $1/N$, the minimum value of the *MPCR* necessary to create a public good problem.⁷ The higher this distance, the more salient is the advantage of cooperative behavior. We successfully test this hypothesis in another series of experiments conducted in our second project.

Our *MPCR*-distance explanation is not to be understood as a substitute for existing theories, which for example explain why contributions in repeated public good experiments are declining (Fischbacher and Gächter, 2010). Rather, our explanation complements these theories as it accounts for the *level* of contributions. It describes the conditions under which the average level of contributions made by large groups is higher or lower, while Olson's theory suggests that contributions are always zero when the *MPCR* is negligible. Our experiments suggest that members of large groups need to recognize that it is more beneficial for everyone to cooperate in order to be willing to cooperate at all. This idea is of great social importance. It highlights that the benefits of cooperation need to become widely known in order to foster cooperation of large groups. We will return to this point in the discussion section.

The contribution of our paper is three-fold. First, we provide evidence that the Olson hypothesis does not hold. Second, we provide an explanation for observed behavior by identifying the salience of the mutual benefits of cooperation as a driver of cooperative behavior. Third, we provide a methodological contribution as we develop a new connected-lab design that allows experiments with large groups to be run under controlled conditions. In all our treatments student subjects interact simultaneously and are incentivized with cash. Therefore, our results can be directly compared to the large body of evidence from experiments conducted with small groups.⁸

Our paper proceeds as follows. Section 2 introduces the design and the results of our experimental sessions run to test the Olson hypothesis. It also includes our conjecture on the specific interplay of *MPCR* and group size, which is based on these results. Section 3 presents the design and the results of our experimental sessions run to test this conjecture. Section 4 contains the discussion of our findings.

2. Experimental test of the Olson hypothesis

2.1. Design and procedure

Our design is based on the Voluntary Contribution Mechanism (VCM) introduced by Isaac et al. (1984). Let z_i denote the initial endowment of group member i , b_i the individual contribution to the provision of the public good, and α the return every group member receives if one monetary unit is invested in the production of the public good. The marginal return on the share of z_i that is not invested in the public good is normalized to 1. Then α is identical to the *MPCR* of investments in the public good. If N is the number of group members, group member i 's payoff π_i is

$$\pi_i = (z_i - b_i) + \alpha \sum_{j=1}^N b_j . \quad (1)$$

A cooperation problem arises if the following holds:

$$\alpha < 1 ; N\alpha > 1 \text{ and, thus, } \alpha > 1/N. \quad (1')$$

An individual investing one monetary unit in the public good receives a return of α . Since $\alpha < 1$, not investing is more profitable than investing from the individual's point of view. The return of each monetary unit he keeps is equal to 1. However, since $\alpha > 1/N$, investing is efficient from the group perspective. Clearly, the cooperation problem becomes more and more severe as α decreases, since the individual loss arising from contributing to the public good $(1 - \alpha)$ increases.

⁵ As it is the case in Diederich et al. (2016).

⁶ Our notion of salience has some links to the burgeoning research field analyzing the salience phenomenon – starting with Bordalo et al. (2012a, 2012b). Our research differs, however, in that we do not create salience by proposing two options a subject has to choose from. In contrast, we analyze in between-subject public good games whether different combinations of *MPCR* and group size are more salient than others by attracting players' attention to the advantages of mutual cooperation.

⁷ This holds if the return on the private good is normalized to 1.

⁸ This differs from the design used by Isaac et al. (1994) and Diederich et al. (2016) in several ways. Most importantly, all sessions in Diederich et al. (2016) and most sessions in Isaac et al. (1994) are based on a multi-session design in which the experiment lasted over several days and in which the default of a subject's decision was set to zero-contribution when he or she did not participate in a round. Isaac et al. (1994, p. 5) state, "Unfortunately, the effective size of laboratory experiments has been limited by both the expense of subject payments and by the capacity constraints of existing laboratories". Therefore, for about 90% of their sessions they employ a multi-session design using extra-credit point incentives for volunteers from undergraduate microeconomic theory classes who sometimes took part in more than one session.



Fig. 1. The four connected laboratories in Germany.

Table 1
Treatment parameters and participants' characteristics.

Treatment	N	MPCR	Sessions/indep. obs.	Lab	Age in years (mean)	Female dummy (mean)
8-0.25	8	0.25	8	Connected	23.297	0.547
8-0.25-L	8	0.25	8/32	Local	22.773	0.590
60-0.02	60	0.02	8	Connected	22.979	0.519
60-0.04	60	0.04	8	Connected	23.125	0.517
100-0.02	100	0.02	8	Connected	23.709	0.439
100-0.04	100	0.04	8	Connected	23.169	0.487

Note: The table shows the parameters of the six treatments. In each treatment, we conducted eight sessions. Due to no-shows, in two sessions of 100-0.02 less than 100 subjects participated (98 and 99). In seven sessions of 100-0.04 we had less than 100 participants (89, 93, 93, 96, 96, 97, and 99). The table also summarizes the average age of participants and the share of female participants.

Due to (1') the $MPCR$ (α) is bounded by $1/N$. In small groups, the value of the $MPCR$, therefore, has to be relatively high for a cooperation problem to arise, while this does not hold for large groups.⁹

Running large-group laboratory experiments for our first project would have required a laboratory where 100 subjects could interact simultaneously. Given the limited capacity of seats in experimental laboratories, we set up a sufficiently large virtual lab by connecting four different laboratories in Germany via the Internet. In all treatments – except for one small-group condition – we employed the connected-lab design: in this design, all groups consisted of subjects located at the laboratories of the Universities of Bonn, Duisburg-Essen, Göttingen, and Magdeburg (see Fig. 1) who simultaneously decided on their individual contributions to the public good. The laboratory in Magdeburg coordinated all the sessions. We used zTree (Fischbacher, 2007) for obtaining subjects' decisions and Skype for communicating between the laboratories. When entering the respective laboratory, subjects could see a (soundless) video conference of the four laboratories on a computer screen. Thus, each subject had the opportunity to verify that all laboratories were indeed connected and subjects were interacting simultaneously in real time. Subjects were not informed about the locations of the other laboratories.

In all the treatments employed to test the Olson hypothesis, a standard linear ten-round public good game with partner-matching was played. The payoff function corresponds to (1) in all treatments, with $z_i = 120$ Euro cents in each of the ten rounds. We collected data for eight groups in each treatment, i.e. we have eight independent observations per treatment.

We conducted treatments with groups consisting of 8, 60, and 100 members (see Table 1).¹⁰ Recall that due to (1'), the $MPCR$ is bounded by $1/N$, i.e. we cannot run all small- and large-group sessions with the same low $MPCR$. For groups of 8, we conducted two treatments with an $MPCR$ of 0.25 to test if the connected-lab design has an impact on behavior. As in all connected-design treatments, in 8-0.25, the members of each group were equally distributed over the four labs (i.e., in this

⁹ See Appendix A for a discussion of the connection between Olson's theory and the VCM literature.

¹⁰ Because of no-shows, less than 100 subjects per group participated in two sessions of 100-0.02 and in seven sessions of 100-0.04, the average numbers being 99.625 and 95.375, respectively. All parameters based on group size were adapted in the respective sessions and subjects were informed about the correct number of participants. We also adjusted our data analyses accordingly. Since each individual decision in the first round is an independent observation, we can check if groups of less than (but close to) 100 behaved differently from those with exactly 100 subjects. We find no significant difference ($p = 0.136$, $n = 797$ for 100-0.02 and $p = 0.390$, $n = 763$ for 100-0.04, two-sided Mann-Whitney U tests).

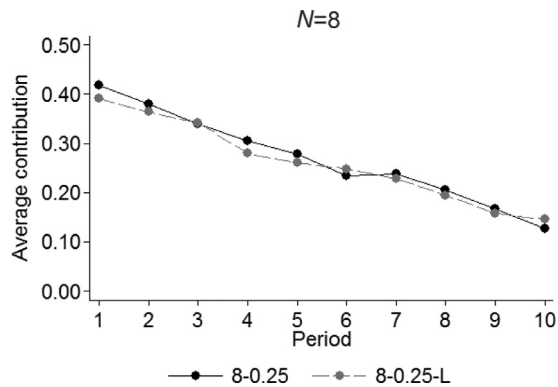


Fig. 2. Average share of contributions in treatments 8-0.25 and 8-0.25-L.

Note: The graph shows the average contributions in each round as share of the endowment.

treatment there were two subjects in each lab) whereas in the control treatment without a connected-lab design, 8-0.25-L, the eight subjects played locally in each of the labs.

At the beginning of each experimental session, subjects received written instructions.¹¹ Before the start of the first round of the public good game, participants had to answer several questions concerning the payoff rules of the game in order to ensure that they had understood the game correctly. In all treatments, subjects were informed after each round about the amount they had kept, their own contribution, the average contribution to the public good of all group members¹², their individual payoff from the public good, their individual earnings in the round just completed, and the cumulated earnings over all previous rounds. They knew that they would be re-matched with the same people in each round and that the experiment would be finished after ten rounds. After round 10, subjects were paid their earnings over all 10 rounds in cash and left.

The sessions lasted for about 90 min and the average earning was 15.23 Euros. Subjects were recruited via ORSEE (Greiner, 2015). A total of 2,840 different subjects participated in the six treatments and each subject participated in one session only. All sessions were run according to the same protocol.

2.2. Results

2.2.1. Impact of connected-lab design

In our first project, before testing the Olson hypothesis, we also study whether the connected-lab design has an impact on subjects' behavior using small groups. First, we find the behavior in treatments 8-0.25 and 8-0.25-L follows the same pattern of contribution decline that is typically found in ten-round public good experiments with small groups of $N \leq 10$ and $MPCRs \geq 0.30$ (cf. Footnote 1): on average, contributions start somewhere between 30% and 50% of the endowment and then decrease from round to round. In our treatments, average first-round contributions are 41.8% and 39.1% in 8-0.25 and 8-0.25-L, and decrease to 12.6% and 14.6%, respectively, with overall average cooperation rates of 26.9% and 26.1% (Fig. 2 and Table 2). Second, we cannot reject the hypothesis that average contributions are unaffected by the treatment variation. We find no significant difference between local groups and groups in the virtual lab, neither regarding average contributions over all ten rounds nor concerning average contributions in each of the rounds.¹³ From a methodological point of view, this finding is good news because it appears that the capacity of laboratories can be multiplied by connecting them virtually without inducing significant behavioral effects.

2.2.2. Testing the Olson hypothesis

The Olson hypothesis says that large groups with an $MPCR$ close to zero are unlikely to provide the public good. In contrast, small groups with a much higher $MPCR$ will be able to provide a considerable amount of it. In our experiment this would mean that average cooperation rates of large groups should not be significantly different from zero. Furthermore, the cooperation rates should be significantly smaller than those observed for small groups. We tested this hypothesis by using large groups of 60 and 100 subjects and very low $MPCRs$ of 0.02 and 0.04 (Table 1). Treatment 8-0.25 served as the benchmark condition for cooperation in small groups with an $MPCR$ that is 12.5 and 6.25 times higher than in the large-group treatments.

In all large groups, we find considerable positive average first-round contributions – between 26.3% and 39.1% (Table 2), which are significantly larger than zero; see the OLS-regressions in online Table C1 of Appendix C, columns (9), (10), (12),

¹¹ See Appendix B for instructions of treatment 100-0.02, as an example.

¹² Subjects knew that they would only receive aggregate information about the behavior of other group members and therefore were not able to identify others' individual behavior.

¹³ $p > 0.264$ for comparing contributions in each of the 10 rounds and $p = 0.685$ for comparing overall contributions (two-sided Mann-Whitney U tests).

Table 2
Summary statistics.

Treatment	Contributions		
	Round 1	Round 10	All rounds
8-0.25	0.418 (0.127)	0.126 (0.101)	0.269 (0.110)
8-0.25-L	0.391 (0.13)	0.146 (0.127)	0.261 (0.146)
60-0.02	0.263 (0.047)	0.028 (0.013)	0.111 (0.021)
60-0.04	0.356 (0.028)	0.075 (0.030)	0.202 (0.019)
100-0.02	0.321 (0.047)	0.037 (0.009)	0.134 (0.021)
100-0.04	0.391 (0.053)	0.077 (0.008)	0.228 (0.031)

Notes: The table shows the average contributions in rounds 1 and 10 as well as the average contribution over all rounds. Standard deviations in parentheses.

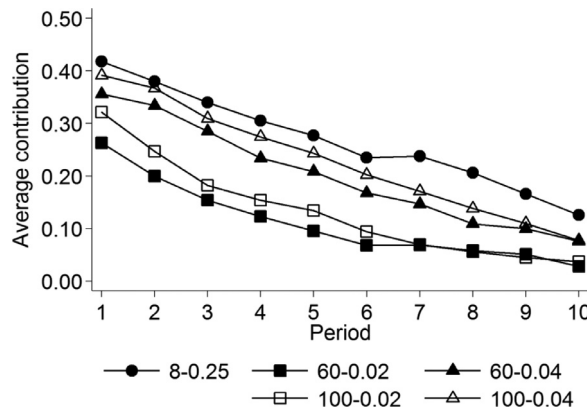


Fig. 3. Average share of contributions per round in large groups of 60 and 100 as well as in treatment 8-0.25.

and (13). Average contributions over all rounds are between 11.1% and 22.8%. Moreover, we observe a pattern of contribution decline similar to that in our small groups. Average contributions in round 10 are between 2.8% and 7.7%.¹⁴ In particular, the dynamics in 60-0.04 and 100-0.04 are rather similar to those in 8-0.25 (Fig. 3 and online Table C1). Average contributions in 100-0.04 do not differ significantly from those in 8-0.25 ($p=0.208$, $n=16$, two-sided Mann–Whitney U test).¹⁵

Our findings above clearly contradict the Olson hypothesis that large groups with an $MPCR$ close to zero are unlikely to provide the public good.

We next analyze the group-size effect, i.e. the impact on cooperation of increasing group size from 60 to 100, while holding the $MPCR$ constant. We also study the $MPCR$ -effect, i.e. how increasing the $MPCR$ from 0.02 to 0.04 affects cooperation at a given group size.

The group-size effect is positive, but moderate. Changing group size from 60 to 100 increases average contributions from 11.1% (20.2%) to 13.4% (22.8%) for an $MPCR$ of 0.02 (0.04) (see Table 2).¹⁶ Columns (1) and (2) of online Table C3 show OLS regression results, revealing that increasing group size pushes up contributions in round 1 significantly by 5.2 percent with an $MPCR$ of 0.02 and by 4.0% with an $MPCR$ of 0.04. With an $MPCR$ of 0.02, contributions decay significantly faster in the larger group, though.

¹⁴ OLS-regressions reveal a quite similar decay across treatments of 3.1% of the endowment in 8-0.25 and between 2.3% and 3.5% in the large groups, again see online Table C1 of Appendix C.

¹⁵ online Table C2 of Appendix C contains the full set of treatment comparison tests for contributions of the first and the last period as well as for average contributions.

¹⁶ For a given $MPCR$, average contributions are (weakly) significantly lower in groups of 60 compared to groups of 100 ($p=0.046$ (0.093) for $MPCR=0.02$ (0.04), two-sided Mann–Whitney U tests). Comparing contributions round by round yields (weakly) significant differences in seven rounds for an $MPCR$ of 0.02 ($p \leq 0.093$). For an $MPCR$ of 0.04 only two rounds differ significantly by group size ($p \leq 0.093$).

The *MPCR*-effect is positive and strong. Increasing the *MPCR* slightly from 0.02 to 0.04 leads to a highly significant increase in average contributions from 13.4% (11.1%) to 22.8% (20.2%) in groups of 100 (60) (see Table 2).¹⁷ OLS-regressions in columns (3) and (4) of online Table C3 show that raising the *MPCR* increases contributions in round 1 significantly by 13.2% in groups of 60 and by 12.0% in groups of 100. In both cases, the larger *MPCR* is associated with a significantly faster decay of contributions.

While the positive *MPCR* effect is in line with the Olson hypothesis, the positive group-size effect seems to be counterintuitive in light of his argument. Moreover, it is not clear why small groups confronted with a high *MPCR* can achieve levels of cooperation similar to those of large groups confronted with very low *MPCRs*. The latter observation suggests that it is neither group size nor the value of *MPCR* alone that determines the level of cooperation, but a specific interplay of both.

The conjecture that the interplay of group size and *MPCR* is decisive for cooperation in public good experiments is also implied by previous research. Isaac and Walker (1988) observe that the impact of varying the *MPCR* (0.3 vs. 0.75) depends on the size of the group: it is much stronger for a group of 4 than for a group of 10. While the authors refer to average contributions, the effects are already identifiable in the first rounds. Another interesting observation made by the authors is that for a high *MPCR* of 0.75 the group-size effect is rather weak (and not significant), but very strong for a low *MPCR* of 0.3 (p. 191).¹⁸ Isaac et al. (1984) make a similar observation, which is replicated in Isaac et al. (1994), who summarize their findings in stating that behavior in public good games “is influenced by a subtle interaction between group size and *MPCR* rather than simply the sheer magnitude of either” (p. 32).

Gunnthorsdottir et al. (2007) find that for groups of 4 varying the *MPCR* (0.3, 0.5, and 0.75) has a positive but non-linear impact on contributions. Increasing the *MPCR* from 0.3 to 0.5 has a strong effect, while a further increase to 0.75 has a rather small effect. The differences between contributions already appear in the first round of the experiment. The authors argue that the increase in contributions can be explained by the fact that a higher *MPCR* makes it more effective to invest in the public good.¹⁹ However, this explanation cannot account for the decreasing strength of the *MPCR*-effect. Nosenzo et al. (2015) report that varying the size of small groups has a rather strong effect on contributions for a low *MPCR* of 0.3, but no significant effect for a high *MPCR* of 0.75.²⁰ Diederich et al. (2016) found a significant but weak group-size effect for an *MPCR* of 0.3 and groups of 10, 40, and 100 members.

Finally, it should be emphasized that the behavior we observed in the large groups is in line with the theory of Fischbacher and Gächter (2010). This theory explains the decay of contributions during the course of public good experiments by social learning of the subjects. In particular, “conditional cooperators” learn that other subjects invest less than they invest and react to this experience with a reduction of their own contributions. This interplay of heterogeneous preferences and social learning also seems to be at work in the groups with 100 and 60 subjects. Although the theory of Fischbacher and Gächter is supported by the large group experiments we have to realize that this theory is not able to explain the interaction of the *MPCR* and group size. For this, it needs a complementary theoretical explanation, which we develop in the next sections.

2.2.3. The interplay of *MPCR* and *N*: The *MPCR*-distance conjecture

Based on our findings from the first project, we provide a conjecture on how the *MPCR* and the group size might interact. This conjecture is different from the approaches suggested by previous research. We test it by running additional treatments that provide a more complex variation of group sizes *N* and *MPCRs* (see Section 3). The development of our conjecture and its experimental test is part of our second research project.

Fig. 4 spans the *N*-*MPCR* space for representing the five connected-lab treatments conducted so far. The $1/N$ curve reveals, for each group size, the minimal *MPCR* necessary to create a social dilemma situation.²¹ For each treatment, the first number in the yellow label displays the average overall contributions in percent.

Fig. 4 reveals two remarkable observations concerning the vertical distance between the *MPCR* and $1/N$, which we will call the *MPCR*-distance (*d*) in the following. The yellow labels display the average contributions followed by the *d* values. First, reducing the *MPCR* at a given *N* from 0.04 to 0.02 results in a decrease in average contributions – yet in a way that contributions are lowest when the *MPCR*-distance is smallest, i.e. at 60-0.02, where $d = 0.003$. Second, when this distance is comparatively large at 8-0.25 ($d = 0.125$), i.e. when reducing *N* to 8 and increasing the *MPCR* to 0.25 at the same time, average cooperation is significantly higher than in the remaining treatments – with the exception of treatment 100-0.04, which has the largest value of *d* among the remaining treatments (online Table C2). Thus, our results suggest that increasing *d* has a positive but non-linear impact on contributions, which is also in line with the findings from the literature discussed in Section 2.2.2.

¹⁷ These differences are significant at the one-percent level when comparing group averages between treatments ($p = 0.001$, two-sided Mann–Whitney *U* tests). Comparing contributions round by round yields significant differences by *MPCR* in all rounds ($p \leq 0.036$ for $N = 100$ and $p \leq 0.005$ for $N = 60$).

¹⁸ Efficiency concerns cannot explain this finding. For an *MPCR* of 0.3, the group payoff resulting from investing \$1 each into the public good is \$1.20 in a group of 4 and \$3.00 in a group of 10. This increase in group size from 4 to 10 significantly increases the contributions observed in the experiment. For an *MPCR* of 0.75 the group payoff resulting from a \$1-investment into the public good is \$3 in a group of 4 and \$7.50 in a group of 10. In this case, the increase in group size shows no significant impact on the average contribution.

¹⁹ In the sense that the total payment to all group members is higher per unit invested in the public good.

²⁰ In later rounds of their experiment, increasing group size turns out to even negatively affect contributions for an *MPCR* of 0.75.

²¹ As we have normalized the return of an investment in the private asset in Eq. (1) to $p = 1$ in our experiment.

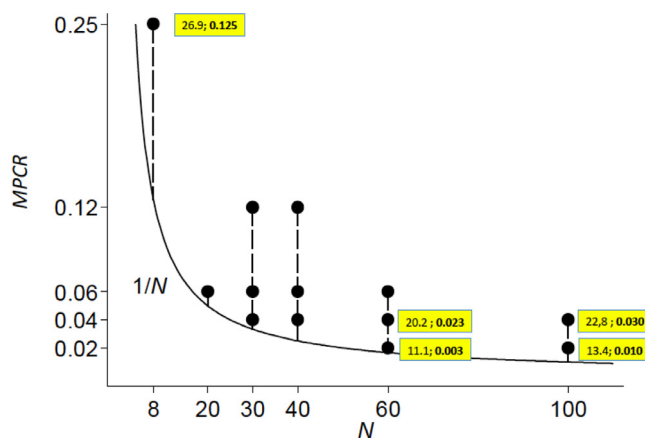


Fig. 4. *MPCR*, *N*, average contributions and *MPCR*-distances of the connected-lab treatments run in the first project.

Note: Each dot in the graph represents one *N*-*MPCR* combination of the connected-lab treatments run in the first project. It also shows the $1/N$ -curve. The first numbers in the yellow labels are the percentages of average contributions for each treatment, the second numbers in bold are the respective *MPCR*-distances *d*. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

This explanation is based on the idea that people confronted with a social dilemma can only be expected to cooperate if group members are aware that it is to everyone's advantage if everyone cooperates (e.g., Fischbacher and Gächter, 2010). That means the mutual benefits of cooperation should be *salient* to the members of the group. Consequently, the more salient the advantage of cooperation, the more subjects can be confident that group members have understood the social dilemma they are in and behave cooperatively.

We suggest that the *MPCR*-distance *d*, i.e. $MPCR - 1/N$, can be interpreted as a *proxy* for the salience of the fact that contributing to a public good is mutually beneficial. The *MPCR* and $1/N$ are parameters of the payoff function, which all subjects are informed about. As long as the $MPCR < 1/N$, investments in the public good are inefficient. If $1 > MPCR > 1/N$, the overall efficiency gains from an investment in the public good increases (for a given *N*) in the *MPCR*. Thus, given our salience assumption, the higher *d* is, the more salient the fact is that cooperation is mutually beneficial. Furthermore, it seems plausible to assume that the positive effect of salience on cooperation rates is non-linear. As subjects become more aware of the mutual benefits of cooperation (due to a higher salience), the additional impact of salience on cooperation rates should decrease.

To develop an intuition for our hypothesis it is helpful to think of $1/N$ not only as the minimal *MPCR* for a public good experiment, but also as a value that informs the group members about their relative weight in the group. The *MPCR*-distance *d* therefore is a measure for the difference between the *MPCR* – the amount a group member receives from investing one Eurocent into the public good – and the relative weight the respective group member has in the group with regard to group size ($1/N$). If the *MPCR* is much bigger than $1/N$, i.e., *d* is large, then the gains from cooperation are much higher than the impact the relative weight of the group member has and, thus, the more salient is the advantageousness of cooperative behavior to the subject. On the contrary, when *d* is small, the gains from cooperation do not appear to outweigh the relative impact the group member has on the group and, thus, cooperation declines.

Assuming that cooperation depends (among other things) on the salience of the cooperation advantage, which can be approximated by the *MPCR*-distance, we formulate the following conjecture:

MPCR-distance conjecture:

1. Increasing the *MPCR*-distance *d* has a positive effect on average contributions.
2. The higher the *MPCR*-distance *d*, the less impact an increase in *d* has on average contributions.

We assume our conjecture also holds for first-round contributions as average cooperation is rather well predicted by first-round behavior (e.g., Keser and van Winden, 2000; Fischbacher and Gächter, 2010; Engel et al., 2014). A test of our conjecture based on additional treatments that provide a more complex variation of the *MPCR* and group size *N* is reported in the next section. In particular, we investigate the extent to which the different explanations (including our own conjecture) can account for observed behavior. It should be mentioned explicitly that the *MPCR*-distance conjecture was developed after the large group experiments we reported so far, but *before* we designed the experiments introduced in Section 3. In Section 4 we will discuss the salience measured by the *MPCR*-distance and sketch a real world cooperation problem it can be applied to.

3. Experimental test of the MPCR-distance conjecture

3.1. The interplay of N and MPCR in the previous literature

There are alternative explanations on the interplay between N and the MPCR mentioned in the literature so far. Isaac et al. (1994) propose an explanation for the phenomena described in the previous sections. As a “starting point for characterizing the joint importance of group size and MPCR” (p. 23) in their VCM environment the authors suggest that cooperation depends on the maximal advantage an efficient solution has over the Nash outcome.

$$\pi_i^{\text{Pareto}} - \pi_i^{\text{Nash}} = z_i[(N * MPCR) - 1]. \quad (2)$$

Since the endowment z_i is given and fixed, (2) is an affine transformation of $N * MPCR$ (i.e., the total payoff resulting from one monetary unit invested in the public good). Referring to Isaac et al. (1994), Davis and Holt (1993) discuss $a = MPCR * N$ as an explanatory variable for contributions. This is the first alternative hypothesis for the interplay of the MPCR and N we will discuss.²²

Davis and Holt (1993)²³ also introduce the Minimal Profitable Coalition (MPC) as a second form of interaction between group size and the MPCR that might be able to explain the contributions in public good experiments (also see Holt and Lury, 2008). The MPC is the minimal percentage of group members who must contribute to the public good such that contributing members have at least the same payoff compared to no one contributing. If the payoff from the private asset is normalized to 1 and $m * MPCR = 1$ then

$$MPC = \frac{m}{N} \quad (3)$$

Davis and Holt argue that cooperative behavior will be inversely related to the MPC. The higher the MPC, the more difficult it may be to build this coalition and the less promising it is to invest in the public good right from the start of the experiment. This highly plausible intuition cannot explain some of the above-mentioned results, though. For example, if for an MPCR of 0.75 the group size is increased from four to ten, this has been found to have only a small impact on contributions, although the MPC falls from 50% to 20%.²⁴ Davis and Holt at least implicitly assume that cooperation increases linearly with both the MPC and the marginal social benefit ($N * MPCR$). This is an important point. If we compare the MPCR-distance d with the MPC, we find that

$$d = MPCR(1 - MPC). \quad (4)$$

This equation implies that for a given N , d and MPC would predict the same ordering of cooperation for different MPCRs if cooperation increases linearly in d and decreases in MPC. $(1 - MPC)$ is the maximal share of non-cooperators that may exist in a group so that someone who cooperates earns at least as much as a non-cooperator. The main difference between our MPCR-distance conjecture and the MPC hypothesis is that it is plausible that the impact on contributions decreases in d , while it does not seem plausible that the impact on contributions decreases in MPC.

At this point, it should be noted that for the solution of real-world public good problems it could be very important whether cooperation behavior depends on the salience of the cooperation advantages proxied by the MPCR-distance or on the size of the MPC.

3.2. Experimental design and procedure

The test of our conjecture and its comparison to alternative explanations in the second project are based on the standard linear ten-round public good game with partner-matching described in Section 2.1. The experimental procedure employed for the eight new treatments is identical. Over all 13 connected-lab treatments (including the five treatments from Section 2), we changed the MPCR from very low (0.02, 0.04) to higher values (0.06, 0.12, 0.25). Likewise, we modified N from large (100, 60) over medium (30, 40, 20) to small (8). Recall that due to (1'), the MPCR is bounded by $1/N$, i.e. we could not conduct all treatments using the same (low) MPCR. Table 3 provides summary statistics for the additional treatments conducted in the second project. Fig. 5 displays all 13 connected-lab treatments in the N -MPCR space similar to Fig. 4.

Overall, we report 14 treatments in this paper and collect data for eight groups (independent observations) per treatment.²⁵ In total, 5,160 different subjects participated in the experiments of both projects.

3.3. Results

Table 4 and Fig. 5 present the average contribution rates in rounds 1 and 10 as well as over all the rounds and MPCR-distances for all 13 connected-lab treatments.

In all new treatments of the second project, we find average first-round contributions between 25.3% and 41.9% (Table 4), which are significantly larger than zero; see the OLS-regressions in online Table C1 of Appendix C, columns (3) to (8), (11),

²² Isaac et al. (1994) also give a second explanation for contributions to public goods. It is based on the idea that subjects could use their contributions as a signal that informs the other players about the own cooperative effort, hoping that this will motivate the other subjects to follow this example. We will not investigate this explanation in detail because there is evidence that the signaling approach cannot explain cooperative behavior in public good

Table 3
Treatment parameters and participants' characteristics in additional treatments.

Treatment	N	MPCR	Sessions/indep. obs.	Lab	Age in years (mean)	Female dummy (mean)
30-0.04	30	0.04	8	Connected	23.287	0.471
30-0.06	30	0.06	8	Connected	22.729	0.525
30-0.12	30	0.12	8	Connected	23.283	0.525
40-0.04	40	0.04	8	Connected	22.734	0.531
40-0.06	40	0.06	8	Connected	23.022	0.478
40-0.12	40	0.12	8	Connected	22.784	0.569
60-0.06	60	0.06	8	Connected	22.723	0.494
20-0.06	20	0.06	8	Connected	22.581	0.500

Note: The table shows the parameters of the additional eight treatments to test the MPCR-distance conjecture. In each treatment, we conducted eight sessions with group size N and the reported MPCR. The table also summarizes participants' average age and the share of female participants.

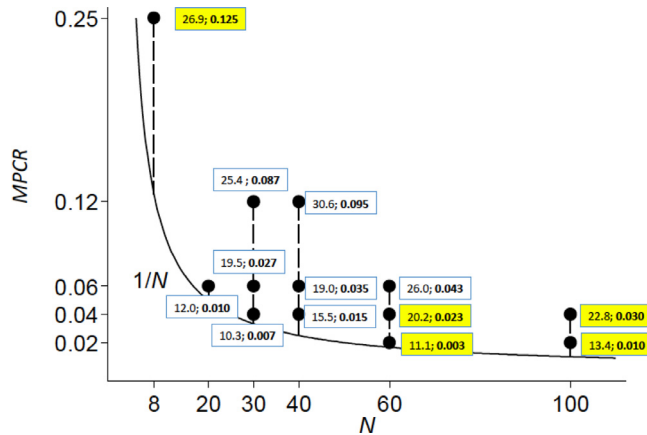


Fig. 5. MPCR, N, average contributions, and MPCR-distances of all 13 connected-lab treatments.

Note: Each dot in the graph represents one N-MPCR combination. It also shows the 1/N curve. The first numbers in the labels are the percentages of average contributions for each treatment, the second numbers in bold are the respective MPCR-distances d. White labels mark additional treatments, yellow labels mark those analyzed in Section 2. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

and (14). The overall average cooperation amounts to between 10.3% and 30.6%. Moreover, we observe a similar pattern of contribution decline as in the treatments run in the first project. Average contributions in round 10 are between 4.0% and 18.3%.²⁶ Fig. 6 and Fig. D1 in online Appendix D illustrates the cooperation patterns observed in the new treatments.

To get a first impression whether the MPCR-distance is a decisive explanatory variable for contributions, we compare contributions in 100-0.02 and 20-0.06. Although N and the MPCR differ by a factor of 5 and of 3, respectively, the MPCR-distance is the same in both treatments. Therefore, our conjecture would predict very similar contributions in both treatments. Fig. 6 demonstrates that this is indeed the case.

For the econometric analysis of our data we use the individual contributions as well as the group average to explain three dependent variables: first round contributions, average contributions, and last round contributions. These six regressions are run as OLS and as Tobit regressions yielding 12 different regressions. In each of these regressions we use 15 different models varying the explanatory variables N, the MPCR, the MPCR-distance d, MPC, and the efficiency measure $a = MPC \cdot N$. All models are also run including a squared term of the explanatory variable to account for a non-linear influence on the dependent variable. In addition we include models with a term accounting for the distance of the MPCR-distance from 1/N. We explain and discuss these models below.²⁷

To compare the different models directly we use the AIC (Akaike Information Criterion) and the BIC (Bayes Information Criterion). BIC differs from AIC insofar as it “punishes” additional parameters more strongly. An improvement in model fit is

experiments. For example, as we have shown in Section 2, in a group of 100 it is nearly impossible to send a signal to the other players, although the cooperation patterns in those groups were the same as those in groups of 8 subjects.

²³ With a reference to Isaac et al (1994).

²⁴ Both a and MPC usually suggest the same ordering of contributions across treatments.

²⁵ The 13 connected lab treatments displayed in Fig. 5 plus the local experiment with 8 subjects.

²⁶ OLS-regressions reveal a significant decay across treatments of between 2.1% and 3.7% (online Table C1).

²⁷ In the regressions based on individual data, we control for gender, the laboratory, and the age of the subjects. For these regressions, the standard errors are clustered based on sessions; for the data based on group averages we report robust standard errors.

Table 4
Contributions and MPCR-distances in all connected-lab treatments.

Treatment	Contributions			MPCR- distance d
	Round 1	Round 10	All rounds	
8-0.25	0.418 (0.127)	0.126 (0.101)	0.269 (0.110)	0.125
20-0.06	0.253 (0.079)	0.045 (0.035)	0.120 (0.053)	0.010
30-0.04	0.264 (0.017)	0.040 (0.032)	0.103 (0.026)	0.007
30-0.06	0.404 (0.060)	0.049 (0.020)	0.195 (0.029)	0.027
30-0.12	0.374 (0.065)	0.148 (0.028)	0.256 (0.039)	0.087
40-0.04	0.348 (0.074)	0.052 (0.034)	0.155 (0.038)	0.015
40-0.06	0.356 (0.036)	0.071 (0.029)	0.190 (0.028)	0.035
40-0.12	0.419 (0.055)	0.183 (0.06)	0.306 (0.059)	0.095
60-0.02	0.263 (0.047)	0.028 (0.013)	0.111 (0.021)	0.003
60-0.04	0.356 (0.028)	0.075 (0.030)	0.202 (0.019)	0.023
60-0.06	0.404 (0.054)	0.103 (0.031)	0.260 (0.046)	0.043
100-0.02	0.321 (0.047)	0.037 (0.009)	0.134 (0.021)	0.010
100-0.04	0.391 (0.053)	0.077 (0.008)	0.228 (0.031)	0.030

Note: The table shows the average contributions in rounds 1 and 10 as well as average contribution over all rounds. Standard deviations are given in parentheses. The MPCR-distance d is shown as well. The bold treatments are those analyzed in Section 2.

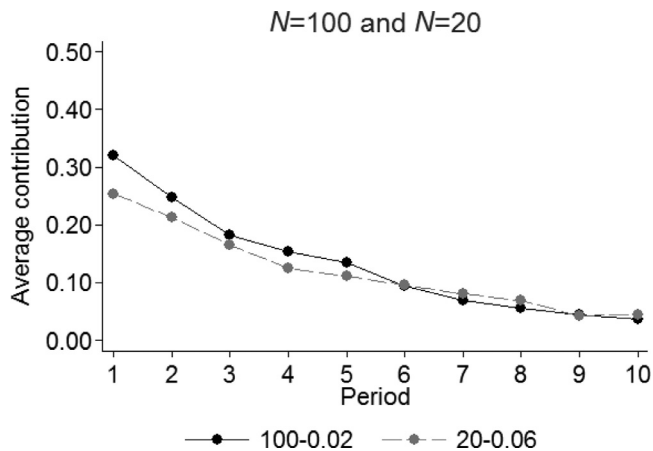


Fig. 6. Average share of contributions per round in treatments with MPCR-distance = 0.010
Note: The graph shows the average contributions in each round as share of the endowment in treatments 100-0.02 and 20-0.06 for $d=0.01$.

indicated by smaller values of AIC and BIC. As an important example, Table 5 reports the results for the Tobit regression of the average contributions using the group averages as independent variables. The complete set of regressions can be found in online Appendix E.

Among the 12 regressions we report in online Appendix E, model (8) is the one with the best fit in 8 of the regressions. It includes d and d^2 as explanatory variables. In one of the remaining regressions model (9) performs better, namely in the OLS and the Tobit regressions on first-round contributions using group averages. In this model, the term d^2 is replaced by the term measuring the distance of the MPCR-distance from $1/N$ ($d^{d < 1/N}$) and by an interaction of this term with d . Note that the distance of d from $1/N$ is equivalent to the distance of the MPCR from $2/N$. See the following section for details.

Table 5
Tobit regression of the average group contribution.

	N				MPCR			d	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
X	−0.000 (0.000)	−0.000 (0.002)	−0.001*** (0.000)	0.692*** (0.165)	2.458*** (0.331)	0.432** (0.172)	1.467*** (0.220)	4.519*** (0.602)	1.016** (0.265)
χ ²		0.000 (0.000)			−6.744*** (1.522)			−25.244*** (5.883)	
J ^{d < 1/N}			−0.143*** (0.027)			−0.100*** (0.021)			−0.087*** (0.015)
J ^{d < 1/N} × X			0.001* (0.000)			0.589 (0.452)			3.019*** (0.579)
Constant	0.208*** (0.018)	0.212*** (0.040)	0.286*** (0.021)	0.145*** (0.011)	0.077*** (0.013)	0.194*** (0.014)	0.137*** (0.008)	0.091*** (0.009)	0.175*** (0.013)
Obs.	104	104	104	104	104	104	104	104	104
AIC	−231.917	−229.945	−289.419	−265.802	−284.811	−294.280	−301.756	−332.282	−318.690
BIC	−223.983	−219.367	−276.197	−257.869	−274.233	−281.059	−293.823	−321.705	−305.468
		MPC			a				
		(10)	(11)	(12)	(13)	(14)	(15)		
X		−0.003*** (0.000)	−0.004** (0.002)	−0.003*** (0.001)	0.049*** (0.004)	0.101*** (0.024)	0.035*** (0.010)		
χ ²			0.000 (0.000)			−0.009** (0.004)			
J ^{d < 1/N}				−0.023 (0.044)					−0.145*** (0.045)
J ^{d < 1/N} × X				0.000 (0.001)					0.075*** (0.023)
Constant		0.325*** (0.012)	0.353*** (0.038)	0.335*** (0.031)	0.076*** (0.012)	0.015 (0.026)	0.125*** (0.034)		
Obs.		104	104	104	104	104	104		
AIC		−308.026	−306.763	−304.320	−302.338	−304.173	−307.886		
BIC		−300.093	−296.186	−291.098	−294.405	−293.595	−294.664		

Notes: Robust standard errors in parentheses.
 * $p < 0.10$.
 ** $p < 0.05$.
 *** $p < 0.01$.

In two cases models involving MPC yield the best fit. Models (10) and (12) perform best for the OLS and the Tobit regressions on first-round contributions using individual data. Notwithstanding, when the first-round contributions are explained by individual data, models (8) and (9) show that the coefficients of d and d^2 are highly significant.

In summary, the comprehensive econometric analysis shows that the MPCR-distance, in particular when combined with d^2 , has a high explanatory power. Although our MPCR-distance hypothesis and the MPC model of Davis and Holt predict the same ordering of contributions²⁸, the models using the MPCR-distance in most of the regressions outperform the model using MPC. We interpret this as strong evidence for our conjecture.

4. Discussion

Public good problems in the real world very often are problems concerning large groups. The question of whether the ability to cooperate depends on the size of a group has been a topic of research at least since Mancur Olson’s famous book about the logic of collective action. However, Olson’s argument has not systematically been analyzed yet.

In the first project we provide the first systematic analysis of what we refer to as the Olson hypothesis. Our experiments with groups of 60 and 100 subjects and very low MPCR of 0.02 and 0.04 demonstrate two central results. First, the level of average contributions and the way it decays over the course of the experiment do not differ from those in small groups of 8 and a relatively high MPCR of 0.25. Therefore, we clearly find no support in our experiment for Olson’s hypothesis that cooperation will break down if the individual impact on group welfare (which can be measured by the MPCR) becomes very small.

Second, the positive MPCR-effect is rather strong, while the positive group-size effect is comparatively weak. These findings go along with the insight that an interaction between group size and MPCR seems to exist, otherwise the similarity in contributions between groups of 8 and an MPCR of 0.25 and a group of 100 and an MPCR of 0.04 cannot be explained. This

²⁸ At least in their linear versions.

interaction might be very important not only for understanding the behavior in public good settings in the lab, but also in reality, and it therefore deserves closer inspection.

Large groups can only be expected to cooperate if the attention of all members is drawn to the fact that each person acting cooperatively is to everyone's advantage. In laboratory experiments, the salience of the advantages of cooperation depends on the information provided to subjects regarding the public good, i.e. the payoff function's parameters. Based on the findings from our first projects, we propose the difference between the actual *MPCR* and $1/N$ (the *MPCR*-distance d) as a proxy for this salience. Note that each public good experiment has to use a d out of the interval $[0, 1]$. If $d=0$, nobody benefits from contributions. For $0 < d < 1$ the benefits for each group member increase; and for $d \geq 1$ a social dilemma does not exist any more because it becomes individually rational to cooperate. Therefore, d gives a clear indication for the positive effect of cooperation. For this reason, we use d as a proxy for salience. We further conjecture that the effect of d on cooperation is non-linear, but decreases with d . If the *MPCR*-distance is large enough, the mutual benefit of cooperation can be assumed as being perceived salient by the group members. Therefore, a further increase in salience would affect contributions only slightly – if at all.

In the second project we test our conjecture based on a second series of experiments. We also compare it with the *MPC* and the marginal social benefit hypotheses introduced by Davis and Holt (1993) and Isaac et al. (1994). The regression analyses support our explanation of the interaction between N and the *MPCR*. Although the *MPC* hypothesis also has its merits, our results show that the *MPCR*-distance performs better with respect to overall contribution levels and, moreover, is compatible with the observations made by Isaac et al. (1994) and Diederich et al. (2016).

One open question is what is meant by the statement the *MPCR*-distance is 'large enough' such that a further increase in d would not affect contributions any more. To answer this question, we rewrite the definition of d as follows:

$$d = \frac{N \text{ MPCR} - 1}{N} \quad (5)$$

The numerator of this term is the net group benefit from a contribution to the public good.²⁹ This net benefit has to be larger than 0 in order to create a public good problem.

One might argue that there exists some level of the *MPCR*-distance d at which the information that cooperation is mutually advantageous is almost common knowledge among group members. In that case, a further increase in d and, thus, in salience may affect contributions only slightly. A natural prerequisite for this would be that the net benefit should be at least as high as the private benefit from *not* contributing to the public good. This implies that the net benefit should be at least 1 and therefore $d = 1/N$. This implies that the salience-critical *MPCR* is $2/N$. The minimal *MPCR* of $1/N$ and the salience-critical *MPCR* of $2/N$ are the boundaries between which the (N, MPCR) combinations are such that a social dilemma exists. But the dilemma is not very salient, because the net group benefit of a contribution is smaller than the individual profit resulting from an investment in the private asset. Thus, variations of d between $1/N$ and $2/N$ should have a rather strong impact on contributions while variations above $2/N$ should have a less pronounced impact. Unfortunately, the design of our experiments does not allow this additional conjecture to be tested. So we have to leave testing this conjecture for further research.

However, even without the additional conjecture concerning the salience-critical *MPCR*-distance, our results have an important implication for the experimental investigation of public good situations. They demonstrate that the behavioral dynamics are the same in small groups with a high *MPCR* and in large groups with a low *MPCR*. Thus, small groups seem to be well suited to cover essential characteristics of public goods in a laboratory situation. For this reason, our theory should also be applicable to experiments with small groups. Fig. 7 shows that this actually is the case.

Fig. 7 exhibits the average *MPCR*/group-size combinations as well as the respective average contribution levels observed in previous small group experiments. These observations are plotted against the $1/N$ curve. Fig. 7 suggests the correlation between average contribution levels and *MPCR* to be strong in the neighborhood of the $1/N$ curve, but becomes weak or non-existent if the vertical distance to this curve is larger. For example, for a group of ten and a *MPCR* of 0.3 the average contribution reported in the literature is about 30%. For the same group size and a slightly higher *MPCR* of 0.375 the reported average contribution increases to 54%, while a further doubling of the *MPCR* has no additional effect in three out of the four reported cases (and in the fourth case the effect is also not significant).

Our explanation of behavior in public good experiments implies that the salience of the social dilemma is of great importance for the investigation of real public good problems. For example, in the case of environmental problems it would be important that, first, people know that their own cooperative contribution is efficiency enhancing and that, second, they are convinced that the social dilemma situation and the mutual benefit of contributions is common knowledge for all the people in the group.

Let us finish our paper with an – admittedly speculative – example on how our notion of salience might relate to reality and on the impact the salience of cooperation advantages could have. The example concerns climate change. The decisive factor probably is how well people are informed about the causes and consequences of greenhouse gas emissions. This in turn will depend on how intensively this issue is dealt with in the media and in the political debate. Germany is a good example for climate-policy relevant topics being frequently discussed in the media. We would interpret this as attracting the German population's attention to the benefits of climate protection making the topic very salient. This example indicates

²⁹ One Euro invested in the public asset results in a total payment to the group of $N \cdot \text{MPCR}$. The opportunity cost of this investment is 1.

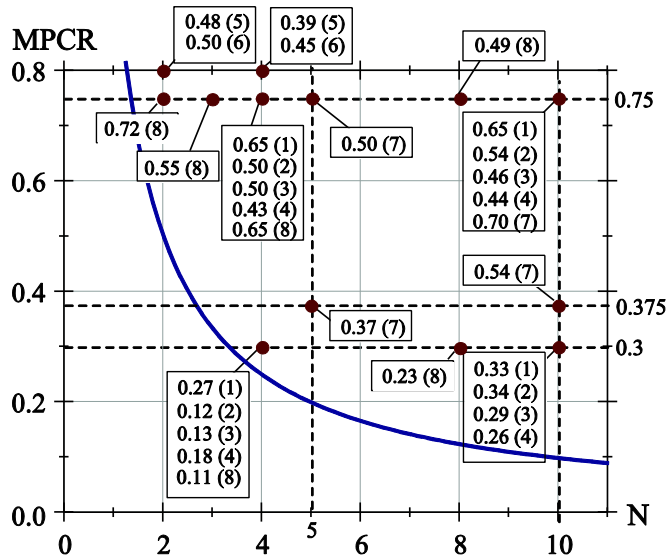


Fig. 7. MPCR, N, 1/N curve, and average contributions found in the literature for different combinations of MPCR and N. Note: The 1/N-curve represents, for each group size, the minimum MPCR required to create a public good situation. The dots exhibit average contributions found in the literature for different combinations of MPCR and N. Numbers in parenthesis correspond to the following references: (1) and (2) Isaac et al. (1984), (3) Isaac et al. (1988), (4) Isaac et al. (1994), (5) and (6) Goeree et al. (2002), (7) Carpenter (2007), and (8) Nosenzo et al. (2015).

that links to phenomena in reality exist that may be supportive to the salience hypothesis developed in this paper. Further research would, however, be needed to show the correctness of our interpretation.

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Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.euroecorev.2019.05.019.

Appendix A. Olson’s theory and the VCM literature

In his book, Olson assumes that in small groups, organizing collective action is easier because these groups are “twice blessed” (Olson, 1965, p.63): First, individual group members may have an incentive to provide the public good because their advantage is greater than the cost of providing it. Secondly, small groups can develop “social incentives” (Olson, p. 63) that favor cooperative behavior. Face-to-face communication, which is possible in small groups, works in the same direction. In large, latent groups, on the other hand, the contribution that the individual group member can make to the provision of a public good is so small that it is hardly noticed by the other group members. Olson concludes that cooperative behavior in large groups is therefore not rational

Experimental research, which has dealt with the private provision of public goods since the mid-1980s, makes use of the Voluntary Contribution Mechanism (VCM) introduced by Isaac et al. (1984) to map the specific incentive structure of a social dilemma in the laboratory as described in Section 2.1.

For the payoff function [1] with the parameters [1’] the static game has a Nash equilibrium in dominant strategies and the finitely repeated game has an unique subgame perfect equilibrium and in all equilibria there is no cooperation. In this respect, the VCM paradigm differs from Olson’s statements. Small groups have the same problem as large groups,

because cooperation is not rational independent of the group size. To model what Olson has described as typical for small groups, one would either have to use a different payoff function (which creates an interior solution), or introduce strong heterogeneity between players, or allow social interaction, for example by allowing players to communicate with each other, leading to reputation effects.

Experimental VCM research has focused, with a few exceptions, on the behavior of small groups (usually with 4–6 members) and relatively high *MPCR* values ranging from 0.25 to 0.7. Some of the important results obtained can be summarized as follows: The Nash equilibrium (pure free riding behavior of all players) is not observed. Nevertheless, the efficiency losses are substantial (> 70%) especially because the contributions to the public good decrease when the experiment is repeated. Communication among subjects increases cooperation. Brosig et al. (2006) show that it is above all face-to-face communication that enables considerable cooperation.

These experimental results could be interpreted as a confirmation of Olson's theory on cooperation in small groups. As long as a group is relatively small, there are mechanisms that at least potentially ensure that cooperation takes place, even if it is too small to generate efficiency. The strong effect of face-to-face communication also corresponds to what Olson said about small groups. In keeping with Olson's intentions, the cooperation problem is thus relaxed for small groups. In fact, anonymous experiments using the VCM do not adequately reflect the cooperation problem of small groups. In reality, the members of small groups facing a cooperation problem normally do not act anonymously. They communicate with each other (mostly face-to-face) and develop social incentives or follow social norms. Some of the experience that people gain in real small groups is obviously also effective in experiments under anonymous conditions and generates a low degree of cooperation.

The VCM is much more appropriate for describing the cooperation problem of large groups. Face-to-face communication and direct social interaction play no role here. Olson's central argument is that in large groups not only the mechanisms that can support cooperation are missing, but also the *MPCR*, the individual contribution that the individual group member can make, becomes smaller and finally is no longer perceptible to the other group members. One could also formulate it this way: The larger the group (and the smaller the *MPCR*), the better the VCM depicts the situation described by Olson and the more likely it may be to observe the Nash equilibrium in an experiment.

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Appendix B. Instructions

Experimental instructions *Treatment 100-0.02*

(Instructions for other treatments can be provided upon request)

Preliminary: You are participating in an economic experiment focusing on decision making. If you have any questions after having read these instructions or during the experiment, please raise your hand. We will then come to your cubicle.

While participating in the experiment, you have to take a sequence of decisions. You will earn money. But, how much money you earn will depend both on your decision and the decisions of the other participants. Your total earnings will be paid in cash at the end of the experiment. Both your decisions and your payoff are confidential, i.e. no other participant will receive this information.

You are part of a group of 100 participants. These 100 people are located in four experimental laboratories across Germany, connected by Internet. All the group members have received the same instructions. Furthermore, the laboratories are linked with a video connection. If you have any doubts about this procedure, please take a look at our video conference.

You and the other 99 group members are facing the following identical decision situation during 10 consecutive rounds. In each round, you receive an endowment of 120 euro cents. You decide how much of this endowment you want to “keep”, and how much you want to “contribute”. Each contribution x creates an amount of $0.02x$ for *each* group member (including the contributor). That means that for every euro cent you contribute, the members of the whole group will be paid 2 euro cents ($0.02 \cdot x \cdot 100$) each. For each euro cent you contribute, you will be paid 0.02 euro cents, like all other group members. That part of your endowment that you do not contribute (i. e. that you “keep”), you keep for yourself.

Summing up in one formula, your earnings in euro cents per round are as follows:

$$120 - \text{Your Contribution} + 0.02 \times (\text{Sum of all group members' contributions})$$

Please note that your contribution per round can be any amount between 0 and 120 euro cents and that all group members are facing an identical decision situation. After each round you will be informed of the amount you kept, your contribution, the average contribution of *all* 100 group members, your payoff based on the contributions of all group members, your payoff in the respective round and your payoff cumulated over all rounds. In addition, you will see a table listing the same information for all previous rounds.

Practice rounds: Before starting the experiment, you have the opportunity to decide in three practice rounds. In these practice rounds, the average contribution of all other group members will be *given* since it is randomly generated. Furthermore, your own contribution will be preset, too. Your task is to calculate the earnings in the respective round yourself. To that end, we will provide you with a calculator, paper, and pencil. After entering your solution into the respective box, please click on the “Solution” button. You then will be informed whether your answer is right or wrong. The calculation method will also be shown. If you have any questions during the practice rounds, please raise your hand. Once the practice rounds are over, the experiment will immediately start automatically.

Payoff: Please stay in your cubicle after all 10 rounds have ended. You will be called individually to receive your payoff. Please hand in your participation number (which you drew at the beginning of the experiment) and enter your name and signature in the payment list. Please leave the laboratory after receiving your money.

Finally, we would like to ask you to not talk to anybody about the content of this experiment to avoid influencing future participants. Thank you for your cooperation!

Appendix C to E

See supplementary material.

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