Situations of collective actions have been modeled as iterated N-person Prisoner's Dilemma games or N-person Chicken games. Although there exists some experimental evidence with regard to the effects of group size in iterated dilemmas, very little attention has been given to one-shot social dilemmas. This article argues that some social dilemmas can be modeled as one-shot games. Furthermore, it discusses and provides experimental evidence on the effects of group size on cooperation in four different one-shot games. The results confirm the hypotheses that there are no group-size effects in the one-shot Prisoner's Dilemma and in the one-shot Chicken game. However, group size does have a negative effect on the cooperation rate in both the Volunteer's Dilemma and in the Assurance game.

Group Size and One-Shot Collective Action

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1. INTRODUCTION

Since Mancur Olson's (1965) influential book *The Logic of Collective Action*, the effect of group size on the voluntary provision of public goods has been the focus of a lively controversy in the social sciences. Olson questioned the widely accepted view that groups of individuals can easily come together to pursue their collective interest, writing that "the larger the 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" (p. 36).

Various authors have subsequently clarified and extended Olson's ideas. In particular, Hardin (1971, 1982) and Taylor (1976, 1987) use game theoretic models to discuss the decisional problems rational actors face in situations

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of potential collective action. Hardin reconstructed the logic of collective action mainly as an N-person Prisoner's Dilemma,[1] whereas Taylor emphasized that many collective action problems are more appropriately modeled as Chicken games or Assurance games, and that the absence of dominant strategies in them has important behavioral consequences. However, both authors agree that most real-life collective action problems are embedded in ongoing social situations and that the decision situations therefore need to be modeled as (infinitely) iterated games. It is thus hardly surprising that one-shot games rarely have been subject to experimental investigation with regard to the group-size effect.

This article argues that at least some social dilemmas can be modeled as one-shot games, and it presents experimental results concerning group-size effects in such situations. The next section presents examples of collective action situations that may be usefully modeled as isolated N-person games with inefficient solutions. The third section briefly reviews the existing literature on group-size effects in social dilemmas, in order to justify the experimental analysis of isolated dilemma situations involving more than just two players. The fourth section describes the design and the hypotheses underlying that analysis, and the fifth section deals with the experimental procedure. The sixth section presents the experimental results and the seventh section puts them in the larger context of the literature. The last section summarizes and concludes the article.

2. ONE-SHOT N-PERSON DILEMMAS

Which situations could be realistically modeled as one-shot N-person Prisoner's Dilemmas? Imagine you are asked to sign a petition (or donate money) for some common good, for example, to support a disadvantaged minority group or an environmental group. Signing (or alternatively donating) is costly because you have to think about the issue, read the petition, decide that you are in favor of the position argued for, and so on. Clearly, the more people who sign, the better the chances that the petition will succeed. However, if many others sign, your signature makes hardly any difference to the overall success of the petition. In fact, even if almost nobody signs, your signature still makes only a small difference. How much of the good is provided depends on how many people sign (or donate), but, for each individual it is best to avoid the time-consuming approval of the petition and walk away. Unfortunately, from a collective point of view, this individually rational behavior results in failure to provide the public good (more justice or a cleaner environment). Furthermore, unlike some other situations, actors cannot easily communicate with other potential supporters of the petition. Thus the situation can realistically be modeled as an N-person Prisoner's Dilemma in which walking away is the dominant defective strategy and signing is the cooperative but dominated strategy. The game is considered to be played simultaneously, because observing the other's behavior is not possible (people who collect the signatures or donations might go from door to door). It is a one-shot situation because one does not get exposed to the same petition again. Noncontribution or noncooperation is a dominant strategy in the one-shot Prisoner's Dilemma game, so players have no incentive to cooperate (such as the desire to favorably influence future games). Hence, mutual defection is the only Nash-equlibrium, and there is no reason to expect that group size should either increase or decrease the chances for cooperation. However, as will be discussed below, past experimental evidence contradicts this hypothesis.

A second social dilemma that can be modeled as a one-shot decision situation is the Volunteer's Dilemma, introduced by Diekmann (1985). Imagine a group of bystanders who are watching an individual in distress. All the bystanders would like to see that the victim receives help, and every bystander could provide the help by him- or herself. However, helping incurs a cost to the helper, so every bystander prefers that another individual provide the help. In this situation, helping can be described as a public good with a step-level production function where a single contribution provides all bystanders with the utility that the victim receives help. In contrast to the Prisoner's Dilemma game, players in the Volunteer's Dilemma do not have a dominant strategy. Assuming a binary choice situation, players may choose to cooperate (provide the good) and receive a payoff of $U - K$, or to defect (free ride) and receive U, where K denotes the cost of cooperation and U the utility of the public good. Because provision is costly ($K > 0$), free riding provides a higher payoff ($U > U - K$). However, if all players wait for another player in the group to contribute, the good will not be provided at all. In this case all players receive a payoff of zero. Thus, if the game is played only once, players face the coordination problem (Harsanyi 1977) of who should make the contribution. If the players can communicate, they can employ a mechanism (e.g., random selection) to choose the volunteer, and if players were to agree on such a mechanism, none of them would have an incentive to break the agreement. Hence, the Volunteer's Dilemma has $N - 1$ asymmetric equilibrium points in pure strategies. A similar solution could be employed if the game is iterated. Players could then take turns in volunteering. Offering sequential choice instead of simultaneous decision making by all players would also solve the coordination problem, because the provision would simply be left to the last player. However, under the assumption of one-shot simultaneous decision making, the Volunteer's Dilemma has only a Nash—equilibrium in mixed strategies, given by $q_0 = (K/U)^{1/(N-1)}$ where q_0 denotes the probability of noncontribution (Diekmann 1985). In this situation the probability that a given actor contributes decreases with the size of the interest group.

The Volunteer's Dilemma is applicable to a variety of social situations other than helping behavior (see Diekmann 1994). One example is the following: imagine an audience in a movie theater. It so happens that the sound is not well adjusted (for instance it is too low) so that people cannot understand the dialog in the movie. It would take just one person to shout "louder" for the volume to be turned up, but shouting causes some embarrassment to the provider, so every one in the audience prefers someone else to do it. The situation is clearly a one-shot decision under anonymity; people in the audience usually do not know each other and do not communicate. Furthermore, once one person shouts "louder" the good will be provided, and there is no need for further provisions.

In the literature, besides the Prisoner's Dilemma and the Volunteer's Dilemma, two other relevant models of collective decision making are discussed: the Chicken game and the Assurance game. Examples of one-shot Chicken games arise when the idea of cost sharing is introduced into the Volunteer's Dilemma. Imagine again a group of bystanders who watch a victim in distress. They have the choice to either help or turn away. Every member prefers to help if no other helps. However, this time even if someone is already helping, further assistance might improve the survival chances of the victim and, therefore, also the utility level of all bystanders. Unfortunately, the marginal costs of helping exceed, from a certain point on, the marginal utility to additional providers, and from this turning point on "don't contribute" becomes the more profitable choice to the bystanders, given that enough others are contributing.[2]

The Assurance game, on the other hand, describes a situation in which all group members have to contribute in order to provide the good. As soon as one member deviates from cooperation, all the others lose their provisions. Examples of an Assurance game are work groups in which each member's contribution is essential for the production of the good. Consider for example a track team in an relay race. Assume, for simplicity, that athletes have the choice to either run at maximum speed or to shirk. As soon as one athlete shirks the chances of winning the race become zero. If we assume that all group members are interested in winning, then cooperation is in the selfinterest of all players. However, cooperation is not a dominant strategy in the Assurance game. As soon as one member expects that someone else is not going to cooperate, defection becomes the most profitable option. The Assurance game does not actually qualify as a social dilemma in Harsanyi's (1977) terms, because players have no incentive to defect from the efficient equilibrium. But the game includes a psychological dilemma, because all players have to trust all the others to cooperate. The risk that a single player might deviate from the equilibrium (for whatever reasons) clearly increases with group size. If players in an Assurance game anticipate this increased risk of group failure in larger groups, a decrease of cooperation rates should be expected with increasing group size. Thus there could be a self-fulfilling prophecy effect at work in the Assurance game, such that the anticipation of others' defection leads to one's own defection.

3. HYPOTHESES AND EXPERIMENTS ON GROUP-SIZE EFFECTS

It seems then that some collective action situations may be modeled realistically as one-shot versions of the Prisoner's Dilemma, the Volunteer's Dilemma, the Chicken game, and the Assurance game. However, with respect to group-size effects, most theoretical as well as empirical work has concentrated solely on the iterated Prisoner's Dilemma. In this game, if group size increases, theoretical reasoning suggests that cooperation becomes increasingly fragile (Raub 1988; Diekmann 1993). The reason for this is that players are more heterogeneous in larger groups, the efficiency of the Tit for Tat strategy decreases, and mistakes (noise or trembling hand effects) are more likely in larger groups. The resulting prediction, that cooperation decreases with increasing group size, was generally confirmed in experiments with the iterated Prisoner's Dilemma game (Bonacich et al. 1976; Fox and Guyer 1977; Hamburger, Guyer, and Fox 1975, Marwell and Schmitt 1972; see Franzen 1994 for a more detailed review). Exceptions to these findings, however, are the studies by Isaac, Walker, and Williams (1991). These found that large groups actually provided more of a public good than smaller groups.

Thus there is some evidence concerning the effects of group size in the iterated Prisoner's Dilemma game. However, there has been very little concern with group-size effects in the one-shot Prisoner's Dilemma. There are in fact only two studies known to the author (Dawes, McTavish, and Shaklee 1977; Komorita and Lapworth 1982) that investigated group-size effects in the one-shot Prisoner's Dilemma. In the Dawes et al. study, no effect of group size was discovered. Komorita and Lapworth, on the other hand, found decreasing cooperation rates with increasing group size. Furthermore, there are no experiments known to the author that investigate group-size effects in the Chicken game or in the Assurance game. However, there are a few experiments with one-shot provisions for public goods whose production function is characterized by a provision point. Such goods are also called step-level goods (Taylor 1982; Hampton 1987), and to provide them, a certain minimum of contribution is needed. This situation is therefore also called the Minimal Contribution Set game. If contributions do not reach a certain minimum, the goods are not provided and all contributions are lost. However, contributions above the provision point are superfluous, because they add no further value to the good. All three studies that tested group-size effects in the step-level goods problem (Kerr 1989; Marwell and Ames 1979; Rapoport and Bornstein 1989) report no group-size effects. It is noticeable that the Minimal Contribution Set game is similar to the Chicken game. In the latter, however, every contribution is of benefit to the group, and if no members or only a few contribute, cooperation yields an even higher payoff than noncooperation.

Group-size effects in the Volunteer's Dilemma were tested by Diekmann (1986).[3] These experiments reported declining rates of cooperation with increasing group size. Group-size effects in the Volunteer's Dilemma are also found in real-life experiments, for example, with helping behavior. The general finding of the research by Darley and Latane (1968) and Latane and Dabbs (1975) (see Latane and Nida 1981 for a review) is that the larger the number of bystanders, the less help will be offered to the victim.

To summarize, some evidence exists concerning the effects of group size in social dilemmas. However, previous experimental research has a major drawback, namely that there has been excessive concentration on some selected social dilemmas, particularly on the iterated Prisoner's Dilemma. Comparatively little attention has been given to other interesting choice situations, such as the one-shot Prisoner's Dilemma game, the Chicken game, or the Assurance game. In fact, these experiments have the further drawback that most of them compare only relatively small group sizes. This is partly because in iterated games, large groups are experimentally difficult to handle because players need to receive the feedback of their co-players' choice. Furthermore, the choice behavior of a given set of individuals has never been tested between different social dilemmas. The following experiment aims to fill these gaps left by existing research and to shed some light on group-size effects in various one-shot social dilemmas in which the independent variable, group size, varies over a large range.

4. DESIGN AND HYPOTHESES

Eight different questionnaires were constructed for the experiment. Each questionnaire contained four different dilemma games: a Volunteer's Dilemma, a Prisoner's Dilemma, an Assurance game, and a Chicken game. In each dilemma subjects had the choice between two alternatives: (A) to cooperate or (B) to defect. The games were presented to subjects as payoff matrices, as depicted in Figure 1. Each of the eight questionnaires assumed a different number of co-players. Subjects were told that they have either 1, 2, 4, 6, 8, 20, 50, or 100 co-players. However, in the experiment, subjects were not actually matched into groups but were told that a certain number of other subjects received the same questionnaire and that all players faced the same payoff structures. Each questionnaire contained explanations concerning the rules of the game. Players were further instructed that the number in the cells corresponded to points that could be accumulated and converted into money. One hundred points corresponded to DM 10 (German Marks) or approximately $7 US. The experiment had a two factorial 4 (Game) × 8 (Group Size) design in which the first factor was measured within subjects and the second between subjects.

The first game presented in the experiment was a Volunteer's Dilemma. Subjects received $U = 100$ in case of collective good production. Providing the good cost $K = 50$. Thus a subject who cooperated by choosing alternative A received $100 - 50 = 50$ points. If no subject provided the good (i.e., all players chose B), each received 0 points. Extending the payoff matrix from a two-person to a N-person game is straightforward (see Figure 1). Nash—equilibrium behavior is given by $q_0 = (K/U)^{1/(N-1)}$. Given $K = 50$ and $U = 100$, players should cooperate with a probability of 0.5 in a 2-person group. If there is equilibrium behavior, the probability of cooperation drops to 0.3 for a 3-person group, 0.16 for a 5-person group, 0.11 for a 7-person group, 0.08 for a 9-person group, 0.03 for a 21-person group, 0.02 for a 51-person group, and 0.01 for a 101-person group. Thus the hypothesis is that the cooperation rate should decline with increasing group size.

The second game (see Figure 1) was a Prisoner's Dilemma game. The payoff matrix was constructed so that mutual cooperation led to a cooperative gain of 60 points per player. Mutual defection yielded 20 points. Thus both players increased their payoff by 40 points in the case of mutual cooperation. This difference might be called "cooperative gain." Every player also faced an incentive of 20 points (about $1.50) to defect from the cooperative alternative. Thus if a player chose to cooperate, he forfeited 20 points. Put

1) Two-person and five-person Volunteer's Dilemma

		column player	
		B	A
row player	A	50	50
	B	0	100

		number of others that cooperate				
		0	1	2	3	4
row player	A	50	50	50	50	50
	B	0	100	100	100	100

2) Two-person and five-person Prisoner's Dilemma

		column player	
		B	A
row player	A	0	60
	B	20	80

		number of others that cooperate				
		0	1	2	3	4
row player	A	0	15	30	45	60
	B	20	35	50	65	80

3) Two-person and five-person Assurance game

		column player	
		B	A
row player	A	0	100
	B	50	50

		number of others that cooperate				
		0	1	2	3	4
row player	A	0	0	0	0	100
	B	50	50	50	50	50

4) Two-person and five-person Chicken game

		column player	
		B	A
row player	A	20	60
	B	0	80

		number of others that cooperate				
		0	1	2	3	4
row player	A	20	30	40	50	60
	B	0	20	40	60	80

Figure 1: Two- and Five-Person Payoff Matrices for Four Social Dilemmas

differently, the cost of cooperation was 20 points. The payoff matrix was extended from the two-person to N-person games by keeping both the gain and the cost of mutual cooperation constant. Thus players in all group-size conditions experienced the same incentive to defect, 20 points. If the game is only played once, simultaneously and under complete anonymity without possible sanctions or side payments, then rational players should choose to defect, since this is the dominant strategy in the one-shot Prisoner's Dilemma game.

Because all relevant payoff parameters remain constant, group size should not have any effect on individuals' choice behavior in this game. In fact, it has been argued (Hamburger, Guyer, and Fox 1975) that large groups induce feelings of greater anonymity and less responsibility in individuals. This effect is sometimes termed the "deindividuation" (Steiner 1972) or "pure member in the group" effect. However, such an effect is very unlikely in this experimental design, because even players in the smallest groups play under anonymous conditions. Hence no group-size effect was expected in the Prisoner's Dilemma game.

The third game presented was an Assurance game. The game has a Pareto-optimal equilibrium. This equilibrium is reached when all players choose A, the cooperative alternative. Thus, according to Harsanyi's (1977) definition, the Assurance game is not a social dilemma. It captures, however, a psychological dilemma (Liebrand 1983). If a single player deviates from cooperation, all A players receive nothing. However, deviating secures a minimal payoff (in this experiment 50 points). Thus all players have to trust that all will cooperate. Among rational players the game should not cause a problem, and group size should not have an influence on subjects' strategy choice. But in reality, even if none of the players is malevolent, they will sometimes make mistakes. Increasing group size clearly increases the chances that a single individual makes such a mistake. The paradox then consists in the fact that individuals might anticipate that others might deviate (e.g., out of anticipation of their deviation) and choose the maximin strategy by themselves. Thus a self-fulfilling prophecy could develop in the Assurance game. The hypothesis is therefore that cooperation should decline with increasing group size.

The fourth game was a Chicken game. The payoff matrix was chosen to make the game most comparable to the Prisoner's Dilemma game. Mutual cooperation yielded 60 points. In the two-person game a player received 20 points more by defecting, given that his co-player cooperated. If the player assumed that the co-player was going to defect, he or she could cooperate and secure the maximin payoff of 20 points. The two-person Chicken game has two asymmetric equilibrium points in pure strategies and one symmetric equilibrium in mixed strategies. If players have no chance to precommit themselves to their favorable pure strategy, they have to turn to the mixed equilibrium strategy. In the mixed equilibrium, ego must be indifferent between cooperation and defection, which requires that alter cooperates with a certain probability.

Based on the payoff matrix of the Chicken game in Figure 1, alter's probability of cooperation (denoted by Θ) is determined by solving:

$$(\Theta)(80) + (1 - \Theta)(0) = (\Theta)(60) + (1 - \Theta)(20)$$

for Θ. That is, $\Theta = 0.5$. Because the game is symmetric, ego has to cooperate with the same probability as alter. The payoff matrix was chosen such that the result of the mixed strategy is 0.5, independent of group size. Thus, according to the mixed equilibrium strategy, players should cooperate with a probability of 0.5, and group size should not make a difference. According to this hypothesis, then, the cooperation rate should be at 50% under all group-size conditions.

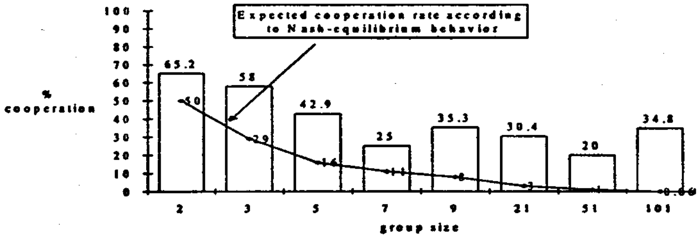
5. EXPERIMENTAL PROCEDURE

Students at the University of Mannheim, Germany, were asked to participate in a study that was labeled "decision making under conflict." If they agreed, they were brought to a separate room on campus. Subjects were randomly assigned to the eight different group-size conditions and received a questionnaire that contained a Volunteer's Dilemma, a Prisoner's Dilemma, an Assurance game, and a Chicken game. Subjects were told that they had either 1, 2, 4, 6, 8, 20, 50, or 100 co-players. The cooperative choice was termed A, the defective B. No hints were given that the decisions bore any relevance to real-life problems. Subjects were simply told that they and their co-players were confronted with a choice situation in which they could earn points that would be converted into money and that the number of points they earned depended on their and their co-players decisions. Each game was explained and demonstrated by a payoff matrix in the questionnaire. The written instructions also included examples of how many points they would receive as a consequence of their own and their co-players choice. Subjects answered the questionnaire in the presence of the researcher and other participants. However, subjects were told that the other participants present were not necessarily the co-players they would be matched with. Aside from asking the researcher questions concerning instructions in the questionnaire, no communication was allowed. It was explicitly mentioned that there was no time limit to answer the questions. Before leaving, participants wrote their addresses on an envelope. Payoffs were then mailed to subjects a week after the experiment.

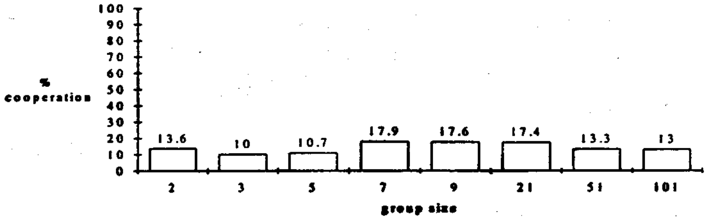
6. RESULTS

Some 203 subjects participated in the study. The average age of subjects was 24.4. About one third were female, and about half were majors in business administration or economics. The percentage of participants that chose the cooperative alternative in the four dilemmas in the various group sizes is displayed in Figure 2. For the Volunteer's Dilemma, Figure 2 shows a group-size effect that is significant according to a chi-square test (chi-square =

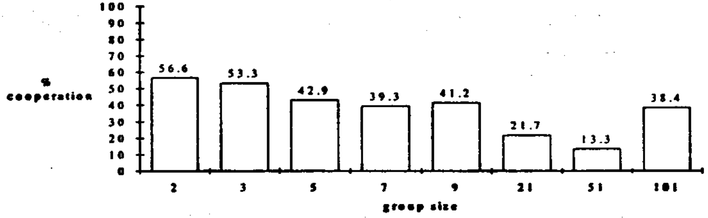
Volunteer's Dilemma



Prisoner's Dilemma



Assurance game



Chicken game

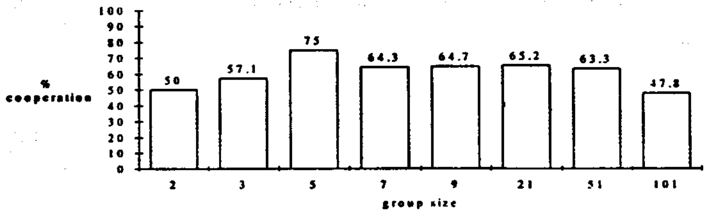


Figure 2: Group Size Effects in Four Social Dilemmas

16.24, *df* = 7, $p < .05$). The cooperation rate declines from 65.2% in the 2-person group to 34.8% in the 101-person group. There is a relatively strong decline for the first four groups, which levels out in the larger group sizes. The solid line describes the expected percentage of cooperation if participants adhered to the equilibrium behavior. In all groups participants' cooperation was substantially larger than expected. Thus players seemed to be risk averse in that they chose the maximin strategy in the Volunteer's Dilemma more often than expected according to Nash-equilibrium behavior. However, the main hypothesis that cooperation decreases with increasing group size in the Volunteer's Dilemma was corroborated.

Group size had no effect on the cooperation rate in the Prisoner's Dilemma (chi-square = 1.24, $df = 7$, $p > .99$). The average cooperation rate equaled 14%. Thus, in agreement with game theoretical considerations and independent of group size, substantial free-riding behavior was observed in the Prisoner's Dilemma game. A clear group-size effect could be observed in the Assurance game. The cooperation rate dropped from 56.6% in the 2-person group to 38.4% in the 101-person group (chi-square = 17.70, $df = 7$, $p < .02$). Considering that players in the Assurance game have no rational reason to deviate from the cooperative choice, the cooperation rate was surprisingly low, even for the small groups. In contrast, no group-size effect at all was observed in the Chicken game (chi-square = 5.71, $df = 7$, $p > .70$). According to the mixed equilibrium strategy a 50% cooperation rate independent from group size should have been observed. As in the Volunteer's Dilemma and Prisoner's Dilemma, subjects displayed somewhat more cooperative behavior than would have been expected according to equilibrium behavior.

To summarize, all of the hypotheses were corroborated. Group-size effects were observed in the Volunteer's Dilemma and in the Assurance game, but they were absent in the Chicken game and in the Prisoner's Dilemma game. Nonetheless, with the exception of the Assurance game, subjects behaved in all the games somewhat more cooperatively than was expected according to game theoretical expectations. In the Volunteer's Dilemma and the Chicken game, this behavior might be interpreted as risk aversion, because the cooperative choice secured the maximin payoff. With respect to the Prisoner's Dilemma, however, the cooperative choice has to be attributed to either subjects' misunderstanding or to their altruism. The highest average cooperation rate across all groups was observed in the Chicken game (61.6%) followed by the Volunteer's Dilemma (36.3%), the Assurance game (35.8%), and finally the Prisoner's Dilemma (14.2%). These observations were confirmed by a multivariate analysis of variance with group size as a between-subject factor and the four different dilemmas as the within-subject factor. The different dilemmas had a significant effect on the cooperation rate ($F = 38.96$, $df = 3$, $p <$

.001). The effect of group size, on the other hand, depended on the dilemma type. Group size alone had no significant effect, but the interaction term between group size and dilemma type is significant according to Hotelling's T^2 (App.*F* value = 1.599, $df = 21$, $p < .045$). Furthermore, none of the controlled social demographic variables such as sex, age, income, and subject of study had an effect on the cooperation rate in any game.

So far, the data have been analyzed on the individual level. It is, of course, a different question to ask whether in real groups the combined decisions of individuals would provide an adequate amount of a public good. For the Volunteer's Dilemma the probability that at least one subject cooperates (and thus provides the whole good) is given by $P = 1 - q^N$, where q denotes the probability of defection and N the size of the group. Substituting q for the mixed-equilibrium strategy yields $P = 1 - (K/U)^{(N/(N-1))}$. Thus under equilibrium behavior the probability of public good production drops from .75 for N = 2, to .65 for N = 3, to .50 for N = 101. However, according to the data the probability that the good would have been provided increased with group size, starting with P = .88 for the two-person group, and .88, .94, .87, .98 for the three-, five-, seven-, and nine-person groups, respectively. Finally, the three largest groups would have almost certainly provided the good ($p >$ .001). Thus, according to the data, large numbers make the provision of the good more likely.

For the Assurance game all participants of a group need to cooperate in order to produce the good. Consequently, the probability of public good production is given by $P = (1 - q)^N$. Based on the experimental results, the chance that a group would have been successful in providing the good is therefore .32 for a two-person group, .15 for a three-person group, and .01 for a five-person group. Chances of production for groups above five members approach zero. So, in contrast to the Volunteer's Dilemma, production of public goods is unlikely even in very small groups if all group members need to cooperate.

For the Chicken game and the Prisoner's Dilemma, calculation of the chances that a good will be produced is less straightforward because the amount of the good increases continuously with the number of cooperators. However, the chance that none of the good will be produced for the Prisoner's Dilemma is $P = q^N$. Because q remained almost constant in the experiment, the chances that none of the good will be produced decreased with group size (from .74 in the 2-person group to .02 in the 21-person group and approaches zero in the larger groups). Alternatively, the chance that none of the good gets provided is $P = (1 - q)^N$, which decreases rapidly with group size. Similar results hold true for the Chicken game.

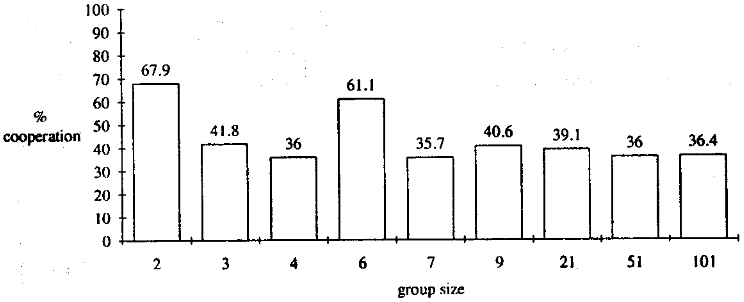


Figure 3: Cooperation and Group Size in the One-Shot Prisoner's Dilemma

7. DISCUSSION

By and large, the hypotheses about the effect of group size in the four different dilemmas were confirmed. With respect to the Volunteer's Dilemma, the results replicate the finding by Diekmann (1986). Diekmann varied group size as a within-subject factor. Subjects were asked whether they would cooperate if they had 1 co-player, 2 co-players and so on up to 10 co-players. The cooperation rate dropped as group size increased in a fashion very similar to what occurred in this experiment. Similar results were obtained in an experiment on group-size effects in the Volunteer's Dilemma by Murnigham, Kim, and Metzger (1993).[4] The experimental finding on group-size effects in the Volunteer's Dilemma is also in line with many real-life experiments that were conducted by Latane (see also Latane and Nida 1981). The general finding of these studies is that subjects were less likely to help a victim (the experimenter or a confederate who faked an emergency) the larger the group of bystanders was.

With respect to the Prisoner's Dilemma, the experiment confirms the result of Dawes, McTavish, and Shaklee's (1977) study. It contradicts, however, the finding of Komorita and Lapworth (1982) in which the cooperation rate dropped from 59% in the two-person group to 44% in the six-person group. Komorita and Lapworth (1982) explain their finding by invoking a deindividuation effect, which, as noted above, means that subjects in the six-person groups felt less responsible for the groups' performance than individuals in the two-person groups. However, in the study by Komorita and Lapworth (1982), subjects faced rather low monetary incentives to defect. Also, the group-size variation was limited to a small range. These two factors could perhaps explain the divergence of the Komorita and Lapworth (1982) results from those presented above.

In order to try to replicate the finding that there are no group-size effects in the one-shot Prisoner's Dilemma, a second experiment was conducted. Besides changing the payoff matrices and the group-size variation, the second experiment was carried out in exactly the same way as the first. The payoff matrix was changed so that the incentive to defect was decreased; mutual cooperation by all players yielded 60 points, mutual defection by all players 10 points, and the advantage of a defective choice over a cooperative choice was 10 points (about 50 cents) versus 20 points in the first experiment. For the group-size variation refer to Figure 3. As in the first experiment no group-size effect was expected on the cooperation rate. However, the average cooperation rate should be somewhat higher due to the reduced incentive to defect. Participating in the second study were 329 students of the University of Mannheim, Germany. The results are depicted in Figure 3.

A bivariate chi-square analysis reveals that group size had no significant effect on the cooperation rate (chi-square = 13.62, *df* = 9, p > .20). Again no effect of subject's sex, age, income, or subject of study was observed. Although the results are not as clear-cut as the results of the first experiment, the major finding, that there are no group-size effects in the one-shot Prisoner's Dilemma, is confirmed. Furthermore, the idea that the average cooperation rate would be higher than in the first experiment was corroborated.

With respect to the Chicken game and the Assurance game there is no former research to compare with the results of this experiment. However, Marwell and Ames (1979), Kerr (1989), and Rapoport and Bornstein (1989) conducted experiments on one-time contributions to public goods that are characterized by a provision point. None of these studies found significant group-size effects on voluntary provisions. Thus the results of the reported experiment confirm the findings of these studies that are related to the strategic aspects of the Chicken game.

8. CONCLUSIONS

The first part of the article argued that the effect of group size on the production of public goods is an issue of controversy in the social sciences. Most past experimental research on this issue was focused on group-size effects in iterated games, compared relatively small group sizes, and produced inconclusive evidence with regard to one-shot games. The current study tested group-size effects in four one-shot dilemma games. The independent variable, group size, was varied by forming nominal groups that ranged from 2 to 101 "players" per group. On the individual level cooperation rates declined as hypothesized in the Volunteer's Dilemma and in the Assurance game. Although a decline in the Volunteer's Dilemma is predicted by Nash-equilibrium behavior, no decline should be observed in the Assurance game, according to game theory. However, a psychological effect is at work in the Assurance game. The larger the perceived group was, the more subjects preferred the maximin strategy. No group-size effect was observed in the one-shot Prisoner's Dilemma and in the one-shot Chicken game. In both cases the observed behavior corroborated game theoretical predictions rather well. Thus the experiment demonstrated that the type of dilemma is very important with regard to the effect of group size on cooperation.

From a "collective good" point of view, the data suggest that the likelihood of public good production increases with group size if one cooperating player suffices for the production of the good (a Volunteer's Dilemma). This result contradicts the game theoretical prediction that the probabilty of public good production should decrease in the Volunteer's Dilemma with increasing group size. Subjects took larger numbers into consideration by cooperating less often, but the likelihood of good production still increased. Thus, according to these results, group size does not necessarily prevent the production of public goods, even under unfavorable (one-shot and anonymous) conditions. However, group size does become a barrier to the production of a public good if all group members need to cooperate (an Assurance game). Here, both individual cooperation rates and, even more, the likelihood of good production decrease with group size.

With respect to individual cooperation rates, no effect of group size was observed in the Prisoner's Dilemma and the Chicken game. This means that the probability of a given proportion of individuals cooperating is constant in both games in all group sizes. Overall, the results of the experiment suggest that group size matters under conditions of one-shot, simultaneous choice with high anonymity, not just in Olson's sense (according to which group size changes the dilemma structure), but also in the sense that within certain dilemmas (e.g., the Volunteer's Dilemma and the Assurance game), the cooperation rate declines with increasing group size.

NOTES

1. Hardin actually asserts: "a pure public good is often not strictly a Prisoner's Dilemma, although this analytical fact often does not matter for behavior" (Hardin 1982, 51, see also the discussion on page 57ff).

2. Taylor (1982) gives other examples for Chicken games.

3. Diekmann (1992) discusses the data concerning the Volunteer's Dilemma reported below as well.

4. For a more extensive discussion on the experimental evidence on group-size effects in the Volunteer's Dilemma see Diekmann (1994).

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