Continuous versus Step-Level Public Good Games

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Running head: Continuous versus Step-Level Public Good Games

Step-level versus Continuous Public Good Games: A critical Assessment of a Methodological Research Tradition

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Overview

We will firstly outline the rationale of a public good game and explain the distinction between a continuous public good game and a threshold public good game. As a vast majority of experimental research in social psychology on public good games has used threshold public good games, we will then outline the structure of a dilemma game with a provision point. Our point is that dilemma games with a provision point violate two important assumptions commonly held for public good games: a) there is always a conflict between the group's interest and the individual's interest; and b) an individual is always better off defecting. A threshold dilemma game is a dilemma with a coordination game embedded in it. Hence it provides focal point solutions and may as a consequence leave less room for other factors to affect behavior. Moreover, games with a provision point might yield different results than games without a provision point. We will argue that above that threshold dilemma games do not provide good models of many the public goods problems that are encountered in real life. We will propose that a public good game with a tilted *S* function provides a more appropriate model of real life dilemmas while fulfilling the defining properties of public good games.

The Prisoner's Dilemma Game, the Public Good Game and what they have to do with Social Psychology

Anyone, who has attended an introductory social psychology class, will be familiar with the Prisoner's Dilemma Game and its rationale. Two people are in an interdependent decision making situation and communication between the two is not possible. They both have two options; they can either cooperate or defect. If they both defect their pay-off is lower compared to when they both cooperate. However, each of them will get the highest pay-off if they themselves defect, while the other cooperates. The cooperator is worst off in case her opponent defects.

Hence, if both cooperate, they both have an incentive to deviate from that situation, which will result in mutual defection as the only equilibrium. Equilibrium is a concept of game theory (von Neumann & Morgenstern, 1947). It refers to a state in which no player has an incentive to deviate from his or her current position, given the chosen strategy of the other player(s).

The Prisoner's Dilemma Game can be extended to more than two persons with more than two decision options representing different levels of cooperation. These are referred to as public goods or resource dilemmas, or also in a very general sense as social dilemmas. The underlying principle of the interdependency for public good, resource dilemmas, or social dilemmas is still the same as for the Prisoner's Dilemma Game: There is a conflict between the group's interest and the interest of each individual. The group as a whole is best off when all decision-makers contribute their endowments in a public good game or leave the endowments in the resource in a resource dilemma. Each individual however is always better off keeping their endowments in a public good or taking everything they can from a common resource in a resource dilemma, no matter what the others do. Thus, the dilemma is between individual incentives to defect and avoiding the collectively bad outcome if everyone defecting. Subsequently we will focus our discussion on public good games, but we ask readers to keep in mind that the same reasoning holds for resource dilemma games.

There are two ways of implementing a public goods game (see e.g. Komorita & Parks, 1996). In the both ways, players are given an endowment of X units and decide how much of the endowment to contribute (Y: $0 \leq Y \leq X$) to the public good, leaving the balance in their private account. In a continuous function version of a public good game, each contribution to the public account is multiplied by a factor of *c* and the public pool is distributed equally among the players at the end of the game. The size of *c* is set so that each player would be better off to keep a unit of her endowment than contributing it regardless of the decisions of the other players. However,

if all players keep their endowments, they are worse off than if they had contributed all of their endowments. This tension between contributing to the public good and keeping one's endowment holds for decisions to increase one's contribution from Y to Y+1, regardless of where Y falls in the interval of 0 to X-1, inclusive. That is, a player's payoff is always better when contributing Y than when contributing Y+1 and, thus, the only equilibrium for such a game is for all players to contribute nothing.

Games with a provision point modify this basic game by defining a level of contribution at which a fixed amount is added to the public good[1]. When total contributions fall short of the provision point, the contributions to the public account are lost. When total contributions exceed the provision point, excess contributions are treated in two different ways: either nothing is gained by the excess contributions or the value of the common pool increases by a factor of *c* as in the continuous function game. Thus, in the region of the provision point, it is no longer necessarily the case that a player is better off not contributing. If her contribution of additional units results in satisfying the provision point, she is better off to contribute than not. If the players' joint contributions sum to the provision point, there is no incentive for any one of them to reduce her contribution. Thus, the addition of a provision point changes the nature of the game in an important way. The presence of a provision point results in multiple equilibriums: everyone contributing nothing is still an equilibrium but also any of the combinations of contributions among the players that equal the provision point are equilibriums. Games with a provision point are also referred to as step-level public good games.

The amount of research that has been conducted on social dilemmas is enormous. Weber, Kopelman, and Messick (2004) reviewed the literature on social dilemmas of the last three decades. Many of the studies have used a game with a provision point, no matter whether they were looking at public good games or resource dilemmas. We have outlined the nature of a game

with a provision point above. The following example illustrates pay-off rules of a game with a provision point: A three-person public good game has a provision point of 9. Everything that the individuals keep to themselves is multiplied by 3, while, as soon as there are 9 or more endowments contributed to the common pool, these endowments are multiplied by 6 and divided to all three of them. If, however, there are less than 9 endowments in the common pool, no pay-off at all would be resulting from the common pool and any endowments that are contributed to the pool are lost. Or, alternatively, players can obtain a fixed bonus when the provision point is reached or exceeded. Remarkably, in many reviews of the literature on public good games, the distinction between continuous and step-level public goods is either not made (e.g. Liebrand, Messick & Wilke, 1992), or when mentioned the review does not distinguish which studies used which type of game nor are the implications of type of game discussed (e.g., Komorita & Parks, 1995, 1996).

The structure of a dilemma-game with a provision point

A public good game or a resource dilemma with a provision point is a dilemma with a coordination game embedded. The task of reaching the provision point is a coordination task. But there is a dilemma involved in how to accomplish that coordination task. However, managing the coordination task, hence successfully reaching the provision point does not display a conflict between the individual's and the group's interests. A contribution X of an individual might ensure the preservation of the common good or resource, because that contribution X would ensure that the provision level is attained. In that case the underlying principle that an individual is always better off by defecting rather than contributing is violated.

Take, for instance a three-person public good game, each of individual has four endowments, which they can either contribute to the common pool, or keep to themselves. There

is a provision point of 9, meaning the common pool will cease to exist if fewer than 9 endowments are in it. If a player knows that there are only 5 endowments in the common pool, the best response for that player is to contribute all of her 4 endowments so that the provision point is reached. Of course, in this decision situation, players do not know the current contributions of the others. As a consequence, she is uncertain whether her contributions are needed, or how many of her contributions are needed, to ensure the attainment of the provision point. Consequently there is no dominant strategy for an individual, meaning there is no choice that would always make her better off, regardless of what the other(s) are choosing.

On a methodological level this means that two fundamental features of a dilemma situation are missing when a provision point exists. First, there is not always a conflict between the group's interest and the individual's interest. Second, an individual is not always better off defecting.

Implications of the structure of a dilemma-game with a provision point for our understanding of human behavior

In their conceptual review about social dilemmas Weber, Kopelman, and Messick (2004) proposed that people use appropriateness rules to make decisions in dilemma situations. One type of appropriateness rule is a coordination rule for attaining provision points. Hence, the question is how much coordination rules tell us about contribution behavior in dilemmas. Providing a provision point basically means that one provides focal point solutions.

Consider the earlier example of a public goods game with three people, each of them has four endowments that they can either contribute to the common pool or keep to themselves. There is a provision point of 9, meaning the common pool will cease to exist, if fewer than 9 endowments are in it. An obvious solution is provided by an equality rule: each of the three

players contributes three endowments. What you usually observe in these experiments is that participants do indeed contribute 3 endowments and there is not much variability around the contribution of 3. When the presence of a provision point provides a focal point for coordinating contributions, there are two consequences of that.

One consequence is that experiments that use social dilemma games with a provision point reduce the opportunity to observe the effects of other factors on behavior. As long as there is an easy and obvious solution, other factors will not matter that much. A related notion stems from Snyder and Ickes (1985), who have made the argument that individual differences will be more influential under weak rather than under strong situations. A second consequence is that games with a provision point may yield different results than games without a provision point.

Consider, for instance, the timing effect in public good games. The timing effect refers to differences in behavior depending on whether players are deciding simultaneously or pseudo-sequentially. When deciding pseudo-sequentially, players make their decision one after the other but their decisions are not revealed to the other player(s) until the game is over. Hence, the information set is the same as in a pseudo-sequential and a simultaneous procedure. In either case, players do not know what the other have decided when they make their choice. The only difference is that they know that they are either deciding simultaneously or sequentially. Abele and Ehrhart (in press), using a continuous public goods game, demonstrated that pseudo-sequential, compared to simultaneous-movers are much more likely to defect, keeping all their endowments to themselves, and are also less likely to reciprocate the level of contributions that they anticipate from others. Note that the order of decision in the pseudo-sequential had no effect; that is, both first and second movers exhibited less cooperation.

Effects of timing have also been observed in dilemmas with provision points. Budescu, Suleiman, and Rapoport (1995), Budescu, Au, and Chen, (1997), had players play a threshold

resource dilemma in a pseudo-sequential order. Players' requests decreased in the first three positions. The implications of this positional order effect in threshold dilemmas are however quite different: It suggests that the timing cue is used as a coordination device. Or, put differently, the one who gets to choose first gets more of the cake, even if moves are unobserved. Hence, while the timing-effect in continuous public good games tells us something about the effects of subtle cues on cooperative behavior, the positional order effect in threshold dilemmas tells us something about the use of subtle cues as coordination devices.

Another example in which games with a provision point yielded different results than games without a provision point is, as Weber et al. (2004) have also noted, when investigating the effect of group size. Kerr (1989) showed that perceived efficacy decreased with group size in a step-level public good game. Perceived efficacy refers to the perceived criticality that group-members ascribe to their own contributions. In one experiment Kerr (1989) did indeed find that group size was per se related to cooperation rates: he observed lower rates of contributing as group size increased. However, Isaac, Walker and Williams (1994) found the opposite effect. They used a continuous public good game and found that groups of size 40 and 100 provided the public good more efficiently than groups of size 4 and 10. Hence, when comparing the results of these two studies, it could be that group size is inversely related to cooperation rates in threshold public good games, while cooperation rates increase with group size in continuous public good games. One should, however, be careful with such a conclusion. Apart from Kerr using a threshold public good game and Isaac et al. using a continuous public good game, there were two other differences between the set ups of their experiments. First, Kerr used discrete contributions, participants could either contribute US$ 10 or not, with everyone getting US$ 20 if the provision point was reached. Isaac et al. permitted any level of contribution between 0 and 50 tokens, the total endowment given to participants. Second, Kerr used a one shot game whereas Isaac et al.

included 10 rounds. We do not want to speculate here how these two factors could have interacted with group size and/or the version of the public good game and produced the obtained results. Our point is that the two data sets give additional reason to believe that continuous and threshold dilemmas public good games can yield different results.

Another instance where step-level public good games yielded different behaviors than continuous public good games was demonstrated by Bornstein (1992). He compared a step-level and a continuous public good, when players consisted of groups of participants, instead of individuals. That is, he had 3-person groups playing against each other in a step-level or continuous public good. He found that more group members contributed in a step level compared to a continuous public good. Also within group discussion was more effective in order to enhance cooperation in the step-level than in the continuous public good.

It is also likely that other interventions will yield different effects in continuous and threshold dilemmas. Consider, for example, the effects of commitment: It has been found that committing publicly to a certain contribution, for instance by announcing it, enhances the likelihood that the decision-maker will stick to this contribution rate. The question is whether this effect is psychologically equivalent in games that have and do not have provision points. When a provision point exists, the provision point likely guides both the commitment and the decision. There are, for instance, three people, each of them has four endowments, which they can either contribute to the common pool, or keep to themselves, and there is a provision point of 9. Players of this particular game are likely, when asked, to commit themselves to contributing 3 endowments and are subsequently likely to contribute them. This means that people are likely to commit themselves to a fair division and stick to it. Indeed, learning that others have committed to a fair distribution of contributions will provide the incentive to stick to the commitment. In a continuous public goods game no such “fairness rule” exists to guide commitments or decisions.

Learning, for example, that others have committed to contributing 3 units of endowment does not provide an incentive to reciprocate this level of commitment. Thus, we cannot conclude that commitment enhances cooperation rates in continuous public good games or resource dilemmas.

Are dilemma-games with a provision point best modeling our world?

Behavioral scientists are often interested in using public good or common resource games to simulate dilemmas encountered in the social world. In this endeavor, it is useful to incorporate features of the real-world dilemma in the game. The question is whether the examples cited in a typical article on public good and resource dilemmas mentions most closely resemble continuous or threshold games. Consider the traditional example from Hardin (1968), who wrote about the commons' dilemma. His example was the grazing of cattle on a common grazing land. If too many farmers put more and more cattle on the common grazing land, the cattle would eat all of the grass and the common grazing land would cease to exist. Whereas one can conceive of the complete destruction of the commons as a threshold, it is not the case that the dilemma is defined only relative to this extreme event. The more likely outcome of overgrazing is that the profit to each farmer decreases because the cattle will not get enough to eat and thus not flourish. In this situation there is no single provision point. Every additional cow that a farmer puts on the grazing land increases the risk of degrading the grazing land and the risk of underfeeding the cattle.

Take another often cited example, the water supply: If people of a community use too much of their fresh water, e.g. supplied by a lake, their fresh water will become a scarce resource, and there will be less for everybody. The lake would cease to exist if every drop of water were used, but again, there is no obvious, single provision point. It is not that the population would know that if together they used a certain number of gallons of water, there would not be any

water any more. It is more of a continuous function. With every gallon of water used, the difficulty and cost of providing water increases.

The same is true for all environmental issues, on which public good and resource dilemmas have also been applied. The air pollution is a dilemma, and we are all involved in it. But there is no provision point. The issue, at least as people experience it, is not that at a certain level of emission of pollutants, the air will be too polluted for us to live in. The issue is that as the level of pollutants increases, the quality of life decreases.

If you take the institutions that collect the public radio license fees (in Germany the GEZ, in the U.S., the public radio and TV), who are depending that consumers of radio and TV to pay their dues. The system can only survive on the long run, if a certain amount of people pays their dues. However there is no threshold, in the sense that if the *n*th person does not pay his or her dues than the system will collapse. Again, the provision of public TV and radio is continuous: The more consumers who contribute, the better the quality and quantity of the public service.

One applied goal of experimental research on dilemmas is to learn how to reinforce behavior that is in the interest of the collective in real life dilemmas: in environmental issues, in the matter of license fees for public radio and TV, and in other cases where a public good needs to be provided or a non-excludable resource preserved (e.g. renewal of the public local library financed through donations or a commons grazing area maintained). But as we have outlined in the last paragraph, most of these real world dilemmas are not dilemmas with an obvious or clearly defined provision point. Thus, we cannot be sure what research using step-level public goods games tell us about behavior in these real world examples. That is, not only do step-level games violate a defining characteristic of a social dilemma, they also compromise ecological validity.

Conclusions and Implications for a tilted S

Why have social psychologists studied threshold dilemmas so extensively? We have outlined in the last paragraph that threshold dilemmas are not a good model of certain real life dilemmas. So insights into behavior in threshold dilemmas may generalize to many of the proposed referent situations in real life. Of course, there is basic research that never claims to model real life situations in experiments, but rather has the goal to gain insights into human behavior on a more fundamental level. But, as we have pointed out in the section about implications of the structure of public good games with a provision point, these games change the nature of social dilemmas in a fundamental way by imposing a coordination problem on top of a dilemma. It is unclear what kind of behavior a threshold dilemma is measuring. It is neither pure cooperative behavior, nor pure coordination behavior, but some mix of both. Thus, we question whether threshold dilemmas do provide an adequate methodological vehicle for exploring the effects of framing, social rules, social identity, feelings of groupness, social motives and other psychological factors that affect social behavior.

One could, however, question whether real life dilemmas are adequately represented by a continuous linear function relating levels of contributing and provision of a public good. For instance, in order to maintain a local library, you need a minimum amount of money for the maintenance of the building, the cleaning of the shelves, and a minimum stock of recent books. Once that building is kept neatly in order, and books are periodically renewed, additional contributions to the library matter, as you can still buy new books, but they might not matter as much as initial contributions that allow for sustaining the essentials of the library. However, if there were not enough contributions to keep the building maintained, the library would not cease to exist; it would just be housed in a shabbier building with fewer new books. Thus that would

mean that some contributions matter more than others, depending on how much has already been given. However, a step-level public good does not model that situation either. Provision points in these games are arbitrarily determined, and represent the provision of the public good as all or nothing. It is for that reason that it violates the basic notion of the conflict between the individual's interest and the interest of the group, and that a pursuit of the individual interest by all makes them worse off than had they pursuit the group's interest. A tilted S-shaped continuous function (or a sine function) may provide a better model of many social dilemmas. The function between contributing and establishing the public good is continuous, which means that every contribution matters for the provision of the public good, and for every contribution an individual faces the conflict between its own interest and the group's interest. With an S-shaped continuous function (as illustrated in Figure 1), it can be that, for any point along the curve, the individual is better off not contributing, but the collective would be worse off if all individuals refused further contributions. Nonetheless, there are regions where additional contributions matter less and regions where they matter more. This is a feature of natural dilemmas that may partly account for the popularity of step-level games in social psychology. In many cases, low levels of contributions cannot provide or sustain a substantial public benefit and, at high levels of contributions, there is relatively little value added to the public good by additional contributions. However, there is a region between these extremes where contributions to the public good matter more. We suggest that these features are modeled better by a continuous S-curve than by a step-level function. What would be implemented with the S-shaped function, as opposed to a linear function, is the variation in the intensity of that conflict. In the regions were the steepness is low, a contribution makes less of a difference to the public good, than in the regions where the steepness is high. [2]

In our comparison of step-level and continuous function social dilemmas, we have raised the concern that one can not assume that findings for one form of the game generalize to the other form. At the heart of this concern is the fact that step-level games often provide a salient coordination rule that changes the nature of the psychological dilemma that arises when there is a conflict between individual and collective outcomes. Nonetheless, one feature of the step-level game that is theoretically and ecologically interesting is the fact that marginal returns to the individual for contributing are not independent of what others contribute. We propose the S-shaped function because it maintains the psychological conflict between individual and collective interests and simultaneously captures the ecologically valid feature that collective benefits, and thus returns on investments, for contributing are typically greater in the mid-range than at the extremes of total contributions. For example, in many public goods problems, people likely recognize that the collective benefit is meager if contributions are too low (e.g., a poorly stocked library in a shabby building serves a community poorly) and the value added by more contributions is limited if contributions are already high (e.g., adding an espresso bar to a well-stocked, well-maintained library adds little to the library's fundamental services). We doubt that people frame their decisions to contribute in terms of being critical to the existence of the public good as they apparently do in a step-level game. That is, they probably do not view their decision to contribute or not as determining whether public good exists at all. Rather their decisions are based on a more complex, and perhaps subtle, set of considerations: e.g., how much will my contribution improve the public good and the benefit I will get from it and how will I feel about myself if I do or do not contribute.

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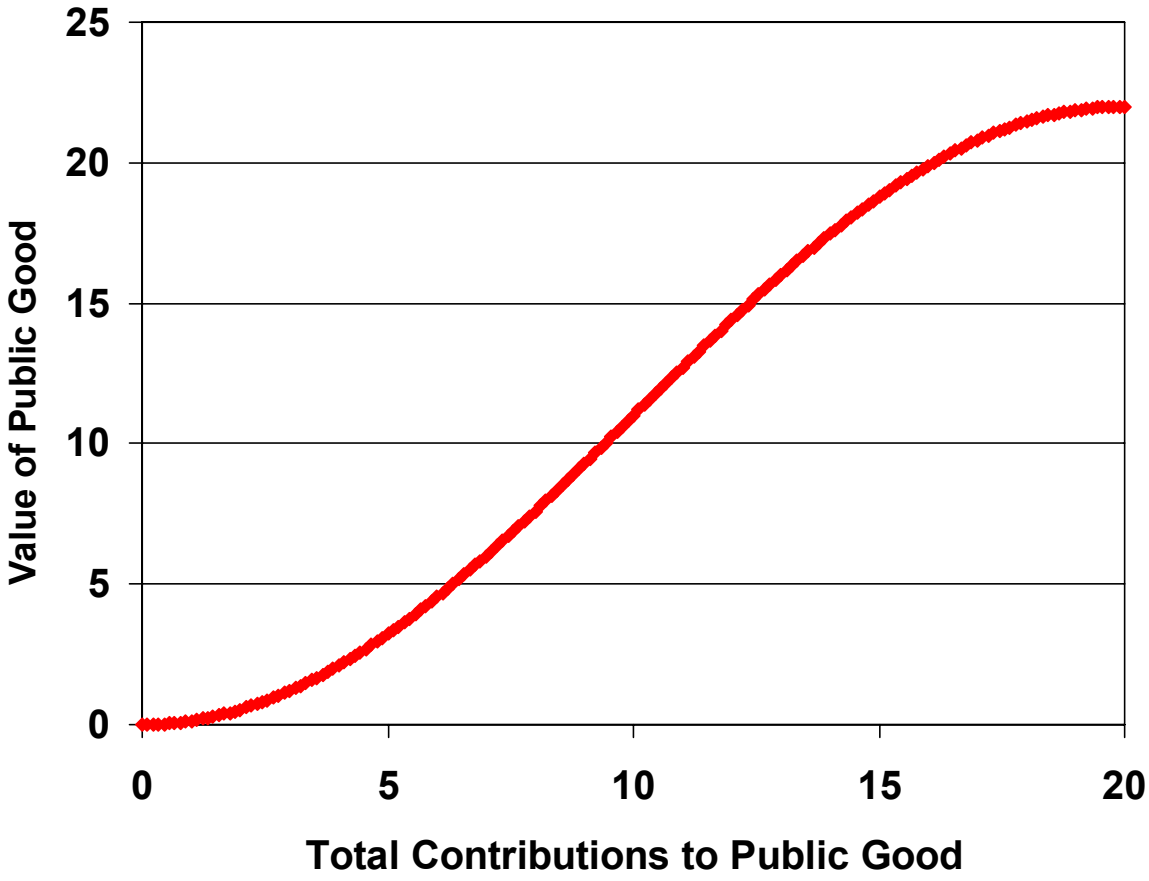
Footnotes

[1] The provision point can also be defined in terms of the number of contributors, not the amount contributed: the minimal contributing set game. These games represent another methodological variation that has the same limitations as a step-level game.

[2] Marvel and Ames (1979) used a game that resembles the one that we are proposing. However, their game, like a step-level game, included a region of total contributions in which it was more beneficial for a player to contribute than not to contribute.

Figure 1. An example of the relationship between levels of contributions and value of the public good as represented by a sine function.


25
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