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Abstract

Conflicts between individuals' and collective interests are ubiquitous in social life. Numerous experimental studies have investigated the resolution of such conflicts using public good games with either continuous or step-level payoff functions. A conceptual analysis using both classic game theory and social exchange theory shows that these two types of games are fundamentally different. A continuous function game is a social dilemma in that it contains a conflict between individual and collective interests whereas a step-level game is primarily a social coordination game. Thus, we conclude that one can not safely generalize results from step-level to continuous form games. Additionally, our analysis shows that the distinction between continuous and single-step games can be blurred by segmenting a continuous function into steps or adding steps to a single-step game. We identify characteristics of the payoff function that conceptually mark the transition from a dilemma to a coordination problem.

Continuous and Step-Level Pay-off Functions in Public Good Games: A Conceptual Analysis

Reconciling individuals' interests with public interests is a challenge for every society. Hence, learning how people can be enticed to forgo individual interests for collective interest is useful for understanding social behavior and developing social policy. Conflicts of individual and collective interests are commonly studied in psychology using experimental games. These games are generically referred to as social dilemmas and include both public goods games and resource dilemmas. Experimental studies have used two fundamentally different games to study the conflict between individual and collective interests: games that use a continuous payoff function and ones that use a step-level function. In this paper, we will point out why it is essential to consider carefully the form of the pay-off function and offer suggestions for improving the theoretical and ecological validity of research that address conflicts of individual and public interests. In many reviews of the psychological literature on social dilemmas, 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 clearly distinguish which studies used which type of game (e.g., Komorita & Parks, 1995, 1996). We argue that the conceptual differences between these games provide no basis for concluding that findings generalize from one type of game to the other.

First we outline the rationale of a public good game and explain the distinction between a continuous and a step-level game. Second, we contrast continuous and step-level games from two theoretical perspectives: game theory and social exchange theory. Third, we selectively review several areas of research that yield different findings depending on the form of the game used. Fourth, we conclude that public good games with a continuous pay-off function are classic social dilemmas but that step-level games are social coordination problems. Finally, we suggest a conceptual framework that represents continuous and step-level games as end points on a conceptual continuum. We additionally suggest that the region between these two types of games contains intriguing theoretical and applied questions that have not been adequately explored.

Continuous and Step-level Public Good Games

The Prisoner's Dilemma Game is familiar to most students of psychology. Two people are interdependent and communication between the two is not possible. Both have two options; they can either cooperate or defect. If they both defect, their pay-off is lower than if 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 economic equilibrium.

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, resource dilemmas, or, often in the behavioral sciences, generally as social dilemmas. The underlying principle of the interdependency for these games is the same as for the Prisoner's Dilemma Game: There is a conflict between the collective interest and the interests of each individual. The group as a whole fairs best when all decision-makers contribute their endowments in a public good game or refrain from taking resources in a resource dilemma. However, regardless of others' action, each individual is always better off keeping their endowments in a public good or taking as much as possible from a common resource in a resource dilemma. Thus, the dilemma is between individual incentives to defect and the collective incentive to avoid the bad outcome of everyone defecting.

In the behavioral sciences, there are two dominant ways of implementing a public goods game (see e.g. Komorita & Parks, 1996). In both ways, players are given an endowment of X units and decide how much of the endowment to contribute to the public good, Y ($0 \leq Y \leq X$). 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 also holds for decisions to increase one's contribution from Y to Y+1 for all Y. That is, a player's payoff is always better when contributing Y than when contributing Y+1 and, thus, the only stable solution (technically, a Nash equilibrium in pure strategies) for such a game is for all players to contribute nothing.

To illustrate, suppose that three players are endowed with 10 resource units or points which have a value of $1 each. They individually decide how many points to contribute to a public account without knowing what the others decide. Points not contributed are kept in each player's private account and retain their value of $1 each. Points contributed to the public account earn a 50% bonus and, thus, have a value of $1.50. The total value of the public good is distributed equally among the three players at the end of the game.

Consider three possible outcomes of this game. The first case is simple: each player keeps the endowment of 10 points and leaves with $10. Nothing is contributed to the public account and nothing is gained from the public account. In the second case, everyone contributes all of their points. As a result, the private accounts contain nothing and the public account contains 30 points which is valued at $45. By everyone contributing everything, each receives $15 (i.e., 1/3rd of the value in the public account). Thus, everyone fairs better if they all contribute all of their points than if no one contributes. In the third case, Players B and C each contribute 10 points but Player A contributes nothing. In this case the public account has 20 points and a value of $30. Thus, Player A receives $10 for the points retained in her private account but also gets $10 for her share of the public account -- $20 in total. In contrast, B and C have nothing in their private accounts and receive only their share of the public account -- $10 each.

The dilemma resides in the fact that each player individually fairs better by not contributing regardless of the others' decisions. As the foregoing example illustrates, when Players B and C contribute all their points, Player A does better by contributing nothing ($20) than by contributing her 10 points ($15). Indeed, Player A does better by contributing nothing regardless of what Players B and C do. However, the other two players are faced with the same contingencies and are likewise economically motivated to contribute nothing.

A step-level game contains a provision point that specifies a level of contribution at which a fixed amount is added to the public good. 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 one of two 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 or reducing her contribution. If her contribution of additional units results in satisfying the provision point, she is often better off to contribute than not. If the sum of the players' contributions is exactly the provision point, there is no incentive for any one of them to reduce (or to increase) her contribution.

In a step-level game, the provision point is defined in terms of the total contributions from all players. For example, suppose that three players were endowed with 10 points and each point in a player's private account were worth $1. As before, each could contribute from 0 to 10 points to the public account. However, in the step level version, any combination of contributions totaling 15 or more points would create a public good worth $22.50. If this provision point were met or exceeded, each player would receive $7.50 from the public good and $1 for each point that was kept in the individual account. If fewer than 15 points were contributed, the public good would have no value, all contributions would be lost, and players would receive only $1 for each point kept in the individual account.

A variant of the step-level game is the minimal contributing set game. In a minimal contributing set game, players contribute either all or none of their endowment. The provision point is defined by the number of players that must contribute to create value in the public account. Thus, the minimal contributing set game is a special case of the step level game and we will focus our comments on the step-level game with the provision point defined by the sum of contributions.

Although the step-level game resembles the continuous function game, it is different in an important way. Namely, it is not the case that players are invariably better off if they contribute less, as opposed to more. A simple thought experiment illustrates this difference. Suppose that Player A expects that the other two players will contribute 5 points. This expectation in the continuous function game does not change the fact that Player A's payoff will be higher by not contributing than by contributing.

In contrast, if Player A expects that the others are contributing 5 points each in the step-level version, the implications regarding what she should do to maximize her individual wealth are different. In this case, her contribution of 5 points plus the 10 points contributed by others will satisfy the provision point of 15 and the public account will be worth $22.50. Thus, her contribution of 5 points will result in her receiving $5 for the points remaining in her private account and $7.50 for her share of the public good – a total of $12.50. If she were to contribute nothing or an amount less than 5 points, the public good would be worth nothing and she would get only $1 for each point not contributed -- $10 if she contributed nothing.

Game Theory

From a game theoretic perspective, these examples are a long way of illustrating two fundamental differences between continuous and step-level public goods games. The first difference is that the continuous-form game has one Nash equilibrium in pure strategies whereas the step-level game has several. A Nash equilibrium is a theoretical concept but has important implications for behavior in interdependent decision making. Formally, a Nash equilibrium is a solution or pattern of choices in which each person's decision is the best response to the others' decisions. As a result, a Nash equilibrium, once it occurs, is a relatively stable solution because no one is motivated to change her choice. Moreover, if players fully understand the game, are motivated to maximize their individual outcomes, and assume that others also fully understand and are so motivated, they will play the Nash equilibrium if one and only one such equilibrium exists. From a dynamical systems perspective, Nash equilibriums tend to act as attractors in repeated games in that decisions tend to move toward a Nash equilibrium over time and once the Nash equilibrium is played there is a strong resistance for anyone to change. In the continuous form of the game, everyone contributing nothing is the only Nash equilibrium. Moreover, the pressure to respond with the Nash equilibrium is strong because not only is contributing nothing the best response to others' contributing nothing but also each player's best response to any pattern of contributions by others is to contribute nothing.

In a step-level game, contributing nothing is not always a player's best response to the decisions of others. That is, there are multiple Nash equilibriums in a step-level game. In the foregoing example of a step-level game, everyone contributing nothing is an equilibrium but it is not the only one. Any combination of contributions that sum to the provision point may also be a

Nash equilibrium. Consider, for example, a case in which Player A contributes 3 points, Player B contributes 5 points and Player C contributes 7 points to reach a provision point of 15. In the aforementioned step-level game, no player in this case would improve her economic outcome if she were to respond differently given what the other players contributed. Player C may think it is unfair that she is contributing more than the others. Nonetheless, she would receive a worse economic outcome if she were to give less than 7 in light of what the others have done. That is, her best economic response to the Players A and B giving 3 and 5, respectively, is to give 7.

Another fundamental difference between step-level and continuous-form games is related to the game theoretic concept of Pareto efficiency. A pattern of decisions or a solution to the game is Pareto efficient if no other solution exists that improves at least one player's outcome without adversely affecting someone else's outcome. In the continuous form game, everyone contributing everything is Pareto efficient but the Nash equilibrium -- everyone contributing nothing -- is not. Compared to everyone contributing nothing, there are many solutions that improved outcomes for at least one player while not adversely affecting others: One of these solutions is, of course, for everyone to contribute their entire endowment. Moreover, everyone contributing everything is the solution that maximizes the collective outcome in the sense that the group earns as much as possible. Thus, behaviorally, Pareto efficient solutions are stable solutions if players are motivated to avoid harm to others. Moreover, in the continuous form game, the motivation for the collective to earn as much as possible is satisfied by the Pareto efficient solution.

In the step-level game that we described earlier, any solution that minimally satisfies the provision point is a Pareto efficient solution. For example, in the case outlined above, three players satisfy the provision point of 15 by contributing 3, 5, and 7 units. If any one of these players tried to improve his individual outcome by contributing less, he would succeed only if another player (or other players) compensated by contributing more in order to obtain the public good. This condition holds for any combination of decisions that minimally satisfy the provision point. As a result, these minimally satisfying sets of decisions are both Nash equilibria and Pareto efficient.

To summarize, continuous form and step level games are distinctly different in game theoretic terms. In the continuous form game, everyone contributing nothing is a Nash equilibrium but everyone contributing everything is Pareto efficient. In the step-level game, many patterns of decisions that minimally satisfy the provision point are both Nash equilibria and Pareto efficient solutions.

Step-level Game: Dilemma or Coordination Problem?

The task of reaching, but not exceeding, the provision point is a coordination task. There is certainly a potential conflict among individuals in solving the coordination problem. However, managing the coordination task and successfully reaching the provision point does not necessarily entail a conflict between the individuals' and collective interests. Consider the aforementioned, three-person public good game. Each individual has an endowment of 10 points and, thus, can contribute 0 to 10 points. Given a provision point of 15, the common pool will have no value if fewer than 15 endowments are contributed. If a player knows that there are only 10 points in the common pool, the best response for that player is to contribute 5 points in order to reach the provision point. Of course, in this decision situation, a player does not know the current contributions of the others. 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. In other words, there is no strategy that would always make her better off, regardless of what the other(s) are choosing.

Thus, two fundamental features attributed to social dilemmas are missing when a provision point exists. First, there is not always a conflict between the collective interest and each individual's interest. Second, an individual can be better off contributing than not contributing. Moreover, for the group, the challenge is to coordinate their behavior so that the provision point is reached but not exceeded. An obvious solution in the foregoing example is provided by an equality rule: each of the three players contributes three endowments. Indeed, a typical experimental result is that the modal contribution in a step-level game is the provision point divided by the group size (van Dijk & Wilke, 1995; van Dijk & Wilke, 2000).

Social Exchange Theory

Kelley and Thibaut (1978), in their classic treatise of social exchange theory, distinguished three components of interdependency in social relationships. They developed their analysis primarily in terms of two-person interactions represented by 2 X 2 payoff matrices. An instructive example is the Battle of the Sexes (BOS) as represented in Figure 1. In the traditional presentation, a wife (W) and her husband (H) are deciding between going to the opera (O) and a football game (F). Stereotypically, the wife prefers O whereas the husband prefers F. However, they also prefer to attend the same event together. Thus, the solutions in which they do the same thing -- (O, O) and (F, F) – are favored over solutions in which they do different things – (O, F) and (F, O). Nonetheless, W prefers (O, O) to (F, F) and H prefers (F, F) to (O, O). This example illustrates two of Kelley and Thibaut's components of interdependency. First, each person has an individual preference that partly determines the value of each solution for each party. Kelley and Thibaut referred to this component as *reflexive control* (RC). That is, the degree that a person prefers one choice regardless of what other's do means that the person's decision directly reflects value back to her. Second, each person's choice affects the values of the other's choices. They dubbed this latter dimension *behavioral control* (BC) because one person's response changes the values associated with the other person's responses. In the BOS, there is *mutual behavioral control* because each person's decision affects the payoffs associated with the other's possible decisions.

The third component in their analysis is *fate control* (FC). This component refers to the degree that one's decision directly affects the outcomes of others. Pure mutual fate control is illustrated in Figure 2. In this example, A responding X gives B a better outcome than if A responds Y. The fate control is mutual because B can likewise directly affect the outcomes of A. If B responds Y, A gets 10 points but B responding X gives A nothing.

Kelley and Thibaut demonstrated that classic interdependencies such as the BOS, Prisoner's Dilemma (PD), and Chicken can be represented as different mixes of reflexive control, behavioral control and fate control. For example, consider the aforementioned Prisoner's dilemma as depicted in Figure 3. Each person's choice is typically labeled as cooperate (C) or defect (D). Whereas the BOS is a mix of RC and BC, the Prisoner's dilemma is a mix of RC and FC. The RC component produces the condition that both players will fair better by defecting (D) regardless of what the other does. The FC component is due to the fact that, by responding D, a player adversely affects the other's outcome whether the other responds D or C. Moreover, the FC component is *noncorrespondent* relative to the RC. That is, by selecting the choice that is favored by the RC component, a player adversely affects the other's possible outcomes.

The BC component of a BOS is experienced as a coordination game; it is mutually beneficial for the players to coordinate their decisions by selecting the same activity. In contrast, the PD is experienced as a game of conflict; acting to improve one's own outcome adversely affects the other's outcome.

Contrasting the continuous form and step-level public goods game in terms of Kelley and Thibaut's components also illustrates that they are fundamentally different games. The continuous form game is a mix of RC and FC with no BC. Each player prefers to contribute less rather than more and the adverse impact of contributing one unit of her outcome is the same regardless of what others do (RC). However, one player's decision to contribute a unit of resource benefits others by a specific amount regardless of what they do (FC). Thus, the continuous-form public goods game, like the Prisoner's Dilemma Game, directly pits RC (individual preference) against FC (the opportunity to help or harm others).

The step-level game is a complex mix of RC and BC. Every player, as in the continuous form of the game, prefers to contribute less rather than more other things being equal. However, other things are not always equal in step-level game. Imagine the entire space of possible solutions. In this space, there is a large region in which the payoffs for one player's decisions are affected by the decision of others. For example, in the game described earlier, three players have to contribute 15 points to obtain a public good worth $22.50, of which each player gets $7.50. Contrast two situations. First suppose that two players contribute a total of 4 points. Then the third player's outcome for contributing nothing is $10 (only the value of the points retained in the private account) and for contributing 5 points is $5 because neither decision satisfies the provision point given the contributions of the others. Thus, in this first case, the third player is better off contributing nothing rather than 5. Consider a second case: the first two players contribute a total of 10 points. Now, the third player is better off contributing 5 than contributing nothing. Contributing 5 yields $12.50 for the 5 points left in her private account plus her share of the public good whereas contributing nothing yields only the $10. That is, the outcomes for contributing nothing and contributing 5 points depend on the decisions of the others: The others have behavioral control over the third player in this case. By recasting this example from the points of view of the other players, it is evident that each player has behavioral control over the others in this region lying close to the provision point.

In the typical step level game, one player cannot directly affect the outcomes of other's regardless of what the others do. Thus, there is no pure fate control. One's decision to contribute a unit of resource does not *directly* impact what others receive. Rather it may change the payoff's associated with the decisions that others make.

To summarize, social exchange theory represents a continuous-form public goods game as combination of RC and FC. Moreover, the RC and FC are noncorrespondent: decisions that increase outcomes for the individual (RC) adversely affect outcomes for others (FC). From this theoretical perspective, the continuous form public goods game is a close relative of the PD and is a game of conflict; one player's action to protect her outcomes adversely affects others' outcomes. The step-level game (as well as the minimal contributing set game) is a combination of RC and BC and, as such, is a close relative of the BOS. Thus, the step-level public goods game, like the BOS, is primarily a coordination game; everyone benefits if they can coordinate their decisions to satisfy minimally the provision point (van Dijk & Wilke, 1995; van Dijk & Wilke, 2000).

<u>Generalizability</u>

In their conceptual review of 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 for coordinating decisions.

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; see also De Kwaadsteniet, Van Dijk, Wit, & De Cremer, 2006), 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 in a pseudo-sequential and a simultaneous procedure. In either case, players do not know what others have decided when they make their choice. Abele and Ehrhart (2005), using a continuous public goods game, demonstrated that pseudo-sequential, compared to simultaneous, deciders are more likely to keep their endowments and less likely to reciprocate the level of contributions that they anticipate from others. Interestingly, the order of deciding in the pseudo-sequential, continuous game had no effect. That is, both first and second deciders exhibited less cooperation than simultaneous deciders.

Effects of timing have also been observed in dilemmas with provision points. Budescu, Suleiman, and Rapoport (1995) and Budescu, Au, and Chen, (1997) observed decisions in a step-level resource dilemma with a pseudo-sequential decision order. Their results were different from the ones observed in the continuous game: Players' requests decreased in the first three positions. Thus, the implications of this positional order effect in step-level dilemmas are 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 decisions 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 step-level 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, 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. More specifically, it refers to the subjective probability that one's contribution is necessary and sufficient for the group to reach the provision point. 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. Moreover, he found that perceived criticality also decreased as a function of group size. In contrast, Isaac, Walker and Williams (1994) found the opposite effect of group size. 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 step-level public good games, while cooperation rates increase with group size in continuous public good games. However, the studies also differed in another way. Kerr (1989) used a one-shot game whereas Isaac et al.(1994) included multiple rounds in their experiments. This difference prompts us to look deeper at the explanations for group size effects in the two types of games.

In addition to the hint that group size may have countervailing effects for the two types of games, the theoretical explanations for the group size effects are different for the step-level and continuous games. Moreover, these explanations do not generalize easily from one type of game to the other. Isaac et al. (1994) attributed the increased contribution at larger group sizes in their continuous public goods games to a signaling effect, meaning that a relatively high contribution in one round should signal a willingness to contribute to other players in succeeding rounds. If such signals prompted others to reciprocate, one's contribution at time one would be recouped by inducing higher contributions by others later. Moreover, for any given level of effectiveness of such signals, the anticipated benefit of signaling should be higher the more people whose subsequent contributions can be influenced. Hence, signaling accounts for the positive relationship between contributions and group size in a multi-trial, continuous form game. Consider this explanation for a multi-trial, step-level game. Although it is plausible that players in a step-level game could use play on one round to influence the play of others on subsequent rounds, presumably the goal of such signaling would be to realize a coordinated solution for reaching but not exceeding the provision point. Thus, increasing contributions with the goal of influencing others to contribute more in subsequent rounds only makes sense if the group has not reached the provision point. Once the provision point is reached contributing more in hopes of inducing others to contribute more is counterproductive. Thus, from a theoretical perspective, there is no reason to expect that group size would have the same effect in multi-round step-level and continuous form games.

Consider also the theoretical explanation for decreasing rates of contributions as a function of group size in one-shot, step-level games. The explanation for diminishing contributions when group size increased is that it becomes less likely that a given player will be a pivotal contributor -- a contributor whose contribution is necessary for reaching the provision point. This explanation of the perceived criticality of contributions can be applied to step-level games, but not to continuous form games. Consequently, a dominant explanation for the observed group size effects in step-level games does not generalize to continuous form games. Thus, both on empirical and theoretical grounds, there are reasons to expect that the effect of group size would be different in step-level and continuous public goods games, whether the games are one-shot or repeated.

It also seems to be the case that other interventions will yield different effects in continuous and step-level dilemmas. Kerr and Kaufman-Gilliland (1994) showed that communication and non-binding commitment increases contributions, using a step-level public good game (more specifically, a minimal contributing set game). However Chen and Komorita (1994) found no effects of communication and non-binding commitment on cooperativeness, using a continuous public good game.

Are nonbinding commitments psychologically equivalent in the two forms of the game? On the one hand, when a provision point exists, the provision point likely guides both the commitment and the decision. If players have made a set of commitments that minimally satisfy a provision point, there is no private incentive for any one of them to renege. On the other hand, when no provision point exists, there is an incentive for everyone to contribute less than their stated commitment. The temptation is to pledge high (in hopes of inducing contribution by others) but to give less. If everyone acts on this temptation, the discrepancy between pledges and contributions erodes the "truth-value" of the pledges and probably induces a mutual sense of distrust.

<u>The Transition from Conflict to Coordination</u>

Although most examples of step-level games in the literature have one provision point, it is easy to conceive of a game with multiple steps. Indeed, if one imagines a game with many steps, it becomes barely distinguishable from a continuous game. Conversely, a continuous game as typically implemented becomes a multiple step-level game because contributions are represented as whole units of points or money. These relationships suggest that it is not the mere presence of provision points (or steps in the function) that shifts a game from a game of conflict to a coordination game. Figures 4 and 5 depict the relationship between the value of a public good and contributions for a continuous public good game and a step level game respectively. Figure 4 depicts the function for the continuous game described earlier. Zero contributions to the public good correspond to a value of zero of the public good. Starting from this origin, the function can be represented as a series of small steps: a contribution of 1 unit increases the value of the public good by 1.5 units; a contribution of 2 increases the value of the public good by 3; and so forth. Because, as implemented, the amounts of contributions are represented in discrete and not continuous units, this conceptually continuous game, in practice, consists of many small steps. If it is not the existence of steps in the function (i.e., provision points), what distinguishes a public goods game that is inherently conflictual from one that presents the opportunity for a stable, coordinated solution?

The distinction centers on the net return that a player expects from a unit of contribution. If at every location in the function one incurs a net loss in outcome by contributing a unit, then players are always tempted to contribute less regardless of what others do. As a result, the game is conflictual. In the language of social exchange theory, the interdependency is dominated by mutual fate control and there is no behavioral control. More formally, let the value of the public good, V_p, be a continuous increasing monotonic function, f, of the sum of the individual contributions, Y_i: $V_p = f(\sum Y_i)$, where the summation is across r players. If an equal share of the public good is allocated to each person (i.e., each player gets V_p/r, as is the case in most experimental applications), the game presents a conflict between individual and collective interests when the rate of change in V_p is less than group size, r, for all values of $\sum Y_i$. For the typical experimental game, the function is linear: $V_p = c\sum Y_i$, $c > 0$. In this case, there is always a conflict between individual and collective interests if $c < r$. When $c < r$, there is a dilemma because the player's share of the increment in the public good does not compensate for a unit of contribution and one is always tempted to contribute less. If $c \geq r$, there is no dilemma. If $c = r$ the individual is indifferent between contributing one or more units of endowment to the public pool and keeping them. If $c > r$, everyone fairs better by contributing.

Extending this logic to a step-level function, let d be the increment in value of the public good at a provision point and p be the total contributions necessary to satisfy the provision point. If $d > r$, then no player is tempted to reduce her contribution by one unit when the provision point is reached, that is, when $\sum Y_i = p$. However, $d > r$ is a necessary but not sufficient condition to insure that a coordinated solution is stable. It is also necessary to show that a solution exists that does require any player to contribute more than d/r to reach the provision point. As depicted by the dashed line in Figure 5, consider a linear function starting at the origin of (0, 0) and continuing through the point (p, d). If the slope of this line, s, is greater than 1 ($s = d/p > 1$), then at least one solution exists that is an equilibrium if p can be equally divided among the players. That is, if $s > 1$ and each player contributes p/r, then each player's compensation exceeds her contribution because p/r is less than d/r. Even if players' contributions are not equal, any solution in which every player's player contribution to reaching the provision point is less than d/r is a stable solution. In this case, the provision of the public good is no longer a conflict between individual and collective interests; it is a coordination problem.

Weber, et al. (2004, see also, van Dijk & Wilke, 1995, 2000) noted that people search for rules that guide decisions in interdependent relationships. In the case of step-level public goods games, a particularly compelling rule, suggested by concepts such as equity and fairness, is to share equally the cost of satisfying a provision point. A similar notion is suggested by the concept of focal points in coordination (Mehta, Starmer & Sugden, 2001; Schelling, 1960). A focal point is a salient solution to a coordination problem. The foregoing analysis identifies another reason to favor equal divisions of contributions in satisfying a provision point. If the provision point in a step-level game permits a solution that is an equilibrium, then an equal division will certainly be an equilibrium whereas other distributions of contributions that satisfy the provision point may not be. In the foregoing example depicted in Figure 5, each of three players contributing 5 to reach the provision point of 15 is an equilibrium: 5 is everyone's best response to the others' contributing 5. However, if Players A, B and C contribute 3, 3, and 9, respectively, to reach the provision point, Player C's best response is not 9 but 0. Thus, this latter solution is not an equilibrium. Aside from concepts of fairness and equity, equal division of contributions are more likely to provide stable, coordinated solutions to step-level games than unequal divisions as long as the public good is equally distributed.

It is informative to note that the superimposed line in Figure 5 represents the same linear function as depicted in Figure 4. Indeed, the provision point (p, d) is a point on the continuous function in Figure 4. Thus, any solution that reaches the provision point in a game that uses this step-level function is also a solution for the continuous game that uses the continuous function depicted in Figure 4. Whereas such a solution may be an equilibrium in the step-level game, it is not an equilibrium in the continuous version. Thus, reframing a continuous game into a one-step game may create an equilibrium. However, adding more steps may also destroy an equilibrium. Figure 6 adds another step to the function by defining a second provision point: if total contributions are 30, the public good is valued at 45 and each of the players receives 15 as a share of the public good. If this were the only step, every player's best response to the others' contributing 10 would be to contribute 10 and there would be no dilemma. However, the existence of the second provision point at 15 provides an incentive for each to contribute less than 10. That is, in this two-step game, if Players B and C were to contribute 10, Player A would earn more by contributing nothing. B's and C's contributions would satisfy the lower provision point creating a public good of worth 22.5 and A would get 17.5 (10 from the private account and

7.5 from the public account). Thus, in this two-step game, everyone contributing his total endowment is Pareto optimal but it is not a Nash equilibrium in pure strategies. Rational players who think that others are also rational would not contribute 10 in this two-step game but would contribute 10 if there were only one provision point at 30. Nonetheless, even in this two-step game, the first provision point at 15 still affords an opportunity for a coordinated solution.

How far can one push this approach to removing the inherent conflict in a continuous public goods game? If imposing one or two steps removes the inherent conflict in the game depicted in Figure 4, does 3, 4 or more steps also remove it? The answer centers on determining whether equal contribution solutions at each provision point are stable in the sense that each player's contribution of a fair share is the best response to the others' contributions of fair shares. In this game, $r = 3$ and $c = 1.5$. Consider imposing 10 equal-sized steps. In this case, the amount of contributions, p, to go from one step to the next is 3 and the increment in the value of the public good at each step, d, is 4.5 (i.e., $d = 1.5*3 = 4.5$). Thus, each player's fair share contribution to move from one provision point to the next is 1 and each gains 1.5 as a share of the public good (i.e., $d/r = 1.5$). However, by starting at the highest provision point and stepping down to the next lower, one can show that at every provision point, except the lowest one, each player is tempted to defect from the equal division solution. For example, suppose that each player contributed 4 points of their 10 point endowment to reach a provision point of 12. The public good would be worth 18 in this case and each would earn 6 from the points remaining in the private account and 6 as the share of the public good – 12 points. However, each of the players best response to the others contributing 4 would be to contribute either 1 or 0, either of which would lead to an outcome of 13.5. In repetitions of such a game, the economic pressure on each player would be to lower one's contributions. The only point at which this pressure would be removed is when (if ever), they each contributed 1 to satisfy the lowest provision point of 3.

In this case, they would each earn 10.5 which is slightly better than simply keeping their endowment of 10.

To summarize, segmenting a continuous public goods game into steps can shift the game from a dilemma to a coordination problem. However, providing several steps is often counterproductive because, with the existence of lower steps, higher steps are no longer equilibria. Nonetheless, as we address in the next section, our analysis suggests a strategy that practitioners of fundraising often employ. Whereas segmenting one iteration of continuous game into multiple steps has limited value in promoting contributions via coordinated solutions, decomposing it temporally into a series of single-step games could be effective. For example, suppose that three players were given the opportunity to contribute 1 point in each of 10 subgames or iterations with each subgame having a provision point of 3 yielding a public good having the value of 4.5. Then the stable coordinated solution to each subgame would be for each to contribute 1 point to reach the provision point. Once the three players obtained the provision point, there would be no temptation for them to defect on subsequent subgames. Thus, in this manner, temporally segmenting a continuous games into several single-step games could promote contributions to the public good.

Ecological Validity

Behavioral scientists are often interested in using public good problems 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. One question is whether the naturally occurring examples of public good and resource dilemmas more closely resemble continuous or step-level games. Consider the often cited example of providing public broadcasting in the US. Public radio and TV is a public good in the sense that no one is excluded from listening or viewing. Moreover, public broadcasting stations rely heavily on fund drives to provide this public good. Although one could conceive of a provision point below which a station ceases to exist, the salient contingency is that programming will be reduced or expanded depending on the success of the fund drive. The economic temptation is to free-ride on the contributions of other listeners because the expected increment in the quality or quantity of programming due to one's $25 or $100 gift is not sufficient to offset the investment for most listeners.

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, 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). Real world dilemmas are typically not dilemmas with an obvious or clearly defined provision point. Thus, research that uses step-level public goods games may tell us little about behavior in these real world examples. That is, not only do step-level games violate a defining characteristic of a public good game – namely a conflict between individual and collective interest, they may also compromise ecological validity.

Interestingly, however, practitioners often reframe situations so that they appear to have steps. For example, fund raisers employ several techniques to counter the individual's assessment that the return in public good is not sufficient to justify a contribution. For example, fundraisers for public broadcasting often add other incentives such as gifts or publicity (announcing a contributor's name). More interestingly, they also create artificial steps in the pay-off function and frame the situation in a way that resembles a step-level game. Consider for example, announcements such as: "We need to raise $1000 within the next hour to support the current program" or "We need to raise $500 in the next 10 minutes to receive a matching grant of $1000 from sponsor X." Such announcements reframe the larger continuous public goods problem into a series of smaller step-level problems. They do so in one or both of two ways.

First, they suggest the presence of a step (e.g., saving the current program). Second, they reduce the apparent size of *p* -- the amount of contributions necessary to reach the step (e.g., we need to get only five $100 contributions to get the matching grant). If a public goods problem can be convincingly reframed as a series of step-level problems, the psychological dynamics may shift from conflict to coordination.

Conclusions

Experimental implementations of public goods games come in two varieties: continuous and step-level. Conceptually, they represent two distinctly different types of social interdependency. Continuous public goods games pit individual against collective interests and conform to two defining characteristics: each individual fairs better by contributing nothing to the creation of the public good regardless of how much others contribute and everyone fairs better if they all contribute as much as permitted than if they all contribute nothing. In the terminology of social exchange theory, continuous public good games are a discordant mix of reflexive control and mutual fate control. In the terminology of game theory, everyone contributing nothing is the unique Nash equilibrium in pure strategies and everyone contributing as much as possible is a Pareto efficient solution. By contrast, a single, step-level game consists of several Nash equilibria: any combination of individual contributions that minimally satisfy the provision point is a Nash equilibrium as long as no one's contribution exceeds the individual share of the public good. Step-level games are a mix of reflexive control and behavioral control and afford mutually beneficial outcomes if players coordinate their decisions. That is, single-step games are coordination problems. Because of these differences, we offer the following recommendations.

First, reviews of the literature should clearly distinguish the form of the game and not generalize, either explicitly or implicitly, findings from one type of game to the other. We are not claiming that empirical findings never generalize but, in the absence of data from both types of games, there are no conceptual reasons to assume that they do.

Second, terminology should not blur the distinction between the two types of the public goods games. Specifically, including both types under the category of *social dilemmas* not only blurs the distinction but is misleading when applied to single-step games. Single-step games, along with games like the Battle of the Sexes, are more aptly called *social coordination* games because they afford solutions that are mutually beneficial to all players. This designation is not meant to imply that such games never contain an element of conflict. In the BOS, the wife prefers the coordinated solution (O, O) whereas the husband prefers the coordinated solution (F, F). Nonetheless, they both prefer to coordinate successfully to attain either (O, O) or (F, F) over not coordinating. Thus, coordination is the dominant goal.

Third, and related to the first recommendation, more research should directly contrast the two types of games. As our selective review suggests, most comparisons between the games are across studies. For example, we argued that nonbinding communication may serve different functions and affect decisions in different ways across the two types of games. However, the empirical evidence is indirect and rests on comparisons across studies that differ in several ways. To our knowledge there is no study that assesses communication effects across the two types of public goods games in one experiment.

Fourth, our analysis shows that continuous and single-step games are fundamentally different but one can blur the distinction by segmenting a continuous function into steps or adding steps to a single-step game. We identified characteristics of the function that conceptually mark the transition from a dilemma to a coordination problem. However, the interesting, and potentially useful, questions are when do the psychological shifts occur and what are the behavioral implications. For example, consider decomposing a continuous game into two steps as illustrated in Figure 6. Each provision point presents opportunities for coordinated solutions if considered separately. However, our analysis suggests that having both provision points makes a solution that satisfies the higher provision point unstable in the sense that it is not a Nash equilibrium. Compared to solutions that satisfy the lower provision point, one might expect that the solution that satisfies the higher provision point would be less likely to occur and less likely to prevail once occurred in an iterated version of this game. However, coordinating on the higher provision point (i.e., everyone contributes all of their endowment) collectively dominates every other solution (i.e. including those that satisfy the lower provision point). Additionally, allowing for the fact that players rarely fully analyze the contingencies, having multiple provision points might disrupt attempts to coordinate on any one, resulting in behavior in multiple-step games that resembles behavior in a continuous game. These are empirical issues that have not been addressed.

In sum, we make a plea for a much more careful consideration of the conceptual nature of the interdependencies that are modeled in experimental games. In pursuit of good methodology, the choice of experimental games should be carefully scrutinized in light of the experimental objectives. If, for example, the intent is to study conflict resolution, a continuous form public goods game is more appropriate than a step-level game. This exercise is not a means to an end but should be understood as a way to insure cleanly designed experiments and validly measured dependent variables. Thus, any paper reporting a study which uses an experimental game should include a justification for the form of the game, and reviews of the literature should avoid generalizing results from one form of a game to a superficially similar game when the underlying interdependencies are fundamentally different.

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Figure Captions

Figure 1. The Battle of the Sexes Game

Figure 2. A Coordination Game with pure mutual fate control

Figure 3. The Prisoner's Dilemma Game

Figure 4. Relationship between the value of the pubic good and contributions for a continuous public good game

Figure 5. Relationship between the value of the pubic good and contributions for a step level game

Figure 6. Relationship between the value of the pubic good and contributions for a game with two steps

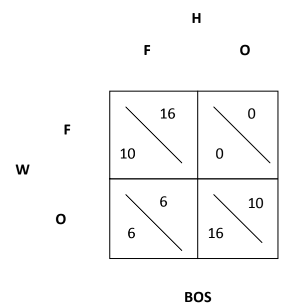

Figure 1. The Battle of the Sexes Game

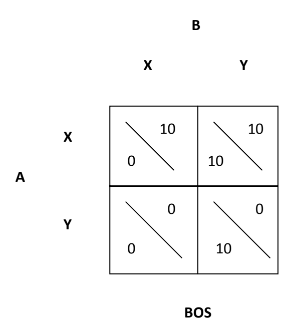

Figure 2. A Coordination Game with pure mutual fate control

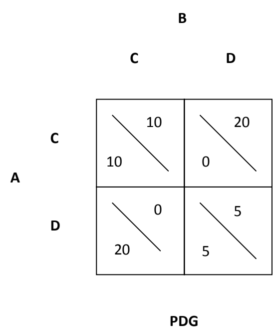

Figure 3. The Prisoner's Dilemma Game

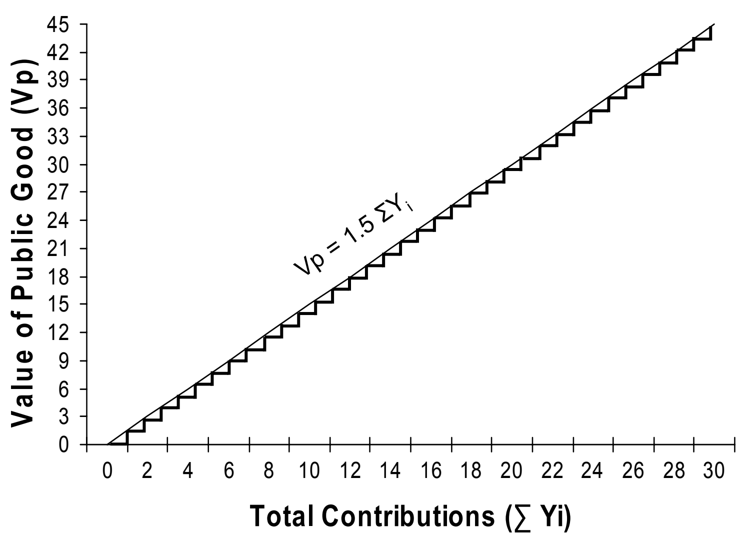

Figure 4. Relationship between the value of the pubic good and contributions for a continuous public good game

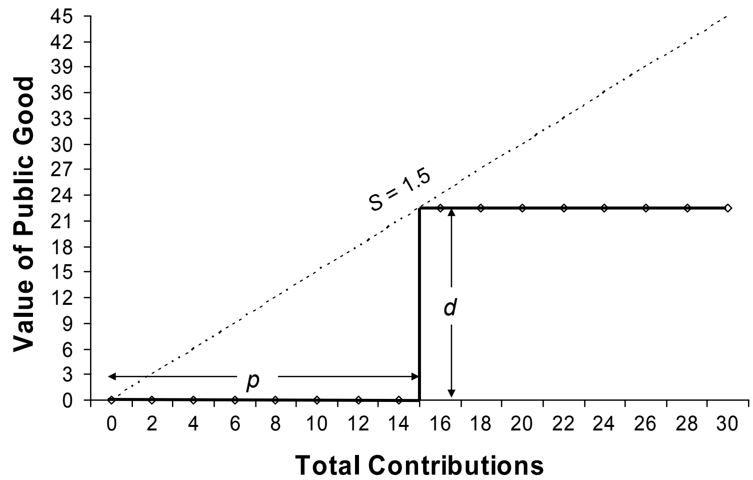

Figure 5. Relationship between the value of the pubic good and contributions for a step level game

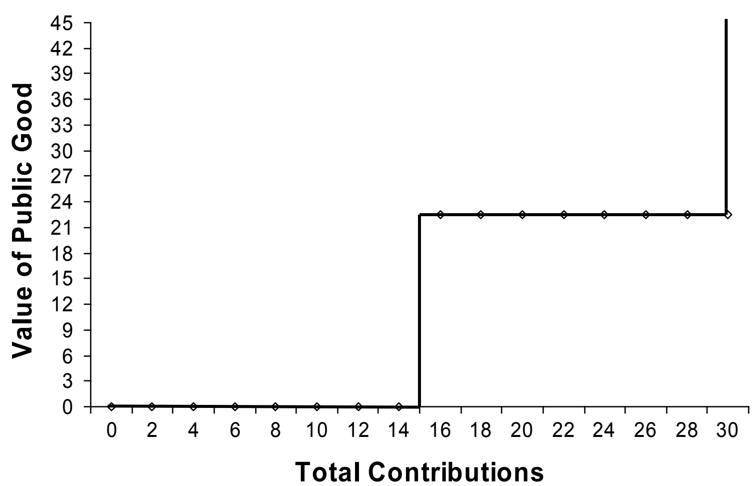

Figure 6. Relationship between the value of the pubic good and contributions for a game with two steps

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