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Positive interactions promote public cooperation

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Abstract

The public goods game is the classic laboratory paradigm for studying collective action problems. Each participant chooses how much to contribute to a common pool which returns benefits to all participants equally. The ideal outcome is if everybody contributes the maximum amount, but the self-interested strategy is not to contribute anything. Most previous studies have found punishment to be more effective than reward for maintaining cooperation in public goods games. The typical design of these studies, however, represses future consequences for today's actions. In an experimental setting, we compare public goods games followed by punishment, reward or both in the setting of truly repeated games, where player identities persist from round to round. We show that reward is as effective as punishment for maintaining public cooperation and leads to higher total earnings. Moreover, when both options are available, reward leads to increased contributions and payoff, while punishment has no effect on contributions and leads to lower payoff. We conclude that reward outperforms punishment in repeated public goods games and that human cooperation in such repeated settings is best supported by positive interactions with others.

The Prisoners' Dilemma illustrates the tension between private and common interest. Two people can choose between cooperation and defection. If both cooperate they get more than if both defect. But if one person defects while the other cooperates, the defector gets the highest payoff while the cooperator gets the lowest. In a one-shot Prisoners' Dilemma it is therefore in each person's interest to defect. However, if pairs of people play the game repeatedly it is no longer obvious that defection promotes the defector's private interest, because today's defection may lead the opponent to defect in the future. Under suitable conditions, such direct reciprocity can support cooperation (1–6). Even if people play different opponents in every round, my opponent tomorrow may condition her choice on my play today. Such indirect reciprocity can also sustain cooperation (7,8). Direct and indirect reciprocity represent fundamental aspects of human interaction, both in evolutionary history and in modern life: repetition is often possible and reputation is usually at stake.

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The Public Goods game is a Prisoners' Dilemma with more than two people (9). Typically there is a choice of how much to contribute to a common pool, which then benefits all participants equally. The maximum payoff for the group is achieved if everyone contributes the full amount, but free riders increase their own payoff by withholding their contribution and still benefiting from the public pool. All of us are engaged in many public goods games, on both large and small scales. For example, reducing CO2 emissions by driving fuel efficient cars and minimizing waste is a global public goods game. On a more local level, public goods games include volunteering on school boards or town councils and helping to maintain the roads and fire department in your city, as well as cleaning your dishes at home and doing your share of work at the office.

It has been suggested that costly punishment can uphold cooperation in public goods games (10–12). People are willing to pay a cost for others to incur a cost. Typically, such punishment is directed towards free riders and therefore could be a deterrent for defection (13–15). One problem with punishment is that it generates a social loss by reducing both players' payoffs. This effect, however, could be small if sanctions are used rarely, such that in the long run punishment increases net payoffs by discouraging free-riding (16), or if punishments are merely symbolic (17–21). Another problem is that punishment is sometimes used by free riders against cooperators, either randomly or as acts of revenge (22–25). Moreover, the extent to which punishment is perceived as justified can greatly affect the response of those who have been punished (26). These observations question the proposal that costly punishment is the optimal force for promoting cooperation (12). More generally, the substantial literature emphasizing the beneficial effects of material and symbolic rewards and the negative effects of sanctions on interpersonal relationships (27–31) casts doubt on whether the threat of costly punishment provides the most appropriate incentive for cooperation.

In this study, we demonstrate that it is not costly punishment that is essential for maintaining cooperation in the repeated public goods game, but instead the possibility of targeted interactions more generally. In the normal repeated public goods game, if one person lowers his contribution, then I cannot directly reciprocate against this person. I could also lower my contribution, but this action harms everyone in the group. Ultimately this leads to a decline in cooperation. Therefore, we consider public goods games where after each round there is also the possibility of targeted interactions with other individuals in the group. One such interaction is costly punishment, but another one is costly rewarding, as captured by the standard Prisoners' Dilemma game. In this scenario, I can reward people who have contributed in the public goods game with cooperation, but punish free riders with defection.

In the course of daily life, people are always involved in both public and private interactions. Opportunities exist for mutually beneficial trade, as well as destructive punishment. My behavior towards others is affected by their previous decisions, both in the private and the public domain. If I resent my neighbor's gas guzzling SUV, I could exercise costly punishment by slashing his tires. Conversely I could be extra helpful to my other neighbor who just bought a low-emission vehicle. Punishment is destructive, and carries the risk of retaliation by those who have been punished. This is particularly true in situations where, unlike in most laboratory studies, interactions are not anonymous. Without the cover of anonymity, it seems probable that people would be less inclined to punish, and more likely to reward. Let us find out if rewards can lead to cooperation in the repeated public goods game.

A total of 192 subjects participated in our study at the Harvard Business School Computer Lab for Experimental Research (32). Subjects interacted anonymously via computer screens

in groups of four. Subjects were told that they would interact with the same three people for the whole session. We performed one control experiment and three treatments.

In the control experiment, subjects play several rounds of a standard public goods game in groups of four (16 control groups). In each round, subjects receive 20 monetary units (MUs) and decide how much to contribute to the public pool, and how much to keep for themselves. The contributions are multiplied by 1.6 and split evenly among the four group members. Subjects are not told the total number of rounds. For a discussion of endgame effects, see (32).

In the three treatments, each public goods game is followed by a second stage, which allows for responses targeted at each other group member. These targeted interactions have different forms in the three treatments (32). In the first treatment (“PN”, 10 groups) subjects can punish or do nothing. In the second treatment (“RN”, 11 groups) subjects can reward or do nothing. In the third treatment (“RNP”, 11 groups) subjects can choose between reward, non-action and punishment.

Figure 1A shows the average contribution to the public goods game in each round. Consistent with previous findings we observe that the average contribution declines in the control experiment, but stays high in the punishment treatment, PN. However, we also observe that the two other treatments, RN and RNP, are equally effective in maintaining cooperation in the public goods game. Therefore, it is not punishment per se which is important for sustaining contributions, but rather the possibility of targeted interactions. This option is present in all three treatments, but absent in the control experiment.

Figure 1B shows the percentage of the maximum possible payoff achieved in each round. The maximum payoff is obtained for full cooperation in the public goods game, no punishment use in the PN treatment and full rewarding in the targeted rounds of the RN and RNP treatments. All three treatments where targeted interactions are possible outperform the control after an initial period of adjustment. We again find that reward works as well as punishment, with no significant difference in percentage of maximum possible payoff between the three targeted treatments.

Figure 1C shows the average payoff in each round, summed over the public goods game and the targeted interaction. In the RN and RNP treatments there is the possibility of generating additional income during the targeted interactions. Thus it follows naturally from Figure 1B that the reward treatments, RN and RNP, generate larger absolute payoffs than the punishment-only treatment, PN. Groups which have the opportunity to reward do better than groups which can only punish. The point we want to make is this: if several targeted interactions can promote cooperation in the public goods game, then those that generate additional positive payoff will result in the best outcomes.

Figure 2 shows the frequency of reward and punishment in each targeted round. We see that both options are used. We also see clear changes in punishment and reward use over time. In the PN and RNP treatments, punishment use decreases over time. In the RN and RNP treatments, reward use increases over time. Importantly, the latter finding suggests that rewarding is stable and does not decay over time – in contrast to findings in a setting where the possibility for direct reciprocity was limited by shuffling player identifiers from round to round (33).

If positive reciprocity alone (RN) and negative reciprocity alone (PN) both increase contributions relative to the control, one might think that putting the two together (RNP) would be best, as found previously in a two player proposer-responder game (34). However, the RNP setting shows that positive and negative reciprocity cannot be combined in an

additive way. The average contribution and percent of maximum possible payoff in RNP are not significantly different from that of RN or PN (Figure 1). Moreover, the average total payoff in RNP is not significantly different from RN, but is significantly higher than PN.

We can also see that when both options are available, groups which reward more earn higher payoffs while groups that punish more earn lower payoffs (Figure 3A, B). It could be that the groups who punished more heavily merely contained more free-riding individuals, and so received lower payoffs due to bad luck as opposed to differences in strategy. However, we see a similar pattern when we examine the probability to punish or reward based on the contribution level in the public goods game (first-order conditional reward and punishment strategies). Groups that are more likely to reward average or above average contributors achieve significantly higher average contributions (Figure 3C). Conversely, the tendency to punish low contributors has no effect on contributions (Figure 3D). As a result, choosing to reward good behavior leads to significantly higher payoffs (Figure 3E), while opting to punish free-riders results in marginally lower payoffs (Figure 3F), because punishing is costly but ineffective in the RNP treatment. When both options are possible, positive reciprocity trumps negative reciprocity for improving contributions in the public goods game and total payoffs.

We have shown that several types of targeted interactions can stabilize contributions in the repeated public goods game. Most previous experiments have focused on punishment and examined situations where subjects cannot track the identity of other group members who punished them. In such settings, typically the groups are changed or the identities of group members are reshuffled in every round. Subjects are often informed about the total amount of punishment they received, but not from whom the punishment came. These designs reduce or eliminate effects of reputation, as well as retaliation by those who have been punished.

Previous studies of reward versus punishment in such settings which limit direct reciprocity have found rewards to be largely ineffective (33–36). In our experiment, however, which is based on repeated interactions where future consequences discipline your actions today, reward is as effective as punishment. We think that this type of truly repeated interaction plays an important role in the study of human behavior. Our ancestors lived in small groups where repeated interactions were common, reputation was often at stake, and the identities of those that chose to punish or reward were usually known (37). Such concerns are still relevant in today's world, because many of our actions have future consequences. This is particularly true in the context of our most important interactions with family members, friends and co-workers. Thus, while we sometimes find ourselves in anonymous one-shot interactions where costly punishment might be more effective than reward, the importance of rewards in repeated interactions should not be overlooked. Moreover, other tools for encouraging cooperation exist beyond monetary punishments and rewards, such as ostracism (19) and appeals to normative values (27). The relative effectiveness of such additional mechanisms merits further study.

Indirect reciprocity settings can also stabilize cooperation in the public goods game (38,39). Such experiments differ from ours in several ways and were not designed to directly compare punishment and reward. Moreover, in these studies, subjects are informed about their partner's full history of past play with all previous partners. In our study, we show that private pairwise interactions, where players do not know what happens in games between others, can still stabilize contributions. It is useful to know that full transparency, which is hard to achieve in the real world, is not necessary for targeted interactions to promote public cooperation.

A common argument for the evolution of costly punishment rests on group selection (40). If group selection is evoked as a mechanism for human cooperation, however, then it is important to note that groups which find positive interactions to maintain cooperation in the public goods game will outperform groups that use costly punishment. Moreover, cross cultural differences have been observed in anti-social punishment, where low contributors punish high contributors (24). While anti-social punishment is rare among subjects from the USA or UK, it was quite common in countries such as Greece and Oman. Thus while punishment may eventually improve payoffs in long games using subjects from the USA or UK, as in the present study and (16), this is almost certainly not the case in areas where antisocial punishment is common. Instead, anti-social punishment could easily result in significantly lower payoffs.

While we have documented the effects that bilateral punishment and reward can have on multilateral cooperation, our experiment does not allow us to look at the reverse effect. That is, we do not know whether there is more or less bilateral reward or punishment than there would have been if the subjects had not also been engaged in the public goods game. This aspect of linking together different games has received little attention in the experimental literature, and deserves further study.

Sometimes it is argued that it is easier to punish people than to reward them. We think this is not the case. Life is full of opportunities for mutually beneficial trade, as well as situations where we can help others, be they friends, neighbors, office-mates, or strangers. We regularly spend time and effort, as well as money, to assist people around us. This assistance can be minor, like helping a friend to move furniture, picking up shifts to cover for an ill coworker, or giving directions to a tourist. It can also be more significant, like recommending a colleague for promotion, or speaking out to support a victim of discrimination. These sorts of productive interactions are the building blocks of our society and should not be disregarded.

Our study allows a direct comparison of various kinds of targeted interactions on promoting public cooperation in repeated games. We find that reward is as effective as punishment in maintaining contributions to the public good. However, while punishment is costly for both parties, reward creates benefit and thus results in higher total payoffs. Furthermore, when both punishment and reward are possible, positive reciprocity supersedes negative reciprocity, and punishing results in lower group-level benefits. While punishment may outperform rewards in one-shot anonymous interactions, our findings suggest that positive reciprocity should play a more important role than negative reciprocity in maintaining public cooperation in repeated situations. Imagine there are groups where people either use punishment or reward to induce public cooperation. Which groups will receive the highest payoffs, and therefore which incentive system is optimal? The results are unequivocal: rewards produce better outcomes than punishment in repeated settings. These findings highlight the importance of developing opportunities for constructive interactions between individuals, to help us prevent tragedies of the commons.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Mean contribution to the public good (A), percentage of maximum possible payoff (B) and mean payoff (C) over 50 rounds of play in the control (Yellow), PN (Red), RN (Blue) and RNP (Green) experiments. All three treatments with targeted reciprocity succeeded equally well at increasing contributions and percentage of maximum possible payoff relative to the control, and thus the reward treatments RN and RNP result in significantly higher actual payoffs than the punishment treatment PN. All data are analyzed at the level of the group to account for interdependence of outcomes for members of a given group. (A) Sign-rank test comparing contributions in Round 1 vs Round 50: Control, $p=0.028$, decrease; PN, $p=0.18$, no change; RN, $p=0.036$, increase; RNP, $p=0.033$, increase. (B) Ranksum comparing

percentage of maximum possible payoff in the second half of the game: PN vs control, $p=0.013$, PN higher; RN vs control, $p=0.048$, RN higher; RNP vs control, $p=0.023$, RNP higher; PN vs RN, $p=0.67$; PN vs RNP, $p=0.46$; RN vs RNP, $p=0.40$. (C) Ranksum comparing mean payoff in the second half of the game: PN vs control, $p=0.013$, PN higher; RN vs control, $p<0.001$, RN higher; RNP vs control, $p=0.001$, RNP higher; PN vs RN, $p=0.001$, RN higher; PN vs RNP, $p=0.005$, RNP higher; RN vs RNP, $p=0.40$.

Figure 2.

Frequency of punishment use (Red) decreases and reward use (Blue) increases over 50 rounds of play in the PN (A), RN (B) and RNP (C) treatments. All data are analyzed at the level of the group to account for interdependence of outcomes for members of a given group. (A) Sign-rank comparing punishment use in rounds 1 and 50: $p=0.12$; comparing rounds 1–5 and 46–50: $p=0.073$, decreases; comparing rounds 1–10 and 41–50: $p=0.037$, decreases. (B) Sign-rank comparing reward use in rounds 1 and 50: $p=0.018$, increases; comparing rounds 1–5 and 46–50: $p=0.033$, increases; comparing rounds 1–10 and 41–50: $p=0.075$, increases. (C) Sign-rank comparing move use in rounds 1 and 50: R, $p=0.007$, increases; P: $p=0.007$, decreases; comparing rounds 1–5 and 46–50: R, $p=0.006$, increases;

P, $p=0.004$, decreases; comparing rounds 1–10 and 41–50: R, $p=0.006$, increases; P, $p=0.009$, decreases.

RNP: when both reward and punishment are possible

Figure 3.

Mean payoff over the 50 rounds of play in the RNP treatment, increases with reward frequency (A) (Tobit, slope=12.7, $p < 0.001$) and decreases with punishment frequency (B) (Tobit, slope=-7.9, $p = 0.030$). Mean contribution to the public good increases with the average probability to reward players who contribute equal to or greater than the group average contribution (C) (Tobit, slope=22.2, $p < 0.001$), and is not significantly related to the probability to punish below average contributors (D) (Tobit, slope=1.1, $p = 0.69$). Mean payoff increases with the probability to cooperate with players who contribute equal to or greater than the group average contribution (E) (Tobit, slope=41.8, $p < 0.001$), and decreases with the probability to punish below average contributors (F) (Tobit, slope=-13.2, $p = 0.066$).

Data are analyzed at the level of the group to account for the interdependence of outcomes for members of a given group. To correctly visualize the results of a multiple regression analysis, the y-axis of each panel is adjusted to account for the variation explained by the independent variable shown in the opposing panel (punishment in panels A, C, E and reward in panels B, D, F). See (32) for regression tables, axis adjustment details and further statistical analysis.