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Punish in public

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ABSTRACT

We report data from public goods games showing that privately-implemented punishment reduces cooperation in relation to a baseline treatment without punishment. When that *same incentive* is implemented publicly, however, cooperation is sustained at significantly higher rates than in either the baseline or private punishment treatments. Our design ensures that this increased cooperation is not attributable to shame, differences in information or signaling. Rather, our evidence is that the ability to observe the punishment of low-contributors can reverse punishment's detrimental effects. This result has important efficiency implications for the design of mechanisms intended to deter misconduct.

1. Introduction

Punishment is widely used to enforce cooperation in social and economic exchange (see, e.g., Andreoni et al., 2003; Fehr and Fischbacher, 2004; Fehr and Gächter, 2000; Fowler, 2005; Ostrom et al., 1992; Sefton et al., 2002; Xiao and Houser, 2005; Yamagishi, 1988). When punishment is sufficiently severe as to overwhelm the expected benefit of defection, it can prevent opportunistic behavior. Nevertheless, as a practical matter, severe punishment usually requires costly monitoring. It can also be extremely time-consuming to implement.[1] Consequently, punishment incentives used to promote cooperation in naturally-occurring environments are sometimes weak in the sense that the expected cost of a violation is less than the expected benefit. For instance, two contexts where this can occur are copyright enforcement and online auction fraud.

Recent prominent results in economics and psychology clearly show that weak incentives can detrimentally affect cooperation (e.g., Lepper and Greene, 1978; Deci et al., 1999; Kreps, 1997; Frey and Oberholzer-Gee, 1997; Tenbrunsel and Messick, 1999; Frey and Jegen, 2001; Fehr and Falk, 2002; Benabou and Tirole, 2003; Fehr and List, 2004). For example, Gneezy and Rustichini (2000) found that when a day care levied a small fine for tardiness, more parents arrived late. In the laboratory, Li et al. (2009), Houser et al. (2008) and Fehr and Rockenbach (2003) used trust games to show that weak punishment has a detrimental effect on cooperation.[2] It is important to note that in these studies, punishment is often implemented privately (i.e., only the punishee is aware of it). By contrast, in natural environments, a significant part of the enforcement strategy often involves publicly implementing weak incentives.

For example, detecting copyright violations has historically been very difficult and costly. Compounding this problem is the fact that copyright infringement can yield large profits for violators (see, e.g., Tyler, 1997). While advances in technology ease detection of copyright infringement, they also provide new ways for infringers to appropriate others' intellectual property. Film and software piracy are excellent examples. Indeed, the Business Software Alliance trade group pegs international losses due to software piracy in 2004 at more than $29 billion,[3] and suggests that more than 1/3 of all installed software is counterfeit. Likewise, Microsoft, in an effort to curb piracy, prominently displays on its website all recent cases of software piracy, along with the type of lawsuit filed against the alleged infringer(s).[4] Yet another example is online auction fraud, which presents a substantial

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[1] A mechanism based exclusively on severe sanctions would also suffer from an absence of marginal deterrence for serious crimes (see e.g., Stigler, 1970).

[2] Bohnet et al. (2001) investigate a dynamic environment where reducing punishment crowds-in norm-based behaviors. Loosely speaking, the reason is that in weak-punishment environments people will not enter imperfectly enforceable contracts with counterparts who do not have sufficiently strong reputations for honesty. Thus, each agent in this environment has an incentive to develop a reputation for honesty and in this way maximize profits. Note that the detrimental effect we discuss stems from profit maximizing motivations crowding-out norm-based motivations. In Bohnet et al. (2001), crowding-in occurs for a similar reason: people desire to obtain contracts and maximize profits.

[3] See, http://news.com.com/Software+piracy+Hype+versus+reality/2008-1001_3-5291273.html.

[4] See http://www.microsoft.com/piracy/partners/alerts.

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worry for intermediaries like eBay (see, e.g., Houser and Wooders, 2006). In fact, eBay has chosen to supplement its publicly-observable feedback pages with a program aimed at promoting buyer and seller trust (VeRO, http://pages.ebay.com/help/tp/programs-vero-ov.html). Public punishment plays an important role in the program.

One evident difference between publicly and privately-implemented punishments is that the former can induce shame (see, e.g., Rush, 1954; Smith et al., 2002). While shame effects have been studied heavily, they nevertheless remain controversial (see, e.g., Braithwaite, 1989; Elster, 1999; Lewis, 1971; Posner, 2000; Whitman, 1998). Many public punishment systems in naturally-occurring environments attempt to avoid shame by announcing the punishment, but maintaining the anonymity of the punished person (see. e.g., Trevino and Ball, 1992).

Our main hypothesis is that, even absent any shame effect, publicly-implemented punishment promotes cooperation more effectively than private implementation of the same incentives. That is, we hypothesize that "experiencing" punishment, either by receiving or observing it, can improve its effectiveness. The logic underlying this hypothesis builds on well-established literatures, as follows.[5]

First, both publicly and privately-implemented punishment mechanisms can express norms of cooperation (see, e.g., Kahan, 1998; Cooter, 1998; Sunstein, 1996; Tyran and Feld, 2006; Xiao, 2010). Punishing violators informs the public that the targeted behavior is not condoned, and thus reinforces the social norms. Next, publicly-implemented punishment, in relation to private implementation, promotes norm salience. For example, publicly-implemented punishment reminds more people more often of the enforced social norm. This is important due to the fact that people's decisions are influenced by both monetary and non-monetary incentives (e.g., social norms, see Elster, 1989; Bicchieri, 2006). Likewise, more salient norms direct behavior more effectively (see, e.g., Berkowitz, 1972; Collins and Loftus, 1975; Harvey and Enzle, 1981; Cialdini et al., 1990).[6] Thus, even in cases where privately implementing a weak incentive detrimentally affects cooperation, publicly implementing the *same incentive* could potentially promote cooperation.[7]

To test our hypothesis, we compare subjects' contributions between public and private punishment treatments in a public goods game. The key feature of our design is that there is only one difference between publicly and privately-implemented punishment: in the private treatment, the only person who knows that punishment has occurred is the individual receiving the punishment. By contrast, in the public treatment, punishment is reported to all group members whenever it occurs. In both treatments, the severity and likelihood of punishment are common information, as are the contribution decisions of all group members. Further, we rule out signaling by employing an exogenous rather than peer-to-peer punishment mechanism. Finally, our design avoids shame by ensuring the anonymity of all who are punished.[8]

In both treatments, each round includes a 50% chance that the lowest contributor's payoff will be cut by a (small) amount that increases with the difference between the contribution of the lowest contributor and the average contribution of the other group members.

[5] We draw from the norm-expression literature, but our hypothesis could be supported using alternative arguments as well. For example, people's understanding of risky situations can vary depending on whether they have experienced the event (see, e.g., Hertwig et al., 2004), and the availability literature makes clear that this can occur in a way that promotes punishment's effectiveness. We discuss this point further in Section 3.4.

[6] For example, Cialdini et al. (1990) hypothesized that focusing people on the idea that one ought not to litter should decrease littering. To test this, the experimenters tucked handbills with different messages under windshield wipers of cars in a library parking lot. Supporting their hypothesis, they found that subjects littered less when the message was "April is Keep Arizona Beautiful Month. Please Do Not Litter" than when the message was "April is Arizona's Fine Arts Month. Please Visit Your Local Art Museum."

[7] Although behavioral economics research connecting norms and decision is active (see, e.g., Fehr and Fischbacher, 2004; Bicchieri, 2006), we are not aware of any formal theory linking economic decisions to the efficacy with which a norm is expressed.

[8] The experimenter does know who is punished, so this could be a source of shame. To the extent this effect exists, it is present in both our public and private punishment treatments, and thus cannot explain differences between these two treatments.

Data from our design provide evidence consistent with our main hypothesis. In particular, we find that implementing punishment publicly can eliminate the detrimental effects of weak punishment.

2. Design of experiment

2.1. Overview

We report data from novel public goods games. These games are popular for punishment studies because they reflect social dilemma situations often faced by companies and communities (see, e.g., Ledyard, 1995; Anderson and Putterman, 2006; Bochet et al., 2006; Carpenter, 2007; Dickinson, 2001; Masclet et al., 2003; Sefton, et al., 2002). Our experiments consist of: (i) a baseline treatment without punishment; (ii) one private punishment treatment; and (iii) one public punishment treatment. In each treatment, subjects play a game for 30 rounds in groups of four. The groups remain fixed for the entire 30 rounds, and subjects know this is the case. We use a "partners" design because repeated interaction is a common feature of naturally-occurring environments (e.g., businesses or collectives) in which punishment often occurs.[9]

To provide clean evidence on the role of public implementation in promoting norms, we use exogenous punishment to eliminate signaling associated with endogenous sanctions.[10] Specifically, in all punishment treatments, subjects are informed that each round has a 50% chance of being monitored, and that if the round is monitored then that round's lowest contributor will incur a small sanction. We use a punishment incentive small enough so that contributing zero remains the earnings-maximizing choice regardless of one's group members' contributions. Additionally, we keep the punishment structure under the experimenters' control. The reason is that this allows for the monitored rounds and for the severity of punishment to be kept fixed through both treatments.[11] This ensures our ability to draw clean inferences regarding the effect of public, as compared to private, implementation of punishment.

The economic incentives between public and private treatments are identical. The only difference between these treatments is that in the public case, all members of a group are told when a round is monitored, as well as the amount of the resulting punishment. When punishment is private, only the punished subject knows that information. The implication of our design's different message structures is that all subjects in the public punishment treatment experience punishment (either by observing or receiving it) 15 times during the course of the game, i.e., each time the lowest contributors punished. On the other hand, subjects in the private treatment only experience punishment if they happen to be punished. The median number of times that people experience punishment is three.

As stated above, our main hypothesis is that publicly-implemented punishment promotes cooperation more effectively than its private counterpart. A possible explanation is that the cooperation norm is more salient in the former than in the latter, due to the fact that in "public," everyone observes punishments for norm violations. In particular, our punishment mechanism: (i) expresses disapproval of free-riding by punishing a group's lowest contributor; and (ii) encourages people to contribute as much as their group members' average contribution by levying greater punishments for greater negative deviations from the

[9] Whether our results extend to "strangers'" designs is an open question. Previous research finds differences in outcomes between partners and strangers public goods games (see, e.g., Andreoni and Croson, 2008; Fehr and Gächter, 2000).

[10] Endogenous punishment can differ from exogenous punishment in many ways. The act of choosing punishment itself might affect individuals' cooperation. Endogenous punishment might also be relatively more effective at conveying a cooperation norm (e.g., Tyran and Feld, 2006).

[11] We randomly selected 15 out of 30 rounds to be monitored, but subjects were not aware of this. In each of the two punishment treatments, subjects knew only that each round had a 50% chance of being monitored and that the likelihood of being monitored was the same for each round.

group members' average. Taken together, one can view our punishment mechanism as expressing the following norm: *contribute at least as much as the average of one's group members*.

Our design eliminates possible influences from shame by ensuring that subjects remain anonymous. In addition, subjects are given full information about both the likelihood of punishment and the way punishment amounts are determined. As a result, our experiment provides no room for subjects to learn about these objective characteristics of the environment.

2.2. Baseline treatment

In each round t, each subject i is given y experimental dollars (E$). The subject chooses, simultaneously with other subjects, how much to invest in the group account g_{it} and how much to keep in his/her individual account. Each E$ kept is worth 1 E$, and each E$ invested in the group account yields $\alpha<1$ E$ to each group member. In a group of n subjects, the payoff π_{it} for each subject i in round t is therefore given by:

$$\pi_{it} = y - g_{it} + \alpha \sum_{j=1}^{n} g_{jt}, \quad 0<\alpha<1<n\alpha \tag{1}$$

Using backwards induction, it is easy to see that in this finite-round game, if individuals are selfish, the subgame-perfect equilibrium requires each subject to contribute zero to the group account each round. This follows from $\partial\pi_{it}/\partial g_{it} = -1+\alpha<0$. However, the restriction $1<n\alpha$ ensures $\partial \sum_{i=1}^{n} \pi_{it} / \partial g_{it} = -1 + n\alpha > 0$, so that the aggregate group payoff $\sum_{i=1}^{n} \pi_{it}$ is maximized if every subject contributes everything to the public good. In our experiment, $\alpha = 0.5, n = 4$ and $y = 10$.

2.3. Punishment mechanism

As noted above, all rounds in both punishment treatments are monitored with 50% probability. When a round is monitored, the earnings of the lowest group account investor are reduced. The amount of the reduction is not distributed to the other group members, and other group members bear no cost for any punishment. If there are multiple lowest contributors, then one of them is randomly selected to be punished and the others receive no sanction. If everyone contributes the entire endowment, there is no punishment when the round is monitored.

The magnitude of punishment depends on the difference between the punished subject's group account investment and the average group account investment of his/her group members. When a subject is punished, his/her payoff is deducted by D%, where D is given by:

$$D = d\cdot(\overline{g_{it}} - g_{it}), \text{ where } \overline{g_{it}} = \sum_{j \neq i} g_{jt} / (n-1) \tag{2}$$

Note that the amount of the punishment becomes larger as the difference becomes larger, and the rate of increase is determined by the positive constant d. Also note that D is non-negative. The reason is that only the lowest contributor is punished.

In our experiment, we set d to unity.[12] Thus, for example, the maximum sanction occurs when a subject makes a zero contribution in a monitored round and all others contribute 10 E$. This results in a 10% reduction in that lowest contributor's round earnings for the round (i.e., 2.5 E$). Our design's sanctions are weak in the sense that standard theory based on self-interested per-round earnings maximizers implies that the subgame-perfect equilibrium is to contribute zero each round, just as in the baseline treatment.

To see this, note that if subject i is the sole lowest contributor to the group account, then his/her expected payoff is:

$$\begin{aligned} E(\pi_{it}) &= \frac{1}{2}\pi_{it}(1-D\%) + \frac{1}{2}\pi_{it} \\ &= \left(y - g_{it} + \alpha\sum_{j=1}^{n} g_{jt}\right) - \frac{1}{2}\left(y - g_{it} + \alpha\sum_{j=1}^{n} g_{jt}\right)\cdot d\cdot(\overline{g_{it}} - g_{it})\% \end{aligned} \tag{3}$$

In our case, with $y = 10$, $\alpha = 0.5$ and $d = 1$, it is trivial to verify that $\partial E(\pi_{it}) / \partial g_{it} = -0.45 + 0.01\overline{g_{it}} - 0.005 g_{it}$. Then, given that both g_{it} and $\overline{g_{it}}$ lie between zero and 10, it follows that the derivative is strictly negative regardless of others' or one's own contributions. Consequently, subjects maximize expected per-round earnings by contributing zero to the group account. Moreover, given that the probability of being punished decreases when there are multiple lowest contributors, it is immediately evident that in this case subjects also maximize expected earnings by contributing zero.[13]

Finally, recall that the norm enforced by this punishment mechanism is to contribute at least as much as one's group members. Therefore when punishment is publicly as opposed to privately-implemented, one's group members' contributions should have a greater impact on one's own contributions.[14]

2.4. Public and private punishment

In all punishment treatments, subjects see a “Payoff Cut Information” box on their screen (see Appendix B). The message in that box, and only that message, differs between treatments. The details of the message in the “Payoff Cut Information” box are listed in Table 1. In the public treatment, all members of a group are told: (i) when a round is monitored; and (ii) the amount of the punishment. In contrast, in the private treatment, only punished subjects are aware of monitoring and punishment. It follows that the public punishment treatment reinforces the norm of contributing at least as much as one's group members to a substantially greater degree than occurs in the private punishment case.[15]

Aside from these messages, the information available to subjects in the public and private punishment treatments is identical (as discussed in the next section). In particular, subjects in all treatments (including the baseline) know precisely how much each member of their group contributed to the public account, and consequently whether they were the lowest contributor. This ensures anonymity, thereby mitigating shame effects.

[12] Fehr and Gächter (2000) find that cooperation is promoted by peer-to-peer punishment opportunities. They also find that individuals are punished more if their contributions deviate more from the average of others' contributions, as in our equation (2). They use an endowment of 20, while we use an endowment of 10. The data they report imply that a subject who contributes 15 E$s (75% of the endowment) less than other subjects has their earnings cut by 70% on average; if the difference is 10 E$s (50% of the endowment), then the expected cut is 50%; a 6 E$ difference (30%) leads to an expected 30% earnings cut; and a 2 E$ difference (10% of endowment) to a 10% expected earnings cut. Consequently, our punishment mechanism matches their data well if $d = 10$. Our use of $d = 1$ means that our subjects faced a punishment only 10% as severe as Fehr and Gächter's (2000) subjects.

[13] Note that this particular punishment mechanism also encourages altruistic subjects to contribute more when their group members give more. The reason is that the more others give, the lower the cost of giving. Alternatively, the more one gives, the greater the incentive for others to not be the lowest giver. Thus, in relation to fixed amount punishment mechanism, the mechanism we use might magnify the role of cooperation norms. This effect cannot account for differences between public and private treatments due to the fact that the incentives are identical between treatments. On the other hand, this effect can potentially help to explain higher cooperation in punishment treatments than in the baseline treatment. It turns out, however, that privately-implemented punishment results in less cooperation than found in the baseline (see discussion later).

[14] This suggests that models of conditional cooperation might have more explanatory power than the standard model in our environment. Although working through such a model is beyond the scope of this paper, research in the area is both important and interesting (see, e.g., Spichtig and Traxler, 2009).

[15] Public messages might reinforce the presence of non-cooperation. If so, this works against our hypothesis that public punishment promotes cooperation.

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Table 1
Payoff cut information in public and private punishment treatments.

Subjects	Punishment	Payoff cut information	
		Not monitored	Monitored
Punishment receiver	Public/Private	N/A	In this round, your payoff was cut by…% (…E$).
Others	Public	In this round, no one's payoff was cut.	In this round, the payoff of a lowest Group Account investor (NOT you) was cut by…% (…E$).
	Private	In this round, your payoff was not cut.	

Note: In the event that everyone contributes the same amount, one member is randomly selected to receive a punishment of zero. In both the private and the public treatments, the receiver sees the message, "In this round, your payoff was cut by 0% (0 E$)." In the public treatment, everyone who was not punished sees, "In this round, the payoff of a lowest Group Account investor (NOT you) was cut by 0% (0 E$)." The single exception to this rule is when every group member contributes the entire endowment, in which case punishment has no role to play in enforcing cooperation. Therefore, punishment is not implemented, and in both treatments everyone receives the message, "In this round, no one's payoff was cut."

2.5. Other information

In both the baseline and the punishment treatments, subjects are informed that they will be in the same group for 30 rounds. The payoff function (1), along with the values of y and α, are common information. In the punishment treatments, all details regarding the punishment mechanism are common information.

In all treatments, subjects are shown all of their group members' contributions in the "Outcome of Round…" box on their decision screen. The instructions in Appendix A describe how subjects access the information box. Appendix B is an example of a screen seen by a subject. Group members' contributions are listed from high to low. The contributions are not connected to any subject's ID number, thus ensuring subjects cannot develop individual reputations.

The "Outcome of Round…" box also includes information related to a subject's earnings, as well as the difference between her group account contribution and the average contribution of her other group members. Again, all the above information is provided in all treatments. In punishment treatments, the box also indicates any punishment amount a subject might have received.

As the experiment proceeds, all information subjects receive at the end of each round is preserved in a "History" box. Subjects are able to access previous rounds' decisions and results at any time. Finally, subjects are reminded about the experiment's key features in a "Note" box appearing on the bottom right-hand side of their screens.

2.6. Procedures

72 subjects participated in our initial experiments, with 24 subjects in each treatment (two sessions with 12 subjects each). All subjects were recruited from George Mason University's general undergraduate population, using standard recruiting procedures in place at the Interdisciplinary Center for Economic Science. Subjects earned a $5 show up bonus for arriving at the lab on time. Subjects earned E$ during the experiment. At the end of the experiment, E$ were exchanged for dollars at the rate of 20 E$ = $1. On average, subjects were in the lab for about 90 min and earned about $22 in addition to the show-up bonus.

Prior to the first round of each session, the 12 participants were randomly arranged into three groups of four and told they would be in the same group for the entire experiment. Subjects then read computerized instructions and answered embedded questions. The experiment started after all subjects successfully completed the instructions and questions. At the beginning of each round, group members received their endowment and made simultaneous investment decisions. Our specific procedures are detailed in the instructions reproduced in Appendix A.

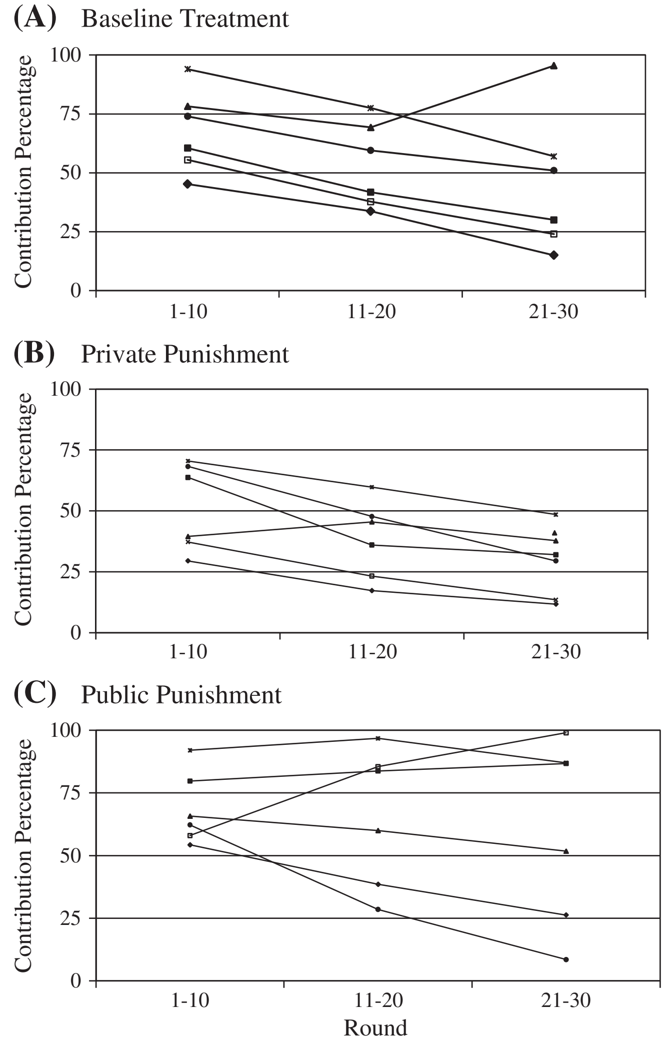

Fig. 1. Mean group contribution to public good by treatment and round.

3. Results

3.1. Cooperative decisions by groups in baseline and punishment treatments

This section offers evidence that the punishment incentive described above has a detrimental effect on cooperation when privately implemented, but promotes cooperation when implemented publicly.

Fig. 1 details our contribution data by group and treatment. Each panel describes, for a specific treatment, the average contribution percentage of each group over the first, second, and third ten round blocks.[16] Panel (A) describes decisions in our standard public goods game, and reflects usual findings. In the initial rounds, groups contributed between 45 and 90% of the endowment to the public good, and the amount tended to decay over time. Panel (B) shows average contributions in the private punishment treatment. Initial round contributions were lower than baseline, and all groups experienced cooperative decay. Panel (C) describes decisions by

[16] Fig. 1 shows that different groups start at different contribution amounts and exhibit different patterns of cooperative decay. Between-group differences have been traced to individual differences in cooperative propensities by a variety of researchers (see, e.g., Kurzban and Houser, 2005; Ashley et al., 2005). Pursuing the source of group differences in the present data is beyond the scope of this paper.

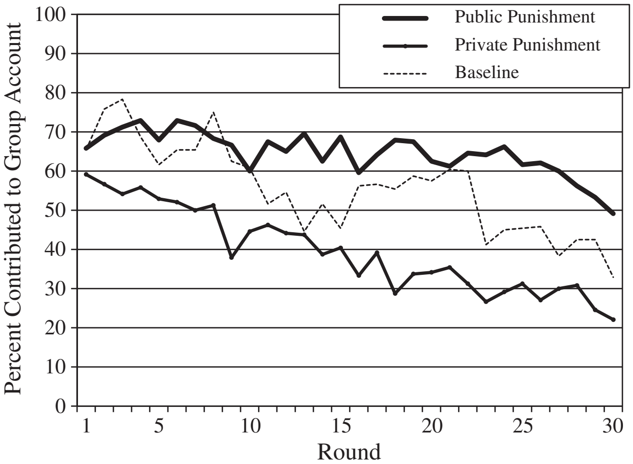

Fig. 2. Mean group account contribution by round and treatment.

groups in the public punishment treatment. Three groups sustained contributions at levels above 80% on average during the final rounds of the experiment, and only two groups contributed less than 50% on average in the last third of the experiment.

Fig. 2 describes round-by-round overall mean contributions to the group account in the baseline and two punishment treatments. Data in the baseline treatment reflect typical findings (Ledyard, 1995). In particular, contributions began at around 2/3 of the endowment and declined to about 1/3 by round 30. Also, subjects knew that the game included exactly 30 rounds, and there was an apparent end-game effect in all treatments. Note that cooperation in the two punishment treatments provides approximate bounds for baseline levels of cooperation. In the private punishment treatment, cooperation was below baseline in every round. By contrast, cooperation in the public treatment was above baseline in most (26 of 30) rounds.

Table 2 reports summary statistics. It shows that both mean and median contribution were lowest in the private treatment (3.95 and 3.82, respectively) and highest in the public treatment (6.47 and 6.6, respectively). The average cost of punishment and the average frequency with which punishment was received were slightly higher in the private (0.07 E$ and 3.71 times) than in the public treatment (0.06 E$ and 3.33 times).

We find significant differences among treatments at the aggregate level. Using groups as the unit of observation, and using the mean contribution over the last 10 rounds for each group (a total of 18 independent observations, six in each treatment), a K-sample median test rejects the null hypothesis that contribution distributions are identical among treatments ($p = 0.048$).[17]

3.2. Individual decisions in public and private treatments

To shed further light on the source of differences between treatments, we report results from multiple censored regression analyses. In all cases, the dependent variable is individual i's round t contribution, g_{it}. This variable is censored from above and below by ten and zero, respectively, and our analysis takes account of these bounds using standard "Tobit" procedures.[18] The independent variables for our first analysis (Model 1) include only treatment dummies, thus providing the first evidence on treatment effects. Models 2 and 3 explore whether treatment effects are robust to the addition of controls (individual fixed effects in the former, and individual and round fixed effects in the latter). Model 4 then incorporates treatment-specific trends in contributions over rounds. Thus, Model 4 informs differences in rates of decay rate among treatments.

Table 3 reports parameter estimates associated with each model.[19] Model 1 reveals statistically significant treatment effects (chi-square test, $p<0.01$). Treatment effects are robust to the addition of individual fixed effects, and individual and round fixed effects in Models 2 and 3, respectively, in the sense that the constant for "private" remains significantly lower than both the public and baseline coefficients (chi-square test, $p<0.01$), and the point estimate for "public" is substantially (14% and 27%) larger than that of the baseline in both analyses (though neither difference is statistically significant).

Results from Model 4 reveal that decay in cooperation is statistically significantly lower when punishment is implemented publicly than in either of the other cases. In particular, the estimated decay rate in "public" (−0.08) is significantly slower than in the private treatment (−0.08 vs. −0.17, chi-square test, $p<0.01$) and also slower than in the baseline treatment (−0.08 vs. −0.19, chi-square test, $p<0.01$). On the other hand, decay in the private treatment is almost identical to the baseline, and the difference is not significant (−0.17 vs. −0.19, chi-square test, $p = 0.32$).

As we discussed above, the norm enforced by the punishment mechanism is to contribute at least as much as one's group members. We thus expect that when punishment is publicly rather than privately-implemented, one's group members' contributions should have a greater impact on one's own contributions. We test this by comparing among treatments the (partial) correlation between one's own contribution in each round and the average contribution of his/her group members in the previous round. We conduct an OLS regression with g_{it} as the dependent variable and the independent variables including subject i's group member's average contribution in round $t-1$ interacted with each treatment. Finally, we include fixed individual and round effects. Consistent with our expectations, the estimated partial correlation is significantly higher in public (0.61) than both private (0.37) and the baseline (0.38), (chi-square test, 0.61 vs. 0.37, $p<0.01$; 0.61 vs. 0.38, $p<0.01$).

Of course, becoming more responsive to group members' decisions does not necessarily imply that aggregate cooperation will increase. Nevertheless, we find that cooperation is highest in our public treatment. Part of the explanation for this may be that unconditional (or "voluntary") cooperation is greater in the public than private treatment due to an enhanced cooperation norm. Greater voluntary cooperation, combined with increased conditional cooperation, could lead to higher overall cooperation in groups. In the next section, we provide additional evidence regarding the effect of public punishment on voluntary cooperation and free-riding.

3.3. Voluntary cooperation and free-riding

For each treatment, we calculated the mean proportion of times subjects contributed their full endowment to the group account, and the proportion of times that subjects contributed zero, over the entire 30 rounds (see Fig. 3). In relation to the baseline, private punishment is associated with a significant decrease in the proportion of full cooperation: it occurs with less than one-tenth of the baseline frequency (3% and 34%, respectively, $p = 0.01$, two-tailed Mann–Whitney test). This result is consistent with the hypothesis that

[17] The null hypothesis of identical contribution distributions among treatments implies that the probabilities with which contributions exceed 50% over the last 10 rounds are identical among treatments. In fact, the number of times this occurred out of six independent samples from each treatment was three, zero and four for the baseline, private and public treatments, respectively. The K-sample test was run on those data.

[18] We conducted our analysis using the STATA "intreg" command, with upper and lower bounds of 10 and zero, respectively, and robust standard errors. The analysis includes 30 rounds for each of 72 subjects, yielding 2160 total observations.

[19] Estimated fixed effects for rounds and subjects are available on request.

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Table 2
Summary statistics (Statistics refer to subjects' decisions and outcomes over 30 rounds).

	Baseline ($N=24$)			Private ($N=24$)			Public ($N=24$)		
	Mean (s.e.)	Med.	[Min, max]	Mean (s.e.)	Med.	[Min, max]	Mean (s.e.)	Med.	[Min, max]
Contribution	5.55 (0.55)	5.17	[0.03, 9.87]	3.95 (0.36)	3.82	[1.2, 7.83]	6.47 (0.54)	6.6	[0.47, 9.83]
Cost of punishment (E$)				0.07 (0.01)	0.04	[0, 0.30]	0.06 (0.02)	0.04	[0, 0.47]
Number of times a subject receives punishment				3.71 (0.55)	3	[0, 11]	3.33 (0.70)	2	[0, 13]
Number of subjects receiving punishment at least once				21			17		

Table 3
Individual contribution dynamics: censored regression model.

	(1) ($N=2160$)	(2) Including individual fixed effects ($N=2160$)	(3) Including individual and round fixed effects ($N=2160$)	(4) Including individual and round fixed effects ($N=2160$)
Private	3.57 (0.15)	3.69 (0.42)	0.76 (0.65)	5.46 (0.59)
Public	7.12 (0.20)	7.06 (0.86)	4.05 (1.15)	7.33 (1.07)
Baseline	6.02 (0.25)	6.18 (0.45)	3.20 (0.67)	8.29 (0.71)
Private × Round				−0.17 (0.03)
Public × Round				−0.08 (0.03)
Baseline × Round				−0.19 (0.03)

Notes: Numbers in parenthesis are robust standard errors. The means of round fixed effects and individual fixed effects are all zero (subsumed in the Public, Private and Baseline intercepts).

external incentives crowd out internal motivations for voluntary cooperation. However, while the extent of both zero and full cooperation under public punishment is lower than the baseline (10% vs. 21%, and 27% vs. 34%, respectively), neither difference is significant ($p=0.15$ and $p=0.52$, respectively, two-tailed Mann–Whitney test).[20]

When combined with increased conditional cooperation, the fact that full cooperation remains high under public punishment, and free-riding low, provides an explanation for the overall greater rates of cooperation encouraged by public punishment. In particular, increased voluntary cooperation is more likely to be met by higher contributions by one's group members in the public punishment treatment, and this can lead to an upward spiral of cooperation in groups.

3.4. Availability heuristic and public punishment

The above provides evidence that experiencing punishment, i.e., receiving it or observing it, can improve punishment's effectiveness in relation to cases where punishment cannot be observed. The explanation we have focused on is that publicly-implemented punishment expresses the cooperation norm more effectively. There are also alternative explanations for "experience" effects.

One possibility is that experiencing punishment can affect people's perception of the risk of punishment. For example, Tversky and Kahneman (1973) argued that peoples' subjective estimates of the probability of an event are increasing in the ease with which that event comes to mind. This availability heuristic may lead people to believe that events they have experienced are more likely to occur than is objectively true.[21] Kunreuther et al. (1978) describe an example of this phenomenon: a substantial number of people buy earthquake insurance after an earthquake, even though the objective chance of a subsequent large quake has not increased (see also, Croson and Sundali, 2005; Camerer, 1989).

Punishment is more salient when it is implemented publicly. Due to the availability heuristic, people might form incorrect subjective beliefs that the likelihood of punishment is higher than its actual (known) probability, and therefore become more likely to contribute more to the public good. In our case, the punishment amount is so small that, even if implemented with probability one, the earnings-maximizing strategy is to free-ride regardless of expectations regarding others' contributions. But not every individual necessarily holds earnings-maximizing preferences. In particular, if some people exhibit sufficient aversion to punishment, then even a small increase in its perceived likelihood could lead these individuals to increase cooperation significantly.

To obtain evidence on the availability heuristic explanation, we conducted a private punishment treatment identical to the earlier private treatment, except that monitoring occurred every round with probability one, and subjects were told that this was the case. If the increased cooperation we observed is only due to an increased belief that one will be punished, then when private punishment is implemented with probability one, it should generate at least as much cooperation as in the public treatment.

In fact, data from this treatment are nearly identical to those from the private treatment (see Fig. 4). Group cooperation is higher when

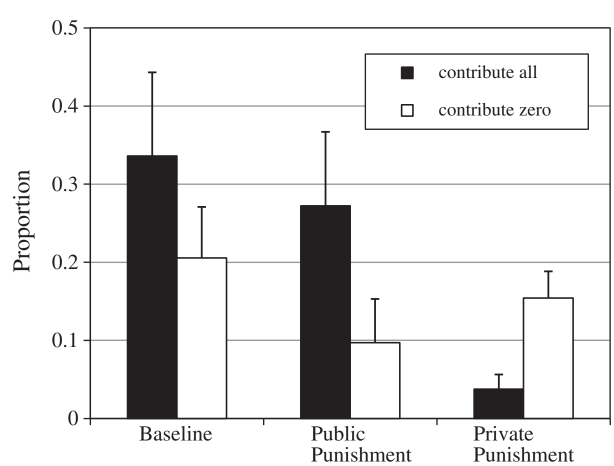

Fig. 3. Effect of treatments on full cooperation (100% contribution) and perfect free-riding (0% contribution).

[20] We conducted a Jonckheere test of the null hypothesis that free-riding is equally frequent among all three treatments, against the alternative that it is ordered from least frequent in the public treatment to most frequent in the baseline without punishment. The null is rejected in favor of the alternative at a (marginally significant) p-value of 0.06.

[21] Hertwig et al. (2004) argue that when events are rare, people's perception of their risk can vary according to whether it is based on personal experience or statistical description. They show that personal experience with low probability events leads to more risk-taking than occurs when the same options are presented using only statistical descriptions.

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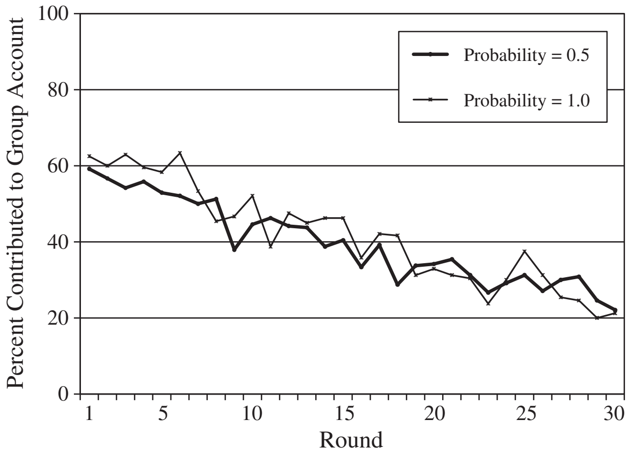

Fig. 4. Mean group account contribution in private punishment treatments.

punishment is implemented publicly with a 50% chance, than when punishment is implemented privately with probability one. This evidence does not seem to support the availability heuristic as an explanation for increased cooperation under public punishment.[22] Nevertheless, it does suggest that public punishment might, at least when monitoring is costly, be able to achieve greater cooperation at lower pecuniary cost.

4. Conclusion

To our knowledge, this paper provides the first systematic evidence comparing the effects of publicly and privately-implemented punishment on enforcing cooperation. Earlier studies have demonstrated detrimental effects of weak punishment, and we provided convergent evidence that small sanctions reduce cooperation when implemented privately. We also demonstrated, however, that these same sanctions promote and sustain cooperation in groups when implemented publicly. The public and private treatments differed in that everyone in the former experienced punishment, while in the latter, only those who received punishment experienced it. We suggested that public punishment may promote cooperation because it is more effective in expressing cooperation norms. We also pointed to several alternative explanations for this effect.

Our findings have useful applications within any community or organization that relies on cooperation. Even in the largely anonymous settings that characterize internet markets, publicly-implemented sanctions might efficaciously deter misconduct and promote trust. Another example relates to enforcing individual codes of honor (see, e.g., McCabe et al., 2001). Many organizations (e.g., West Point and Kellogg Graduate School of Management) provide feedback to the community when an honor-code violation occurs, but do not name the guilty party. Our results may help to explain the use of such strategies.

Our investigation is a small step towards an improved understanding of how the process of punishment affects its efficiency. Future research might explore factors such as shame, learning, justice judgments and emotional responses to experiencing punishment, all of which can impact punishment's efficacy (see. e.g., Elster, 1999; Bandura, 1977; Trevino and Ball, 1992; Ball et al., 1994; Lind and Tyler, 1988; O'Reilly and Puffer, 1989; Xiao and Houser, 2005). Understanding the links between punishment's process and its consequences will result in improved institutions for efficient reduction of misconduct in social and economic exchange environments.

[22] Punishment aversion might be greater when punishment is implemented publicly, even under anonymity. Our analysis does not capture this effect, but it is an alternative explanation for our data.

Acknowledgements

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Appendix A

A.1. Private punishment treatment

Thank you for coming! You've earned $5 for showing up on time, and the instructions explain how you make decisions to earn more money. So please read these instructions carefully! There is no talking at any time during this experiment. If you have a question please raise your hand, and an experimenter will assist you.

The experiment is divided into different rounds. In all, the experiment consists of 30 rounds. You will be randomly assigned to a group with 3 other participants. *The composition of each group will NOT change during the experiment.* You won't know the identities of your group members.

At the beginning of each round each participant receives 10 E$. At the end of the experiment the total number of E$ you have earned will be converted to dollars at the following rate:

20E$ = $1

In each round, you will decide how to allocate your E$s. After each member in your group makes her decision, the computer will randomly decide whether to monitor the group this round or not. If the group is monitored, then one person in that round might receive a payoff cut. Additional information about the monitoring and payoff cuts is given below.

At the beginning of each round, you decide how many of your 10 E $ to invest in the *Group Account*(G) and how many to invest in your *Individual Account* (I). These two accounts are explained below.

Individual Account (I)

Every E$ you assign to the Individual account will return one E$ at the end of the round.

For example, if you invested all 10 E$ in your Individual account, you would earn 10 E$ from the individual account at the end of the round. If you invested 5 E$ in your Individual account, you would earn 5 E$ from the individual account at the end of the round.

Group Account (G)

Your earnings from the Group Account depend on the number of E $ that *you and your other group members* invest in the Group Account. All E$s that you and your group members invest in the Group account are added together and form the group investment. The group investment generates return of 2 E$ for every 1 E$ invested. These earnings are then divided equally among all group members. Your group has 4 members (including yourself). So, every E$ invested in the Group account will return half of an E$ to each group member at the end of the round.

Some examples of returns to group investment are illustrated in the table below. The left column lists various amounts of group investment; the right column contains the corresponding personal earnings for each group member:

Total Group investment amount by your group (TG)	Return to each group member (from Group investment)
0	0
8	4
10	5
14	7
28	14
40	20

As you can see, it does not matter who invests E$s in the Group account. Everyone will get the same return from every E$ invested there—whether they invested E$ in the Group account or not.

A.1.1. Monitoring

After all members of your group have made their decisions, the computer will *randomly* decide whether to monitor the round. *Each round has a 50% chance of being monitored, and whether a round is monitored does not depend on whether other rounds were or were not monitored.*

Here is what monitoring means. If the round is monitored, then the lowest investor in the Group Account will have his or her payoff for that round cut by some amount. If two or more group members invest the same lowest amount in the Group Account, then the computer will randomly choose one of them to receive the payoff cut. If all the group members invest all their 10 E$ to the Group account, no one will receive a payoff cut when the round is monitored.

Payoff cut

Here is how the payoff cut amount is determined. When a subject's payoff is cut, his or her payoff in that round will be reduced by a certain percentage. This percentage is determined by the difference between his/her Group investment (G) and the average Group investment of his/her other three group members (OG). The specific formula used to determine the amount of the payoff cut is:

Payoff cut Percentage = (OG−G)%
Payoff Cut = Original Payoff (before cut) × Payoff cut Percentage

You have been given a chart that shows the payoff cut percentage for different values of G and OG. From the chart you can see that the payoff cut percentage becomes increasingly larger as G becomes increasingly smaller than OG. Please raise your hand if you do not understand this chart.

Example: If a subject receives a payoff cut, his/her Group investment is 2 and other three members' average Group investment is 6, then his/her payoff cut percentage will be $(6-2)\%=4\%$. You can double check this answer with the chart. It shows that when $OG-G=4$, the payoff cut percentage = 4%. This means that 4% of the subject's original payoff (for that round only) will be cut.

If a subject receives a payoff cut, his/her Group investment is 1 and other three members' average Group investment is 7, then his/her payoff cut percentage will be $(7-1)\%=6\%$. You can double check with the chart which shows that when $OG-G=6$, the payoff cut percentage = 6%. This also means that 6% of the original payoff will be cut in that round.

Important: Each round you will only be told whether you received a payoff cut. No group members will know if any other group member's payoff was cut.

Your earnings in each round

The total E$s you earn at the end of each round is the sum of your earnings from each of the two accounts:

1) E$s earned from your Individual account = amount of E$s you invest in the Individual account.(I)
2) E$s earned from the Group account = 0.5 × the total invested E$s of all 4 Group members to this account.(TG)

So your earnings at the end of each round =

$I+0.5\times TG$, if there is no payoff cut, and
$I+0.5\times TG-$ *Payoff Cut amount*, if there is a payoff cut.

Example

Suppose that you invested 8 E$s in your Individual account and 2 E$s in the Group account, and the three other members invested a total of 18 E$s in the group account. This means there is a total of 20 E$s in the group account. Then your earnings from the Group account would be $20\times 0.5=10$ E$. Each other subject in your group would also earn 10 E$s from the group account. If the computer does not monitor the round, or if the round is monitored but you are not the lowest investor in the Group account, then your total E$s earned would be 8 (from your Individual account) + 10 (from the group account) = 18 total E$s earned.

However, if the round was monitored and you were the lowest investor in the Group account, then your final earnings in this round would be deducted by some amount, (from the chart, as $OG-G=6-2=4$, the payoff cut percentage is 4%), so the payoff cut amount will be $18\times 4\%=0.72$ and then your total earnings in this round would be $18-0.72=17.28$ E$

How to make your decisions in each round

You will make decisions by entering numbers into boxes on your computer screen (If you want to see what the screen looks like, please click the button on the left corner and you will be able to return to the instructions by clicking "Click for instructions" button). The screen will also give you important messages and other information. It is important that you understand the information on the screen. If after reading these instructions you still do not understand your screen, then please raise your hand and an experimenter will assist you.

The round number appears in the top left corner of the screen. In this experiment there will be exactly 30 rounds. The screen will show you both the current round, and how many rounds there are in this experiment in total.

The upper left part of the screen also includes a box that shows your "endowment," which is the number of E$ that you are given each round. In this experiment your endowment is 10 E$ each round. You have to decide on the number of E$ to place in both the Individual and in the Group accounts.

To invest in the Individual account, use the mouse to move your cursor to the box labeled "Individual Account", click on the box and enter the number of E$ you wish to allocate to this account. Do the same for the box labeled "Group Account" to make your group investment. Entries in the two boxes must be positive whole numbers that sum to your endowment (10 E$). To change any of your entries, use the mouse to select what you have previously typed in that box and simply overwrite. To submit your investment, click on the "Submit" button. Once you have done this, your decision can no longer be revised. You will then wait until everyone else has submitted his or her investment decisions.

Seeing your results

Once every member of your group has entered a decision, the outcome of the round will be displayed directly below the boxes where you entered your investment amounts. There are two information boxes on the left. One is the "Payoff Cut Message", from which you will see whether your payoff will be cut by some amount. *Again, this message only shows you whether you received a payoff cut or not. You won't know whether any other of your group members received a payoff cut. Similarly, your group members will not know whether you received payoff cut*.

The other information box is labeled "Outcome of This Round" and will show you:

(1) how much each of your group members invested in the Group Account (IDs are NOT listed);
(2) your Individual investment(I) and Group investment(G);
(3) the difference between your G and the average investment amount of your other 3 group members(OG). This is listed in the column titled as OG − G;
(4) if you received a payoff cut, the payoff cut amount;
(5) your final earnings for this round.

You can move your mouse to the information box and it will extend to display all of this information.

The *History Record* on the left side of the window records the data from all of the rounds you've played so that you can review previous rounds' outcomes anytime. Again, you might need to move your mouse to the box to see the complete information. You might also have to scroll up to see early records. The right bottom box will show you the current status of the experiment. In addition, several important things to know about the experiment will be listed there for your easy reference.

After you finish reading the information, please click the "Click when ready" button. Once every subject clicks the button, you will begin the next round.

At the end of the experiment, your E$s earned in each round will be added together, and you will be paid privately at the rate 20 E$ = $1.

Summary

1. Your task: Decide how to invest your 10 E$ in each round.
2. Monitoring: Each round has 50% chance being monitored. If monitored, the lowest Group account investor will receive a payoff cut.
3. The amount of payoff cut percentage is determined by the difference between the average of your other 3 group members' Group account investment (OG) and your Group account investment (G). When the difference OG − G is bigger, the payoff cut (if any) will be larger.
4. At the end of each round, each member will be informed whether he/she received a payoff cut. No investor will know if a different member received a payoff cut.

A.2. Public punishment treatment

Thank you for coming! You've earned $5 for showing up on time, and the instructions explain how you make decisions to earn more money. So please read these instructions carefully! There is no talking at any time during this experiment. If you have a question please raise your hand, and an experimenter will assist you.

The experiment is divided into different rounds. In all, the experiment consists of 30 rounds. You will be randomly assigned to a group with 3 other participants. *The composition of each group will NOT change during the experiment.* You won't know the identities of your group members.

At the beginning of each round each participant receives 10 E$. At the end of the experiment the total number of E$ you have earned will be converted to dollars at the following rate:

20E$ = $1

In each round, you will decide how to allocate your E$s. After each member in your group makes her decision, the computer will randomly decide whether to monitor the group this round or not. If the group is monitored, then one person in that round might receive a payoff cut. Additional information about the monitoring and payoff cuts is given below.

At the beginning of each round, you decide how many of your 10 E$ to invest in the *Group Account* (G) and how many to invest in your *Individual Account* (I). These two accounts are explained below.

Individual Account (I)

Every E$ you assign to the Individual account will return 1 E$ at the end of the round.

For example, if you invested all 10 E$ in your Individual account, you would earn 10 E$ from the individual account at the end of the round. If you invested 5 E$ in your Individual account, you would earn 5 E$ from the individual account at the end of the round.

Group Account (G)

Your earnings from the Group Account depend on the number of E$ that *you and your other group members* invest in the Group Account. All E$s that you and your group members invest in the Group account are added together and form the group investment. The group investment generates return of 2 E$ for every 1 E$ invested. These earnings are then divided equally among all group members. Your group has 4 members (including yourself). So, every E$ invested in the Group account will return half of an E$ to each group member at the end of the round.

Some examples of returns to group investment are illustrated in the table below. The left column lists various amounts of group investment; the right column contains the corresponding personal earnings for each group member:

Total Group investment amount by your group (TG)	Return to each group member (from Group investment)
0	0
8	4
10	5
14	7
28	14
40	20

As you can see, it does not matter who invests E$s in the Group account. Everyone will get the same return from every E$ invested there—whether they invested E$ in the Group account or not.

Monitoring

After all members of your group have made their decisions, the computer will *randomly* decide whether to monitor the round. *Each round has a 50% chance of being monitored, and whether a round is monitored does not depend on whether other rounds were or were not monitored.*

Here is what monitoring means. If the round is monitored, then the lowest investor in the Group Account will have his or her payoff for that round cut by some amount. If two or more group members invest the same lowest amount in the Group Account, then the computer will randomly choose one of them to receive the payoff cut. If all the group members invest all their 10 E$ to the Group account, no one will receive a payoff cut when the round is monitored.

Payoff cut

Here is how the payoff cut amount is determined. When a subject's payoff is cut, his or her payoff in that round will be reduced by a certain percentage. This percentage is determined by the difference between his/her Group investment (G) and the average Group investment of his/her other three group members (OG). The specific formula used to determine the amount of the payoff cut is:

$$\text{Payoff cut Percentage} = (\text{OG}-\text{G})\%$$
$$\text{Payoff Cut} = \text{Original Payoff (before cut)} \times \text{Payoff cut Percentage}$$

You have been given a chart that shows the payoff cut percentage for different values of G and OG. From the chart you can see that the payoff cut percentage becomes increasingly larger as G becomes increasingly smaller than OG. Please raise your hand if you do not understand this chart.

Example: If a subject receives a payoff cut, his/her Group investment is 2 and other three members' average Group investment is 6, then his/her payoff cut percentage will be $(6-2)\% = 4\%$. You can double check this answer with the chart. It shows that when $OG - G = 4$, the payoff cut percentage $= 4\%$. This means that 4% of the subject's original payoff (for that round only) will be cut.

If a subject receives a payoff cut, his/her Group investment is 1 and other three members' average Group investment is 7, then his/her payoff cut percentage will be $(7-1)\% = 6\%$. You can double check with the chart which shows that when $OG - G = 6$, the payoff cut percentage $= 6\%$. This also means that 6% of the original payoff will be cut in that round.

Important: Each round you will be told whether you received a payoff cut. In addition, you will know if the least group account investor's payoff was cut.

Your earnings in each round

The total E$s you earn at the end of each round is the sum of your earnings from each of the two accounts:

1) E$s earned from your Individual account = amount of E$s you invest in the Individual account.(I)
2) E$s earned from the Group account = $0.5 \times$ the total invested E$s of all 4 Group members to this account.(TG)

So your earnings at the end of each round =

$I + 0.5 \times TG$, if there is no payoff cut, and
$I + 0.5 \times TG -$ *Payoff Cut amount*, if there is a payoff cut.

Example

Suppose that you invested 8 E$s in your Individual account and 2 E$s in the Group account, and the three other members invested a total of 18 E$s in the group account. This means there is a total of 20 E$s in the group account. Then your earnings from the Group account would be $20 \times 0.5 = 10$ E$. Each other subject in your group would also earn 10 E$s from the group account. If the computer does not monitor the round, or if the round is monitored but you are not the lowest investor in the Group account, then your total E$s earned would be 8 (from your Individual account) + 10 (from the group account) = 18 total E$s earned.

However, if the round was monitored and you were the lowest investor in the Group account, then your final earnings in this round would be deducted by some amount, (from the chart, as $OG - G = 6 - 2 = 4$, the payoff cut percentage is 4%), so the payoff cut amount will be $18 \times 4\% = 0.72$ and then your total earnings in this round would be $18 - 0.72 = 17.28$ E$

How to make your decisions in each round

You will make decisions by entering numbers into boxes on your computer screen (If you want to see what the screen looks like, please click the button on the left corner and you will be able to return to the instructions by clicking “Click for instructions” button). The screen will also give you important messages and other information. It is important that you understand the information on the screen. If after reading these instructions you still do not understand your screen, then please raise your hand and an experimenter will assist you.

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To invest in the Individual account, use the mouse to move your cursor to the box labeled “Individual Account”, click on the box and enter the number of E$ you wish to allocate to this account. Do the same for the box labeled “Group Account” to make your group investment. Entries in the two boxes must be positive whole numbers that sum to your endowment (10 E$). To change any of your entries, use the mouse to select what you have previously typed in that box and simply overwrite. To submit your investment, click on the “Submit” button. Once you have done this, your decision can no longer be revised. You will then wait until everyone else has submitted his or her investment decisions.

Seeing your results

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The other information box is labeled “Outcome of This Round” and will show you:

(1) how much each of your group members invested in the Group Account (IDs are NOT listed);
(2) your Individual investment (I) and Group investment (G);
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Summary

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4. At the end of each round, each member will be informed whether anyone in his/her group received a payoff cut.

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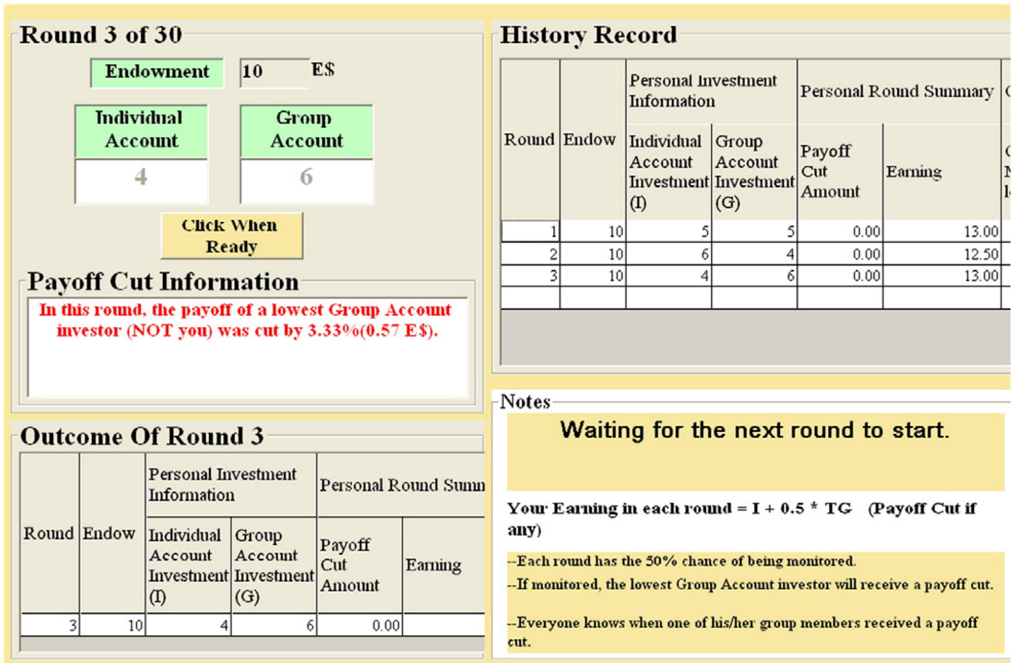
Appendix B

Decision screen for public punishment treatment



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