Keeping up appearances: Experiments on cooperation in social dilemmas

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Publication date
2014

Chapter 4: Group competition and punishment

4.1 Introduction [48]

Taking the group composition in a public goods game (see Chapter 3) as given, we now focus on the effects of the presence of other groups. As before, a public goods setting is characterized by the tension between the welfare of the group and the interests of the individual group members. As described in Chapter 1, the possibility to exert costly punishment has been shown to enforce contributions in public goods games. Therefore the exertion of altruistic punishment has been put forward as an explanation for the existence of cooperation in human societies (Fehr and Gächter, 2002).

Another institution that has been shown to promote cooperative behavior in social dilemmas is group competition (Gunnthorsdottir and Rapoport, 2006). The key to group competition is that the payoff to members of one group is contingent on their performance relative to another group's performance, as the groups that do better have additional advantages[49]. Competition adds two components to a public goods game. First, individuals may learn about the decisions of (members of) other groups; second, the earnings of the winning group may be increased at the expense of the losing groups. We refer to the former effect as 'group observation' and to the latter as 'group earnings competition'. Either of these alone has been shown to increase contribution levels relative to single groups (Bardsley and Sausgruber, 2005; Böhm and Rockenbach, 2013).

In this chapter, we will focus on the simultaneous occurrence of punishment and group competition. This is important because their net effect is not clear a priori. Although taken separately both effectively reduce free-riding in a group, punishment costs may be detrimental to a group's relative performance in competition with other groups. Costs incurred by the punisher and costs imposed on the punished accrue at the group level, making groups with

[48] This chapter is based on Van den Broek, Egas, Gomes and Riedl (working paper, 2010).
[49] In the extreme case of lethal group competition, the losing groups leave the stage (Egas et al., 2013.).

more punishment worse off compared to groups where no punishment is exerted. In theory, groups in which the number of potential punishers is sufficiently large may outperform groups with fewer punishers in terms of cooperation rates (Boyd et al., 2003). The net effect of increased cooperation and increased punishment costs remains unclear, however. Hence it is still an open question whether exerting punishment contributes to winning a competition in terms of group earnings. This chapter addresses this question.

The effect of competition between groups on contributions in a public goods game has previously been studied without punishment options. This literature shows for prisoners' dilemma games that the implementation of competition for a prize increases cooperation levels (Bornstein, 1993; Bornstein et al. 2002; see also Nalbantian and Schotter, 1997). Moreover, group competition (without punishment) increases efficiency in social dilemmas (Puurtinen and Mappes, 2009; Egas et al., 2013).

As for the effects of punishment in social dilemmas, the notional detrimental effects of punishment on efficiency seem to disappear if the duration of the game is extended (Gächter et al., 2008). Yet, subjects do not immediately anticipate that the possibility to punish will increase their earnings: when given the choice between institutions, they initially prefer a setting without sanctions (Sutter et al., 2010). They quickly learn, however, and change their mind after experiencing the higher payoffs in the sanctioning regime (Gürerk et al., 2006). Lastly, the interaction of punishment with another institution promoting cooperation, to wit, indirect reciprocity, increases the efficiency of cooperation (Rockenbach and Milinski, 2006). We conclude from these recent insights that the effect of punishment on group welfare interacts with the cooperation–inducing mechanisms. Hence, the effects of punishment on earnings are as yet unpredictable if it occurs in combination with group competition on outcomes.

To our knowledge, there has been no systematic analysis of the combined effect of intergroup competition and intra-group punishment[50]. By filling this gap an important debate can be

[50] Bornstein, Kugler and Goren have run a competitive public goods game with punishment, and found that the punishment option increased contribution levels to 50 percent (not published, personal communication).

resolved: whether it is in principle possible to sustain cooperation by means of punishment under the threat of competition (Boyd et al. 2003; Dreber et al, 2008). The main research questions in this chapter are thus:

(i) Does intergroup competition lead to higher contributions?

(ii) Does competition lead to higher levels of punishment?

(iii) Does competition lead to higher levels of efficiency in terms of earnings?

Our results indicate that the mere presence of another group (even without formal intergroup competition) induces higher cooperation and punishment levels. Group competition attenuates punishing behavior, however. Nevertheless, this does not affect contribution levels, which remain equally high when groups compete as when they only observe each other. This leads us to the conclusion that intergroup[51] competition makes punishment more effective.

The remainder of this chapter is organized as follows: Section 2 describes the basic public goods game with extensions and theoretical predictions; section 3 gives the experimental design; section 4 reports the results and section 5 concludes.

[51] We use competition as shorthand for intergroup competition.

4.2 Theoretical predictions

Consider the standard linear public goods game as introduced in Chapters 1 and 3. Punishment is implemented by the possibility for subject i to allocate p_{ki} points to a fellow group member k at a cost c, with an impact of d per allocated point (assuming p_{ii} = 0, i.e., a subject cannot punish himself). As a consequence, the payoff function becomes

$$\hat{\pi}_i = \omega - g_i + a\sum_{k=1}^{m} g_k - c\sum_{k=1}^{m} p_{ik} - d\sum_{k=1}^{m} p_{ki} \qquad (1)$$

Group competition is modeled as a transfer t between the individuals of two groups. The payoff π_i for subject $i \in K$ after group competition can now be written as:

$$\pi_i = \omega - g_i + a\sum_{k=1}^{m} g_k - c\sum_{k=1}^{m} p_{ik} - \sum_{k=1}^{m} p_{ki} + t_{i\in K} \qquad (2)$$

with $t_{i\in K}$ being the transfer to subject $i \in K$ and the costs of punishing again set to 1. We model this by assuming that the transfer $t_{i\in K}$ is a linear function of the difference in the two groups' aggregate payoffs before competition. Denoting groups by K and L (hence, m = |K| = |L|), these payoffs are given by $\hat{\Pi}_K$ and $\hat{\Pi}_L$, the earnings before group competition. Using a factor f to scale the impact of group competition this yields:

$$t_{i\in K} = f\,\frac{\hat{\Pi}_K - \hat{\Pi}_L}{m} \quad \text{with} \qquad (3)$$

$$\hat{\Pi}_L = \sum_{i=1}^{m} \hat{\pi}_{i\in L} \quad \text{and} \quad \hat{\Pi}_K = \sum_{i=1}^{m} \hat{\pi}_{i\in K} \qquad (4)$$

Conversely, the payoff for subject $j \in L$ is:

$$\pi_j = \omega - g_j + a\sum_{l=1}^{m} g_l - c\sum_{l=1}^{m} p_{jl} - \sum_{l=1}^{m} p_{lj} + t_j \qquad (5)$$

with

$$t_j = f\,\frac{\hat{\Pi}_L - \hat{\Pi}_K}{m} \qquad (6)$$

Note that transfer is the same for every individual in a group and has opposing signs for group L and group K.

The aggregate payoff in a period now not only depends on contributions and punishment in a subject's own group, but also on the outcome of the group competition. As a consequence, the MPCR (Marginal Per Capita Return), which denotes relative earnings of investing in the public account versus investing in the private account, is no longer directly determined by parameter a. An increase in contribution to the public account now not only leads to a negative effect on the earnings before competition (because a<1), it also yields a positive expected return from group competition, because the group payoff $\hat{\Pi}$ will increase (when ma>1).

We therefore proceed with determining the 'adjusted' MPCR. This gives the payoff change that occurs from contributing one monetary unit to the public good as opposed to keeping it. Aside from the direct MPCR, captured by a, the adjusted MPCR also captures the indirect effect through the change in relative group payoffs.

We first determine the derivative of the payoff after group competition (Eq. 5):

$$\frac{\partial \pi_j}{\partial g_j} = -1 + a + \frac{\partial t_j}{\partial g_j} \tag{7}$$

Rewriting Equation 6 in a term for j and one for i ≠ j

$$t_j = \frac{f}{m}[\,\hat{\pi}_j + \sum_{i \neq j}^{m} \hat{\pi}_i - \hat{\Pi}_K] \tag{6a}$$

Therefore,

$$\frac{\partial t_j}{\partial g_j} = \frac{f}{m}\,(-1 + a) + \frac{f}{m}\,(m - 1)a - 0 \tag{8}$$

Substituting Equation 8 in Equation 7:

$$\frac{\partial \pi_j}{\partial g_j} = -1 + a + \frac{f}{m}(-1 + a) + \frac{f}{m}(m - 1)a$$

The marginal incentive to contribute to the game with group competition is thus given by:

$$\frac{\delta \pi_j}{\delta g_j} = a - 1 + \frac{f}{m}\ (ma - 1) \tag{9}$$

The social dilemma is bounded by the parameters *ma > 1* as before. In addition, for this to constitute a social dilemma, it must be a dominant strategy for (self-interested) *i* to contribute nothing, i.e., the right hand side of (9) must be smaller than 0, which gives

$$a + \frac{f}{m}(ma - 1) < 1 \tag{10}$$

The standard equilibrium prediction assuming self-interested players is then once again that they contribute zero to the project. Since punishing lowers their payoff, such players never resort to punishing and therefore never expect to be punished, independently of the MPCR. Competition does not change the predictions under the standard rationality assumptions. Therefore we correct the MPCR for contribution incentives under competition, but we do not correct for the increased cost and impact of allocated punishment points.

Before continuing with our design, we briefly discuss the implications of three alternative models, which incorporate social preferences. First, for a person who is inequity averse (Fehr and Schmidt, 1999), the motivation to contribute in a competitive setting is unclear. Competition makes it even harder to predict the levels of punishment; there is a multiplicity of equilibria and therefore we do not discuss all possibilities. Note that by contributing to the in-group, an agent raises the income of the in-group members, but at the same time creates inequality between the in-group and the out-group members. Hence, the predicted outcome depends on who the agent sees as its reference agents. Second, agents with welfare maximizing preferences (Charness and Rabin, 2002) will contribute but not punish. Competition does not change these predictions, since a transfer does not change the overall welfare. Third, introducing spite into the model (Andreoni and Miller, 2002) increases the incentive to hurt the out-group.

4.3 Experimental design and procedures

The experiment was conducted at the CREED laboratory at the University of Amsterdam in 2006. A total of 231 subjects participated in 16 sessions, mostly undergraduate students at the University of Amsterdam. Participants majored in economics (34%) and in a variety of other fields. No subject was allowed to participate in more than one session. Their average age was 22 and 33% of the participants were women. Average earnings were 19.50 euro (plus 5 euro show-up fee). The experiment lasted for one hour. Subjects were paid anonymously and no communication was allowed during the experiment. The experiment was computerized and written in zTree 2.1.0 (Fischbacher 2007). Written instructions (see Appendix A for a translation) were provided to the subjects. We checked for understanding by means of a questionnaire; subjects with incorrect answers or with questions were individually advised. After the experiment we acquired personal information and conducted a personality test before the anonymous payment took place.

The basic design of our experiment consists of the three-person public goods game presented in Chapter 3, repeated for 30 periods. Group composition was constant across periods and subjects were not informed about the identity of the other group members or other players in the game. We are interested in the effect of punishment and group competition and the interaction between these mechanisms. For group competition, as argued in the introduction, we need to distinguish between group observation and group earnings competition. Because the latter is impossible without group observation, we isolate the effect of observation by introducing a treatment with only group observation. All in all, we systematically varied (1) the opportunity to punish fellow group members and (2) group interaction (no group interaction, group observation without competition, and group observation with competition) in a complete 2x3 design. This leads to 6 treatment conditions (see table 4.1).

Table 4.1 Treatment conditions

	no group interaction	group observation	group competition
without punishment	Base (7 groups, 3 subjects)	Obs (8 groups, 2x3 subjects)	Comp (8 groups, 2x3 subjects)
with punishment	BaseP (6 groups, 3 subjects)	ObsP (8 groups, 2x3 subjects)	CompP (8 groups, 2x3 subjects)

Notes. Treatment conditions and number of independent observations

The treatments without group interaction (Base and BaseP) serve as control treatments, where one group of three subjects plays a public goods game respectively with (BaseP) or without (Base) punishment opportunities. In the group observation treatments (Obs and ObsP) we investigate the effect of observation without monetary consequences. With these treatments we can identify without confounds the effect of observing another group's earnings, which is, as argued above, an inherent component of group competition. In the observation treatments, two groups are paired for the duration of the whole experiment. Group members learn in a specific subset of periods the total group earnings of the group they have been paired with, without any consequences for their own payoffs. In the treatments with group competition (Comp and CompP), the individuals in the group with the higher aggregate earnings each receive the difference between the two groups' total earnings in that period. These earnings are deducted from the individuals in the group with the lower total earnings. Details are given below.

Linear group competition has large effects on incentives and therefore may drive up contributions to the maximum. In order to downscale the effect of competition and to attenuate these ceiling effects, we chose to let group interaction occur with a certain probability in each period. Groups met with a probability of $q=0.2$ in each period; the group interaction periods were randomly determined beforehand for the purpose of comparison across treatments. Subjects did not know in which periods group interaction would occur, only that it would occur with a given probability. Importantly, they are told whether or not group interaction will take place only after the contribution and punishment decisions have been made.

In all treatments, every period of the game consists of a decision stage and a punishment stage (if applicable), followed by an 'information stage' in case of a group interaction period. In the decision stage, subjects decide simultaneously and independently how much of their endowment (20 points) they want to contribute to the public good. We use an MPCR of 0.4 in treatments without competition, which is adjusted for the competition treatments as described below. At the end of the decision stage, the participants receive information about the individual contributions of all group members, the total return from the project, the personal return from the project, personal earnings, and the total earnings of the group. Subsequently, subjects in the punishment treatments can simultaneously and independently decide to assign at most a total of 10 punishment points to any other group member. A punishment point (called 'subtraction point' during the experiment) costs 1 point to the individual allocating it and 3 points to the group member receiving it. At the end of the punishment stage, subjects are informed about punishment points involving themselves, the incurred costs and the payoff consequences. Individual subjects are not recognizable across periods. The treatments with group observation and group competition are characterized by an additional subsequent information stage in periods of group interaction. Subjects are informed about the total earnings of the group they are paired with, the difference with their own group and the transfer of earnings resulting from group competition (in the competition treatments only).

The implementation of group competition with probability q per period changes the marginal incentive to contribute (eq. 9) to:

$$\frac{\delta \pi_j}{\delta g_j} = a - 1 + \frac{qf}{m}\ (ma - 1) \qquad (11)$$

The experiment was designed to capture group competition in its simplest form. To keep the MPCR constant across contribution levels, we chose a linear transfer between the two groups[52]. Furthermore, we were careful to implement group competition such that the material

[52] The linear function implies that every subject in the winning group receives a scaled difference between the groups from a subject in the losing group. A different functional form of the difference between the two would imply that the MPCR in the group competition treatments would not be a constant.

incentives were equal in treatments with and without competition. Although theoretically the difference in the MPCR between both cases will not affect choices, it has been shown that the MPCR does strongly affect contribution, even when it is predicted not to do so (Isaac and Walker, 1988a; Isaac and Walker, 1988b). If we were to observe higher contributions with group competition, this could then be ascribed to the mere effect of increasing the MPCR to the expression in (9). To disentangle this effect from a 'pure competition effect', we used an adjusted MPCR in the treatments with group competition. The adjustment needed was determined as follows. Since subjects in the competition treatment could not predict in which periods group competition would occur, the marginal incentive to contribute in each period is defined by equation (11). The MPCRs were equalized across treatments to keep marginal incentives across treatments identical, i.e., a's were chosen such that the equation for the marginal incentive to contribute in the treatments without group competition, $\frac{\delta \pi_j}{\delta g_j} = a - 1$, equals the marginal incentive for the group competition treatments, equation (11). Given MPCR a in the treatment without group competition, for the group competition treatment we chose a' such that:

$$a` = \frac{a + \frac{qf}{m}}{1 + qf} \tag{12}$$

We set the transfer factor f such that a' is smaller than a.[53]

Other parameters for the public good game were set as follows. For the endowment, we use $\omega = 20$, the MPCR $(a) = 0.4$, and group size $(m) = 3$. The transfer factor between groups (f) was set to 3, which essentially implies that each group member of the winning group receives the difference in the two group's earnings from a member of the losing group. A steeper or flatter linear transfer rate would have meant either that in many cases, money from previous periods would have to be deducted after losing the competition, or that there was no noticeable effect of the competition at all. Negative earnings in a period were deducted from the total account; with the above parameters, however, negative earnings are not possible in the treatment

[53] We did so to ensure that if we were to observe higher contributions with group competition, it would not be due to the material incentives by itself.

without punishment.[54] The interaction periods were predetermined at period 3, 6, 13, 17, 21 and 27 in all treatments and replicates. Subjects could allocate up to 10 punishment points per period. To compensate for the change in incentives for contribution as a result of group competition as described above, the MPCR for the competition treatments (*a`)* was set at 0.375 (eq. 12).

[54] Without punishment, the lowest earnings for a participant occur in a competition period if he is the only person contributing in his group and everyone contributes in the other group. He then earns $\omega - g_i + 0.4*\sum(g)$, or (20-20 + 0.4*(20+0+0)) or 8 points, from which the difference between groups is deducted (8 – ((8+28+28)-72) = 0.This occurs in expectation in 6 out of 30 periods (during which he earns 7.5 in the worst case).

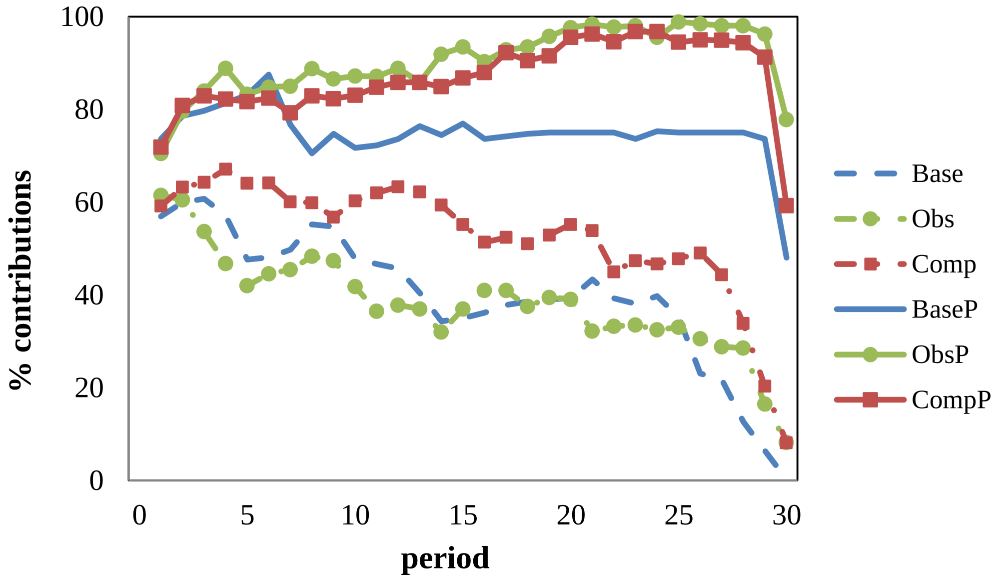
4.4 Experimental results

This section is divided into four subsections. After an overview of contributions in the different treatments, we describe how the exertion of punishment and subjects' reactions to the received punishment differ across treatments. We conclude with the effects of group competition and punishment on the efficiency of the public good provision.

4.4.1 Contributions

Figure 4.1 shows the average percentage of contributions per period for the different treatments. The same data are summarized in Table 4.2. These results show that the control treatments with and without punishment, Base and BaseP, display similar patterns to those observed in previous studies on public goods games (Fehr and Gächter, 2000), namely a steady decrease in contributions in Base and for the punishment case (BaseP) an increase in contributions in early periods, followed by stable levels at approximately 70 % of the endowment. Across all treatments, those that include the option of punishment show higher initial and average contributions than any of the treatments without punishment opportunity. The introduction of competition increases contributions (Comp), but less so than punishment (compare, for example, the difference Comp−Base to the difference BaseP−Base). Observation (Obs) only increases contributions in combination with punishment (Obs and Base are indistinguishable but ObsP shows higher contribution levels than BaseP). It also appears from figure 4.1 that all treatments exhibit end game effects. Because we are not interested in this effect per se, we will exclude period 30 from all of the tests to be presented in this section.

Figure 4.1. Contributions



Notes. Average percentage contributions over 30 periods in the control treatment (Base), Observation (Obs) and Competition (Comp), with (P) and without punishment.

Furthermore, we infer from visual inspection that the last third of the periods (20-29) is most stable (see Table4.2 for a numerical comparison of treatments). In earlier periods there is an upward trend noticeable for the treatments with group interaction and punishment (ObsP and CompP); all other treatments are either downward sloping or approximately constant. Lastly, standard deviations of group contributions differ substantially across treatments (cf. the last row of Table 4.2). Most diverse are groups in the competition treatment without punishment.

Table 4.2. Contributions in numbers

Treatment	Base	Obs	Comp	BaseP	ObsP	CompP
Av. % 1-30	39.70	38.24	52.68	74.81	90.41	86.96
Av. % 1-29	41.06	39.27	54.22	75.73	90.84	87.92
Av. % 20-29	29.88	30.79	44.35	74.75	97.68	94.99
Corr. Contr. / Period	-0.36***	-0.31***	-0.4***	0.03	0.33***	0.36***
% Full contr	25.12	25.22	15.30	60.92	70.26	61.85
% Free riders	37.93	40.80	28.52	12.26	2.85	3.74
Av. SD	22.91	15.08	38.29	15.08	18.55	21.33

Notes. Columns indicate treatments without group comparison (Base), with group observation (Obs) and with group competition (Comp), with (P) and without punishment. Av.% 1-30 is the percentage of endowment contributed over all periods; Av.% 1-29 over the first 29 periods; Av. % 20-29 over period 20-29; Corr. Contr. /Period is the correlation (Spearman's **ρ**) between contributions and periods, *** indicates statistical significance at $p < 0.001$ with the group as unit of analysis; % Full contr is the percentage of groups that contributed fully in a certain period (1-29); % Free riders is the percentage of individuals that contributed 0 in a period (1-29); Av. SD is the average standard deviation of contributions across groups (period 1-29).

4.4.1.1 Effects of punishment on contributions

Average contributions differ across treatments (Kruskal-Wallis for group averages[55] across 29 periods, p<0.01). In the treatments without punishment, pairwise comparisons reveal that contributions do not differ significantly between any pair of the three treatments (Base, Obs and Comp). Similarly, the treatments with punishment show no pairwise significant differences in contributions either[56]. The overall effect of punishment on contributions in the control condition is only marginally significant (MW (Base-BaseP), p=0.09). The effect of punishment in the observation treatments is significant (MW p<0.01). Lastly, the punishment opportunity also increases contributions in the competition treatments (MW, p<0.01). The

[55] In all statistical tests the group is the unit of observation, unless stated otherwise. For the group interaction treatments (CompP, ObsP, Comp, Obs), a statistical group consists of 6 subjects, because their actions are interdependent; for the BaseP and the Base treatment, a group consists of 3 subjects. Unless stated otherwise, two-sided Mann-Whitney test statistics with group averages over 29 periods are reported; for multiple comparisons the significant p-value has been adjusted.
[56]Neither do contributions in period 20-29 vary significantly across any of the punishment treatments.

difference in contributions between these two treatments, Comp and CompP, is already significant in the first period (MW, p<0.05)).

4.4.1.2 Effects of punishment compared to observation and competition

The increase in contributions (in periods 1-29) caused by the punishment institution separately (84%, BaseP compared to Base; recall that this is marginally significant) is larger than that of observation (-4% increase for Obs compared to Base; recall that this is not significant). The difference between the contributions in these two treatments is significant (MW BaseP-Obs, p<0.04). Analogously, if we compare the increase in contributions caused by the punishment institution with the increase caused by the competition treatment (a 32% increase compared to Base; recall that this is not significant), we do not observe a significant difference (MW BaseP-Comp, p=0.12). The combination of punishment and competition increases contributions by 114% compared to Base, which is a significant increase (MW CompP-Base, p=0.02).

4.4.1.3 Effects of observation and competition on contributions

Further analysis reveals that although average contributions in ObsP and CompP are very similar, the proportion of groups where all members unanimously contributed in a period is significantly higher in the observation treatment (Two sample proportion test, ObsP-CompP, p<0.01). We find the same effect in the treatment without punishment (Two sample proportion test, Obs-Comp, p<0.01).

To better understand the underlying differences between the two-group interaction treatments with punishment, we distinguish between 'winning' and 'losing' groups. Winning (losing) groups are defined as groups with the higher (lower) earnings of the two matched groups in the majority of the 29 periods. The winning groups in the competition treatment contributed a significantly higher percentage of their endowment (98.64%) than those in the observation treatment (91.62%, MW ObsP - CompP, p<0.01); for the losing groups, the difference in contributions between treatments was larger and went in the opposite direction (88.85% in ObsP versus 77.19% in CompP, p<0.10). Competition thus drives up the difference between two competing groups more than observation.

Results 1: *Without punishment, neither observation nor competition affects contributions. Punishment alone increases contributions more than observation or competition alone. Punishment increases contributions in the observation and competition treatments. The increase is largest when punishment and observation or competition are combined: in that case the contribution rate increases to 100 percent in 60-70 percent of the groups across periods.*

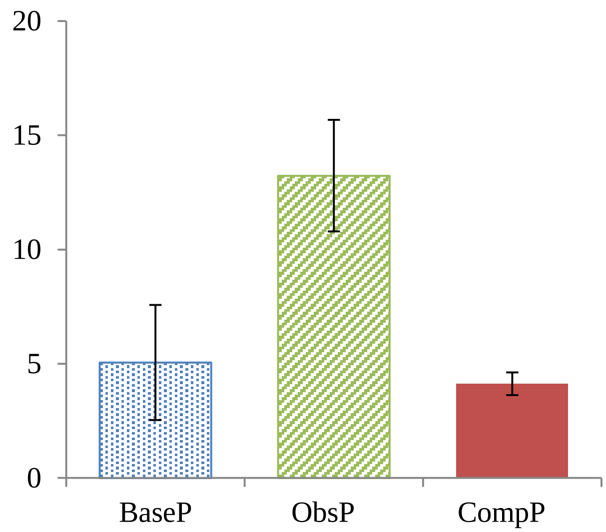
4.4.2 Punishment behavior

We now turn to a comparison of punishment behavior across treatments. After presenting an overview of the allocated punishment points and their impact in treatments with and without competition, we focus on the determinants and responses to punishment and how these differ in the presence of competition.

4.4.2.1 Average allocated punishment points

The average numbers across treatments of punishment points allocated are shown in figure 4.2. The highest degree of punishment (on average 13.22 points in 29 periods) is observed in the observation only treatment (ObsP) and the lowest (4.13) in the competition treatment (CompP), with BaseP (5.05) in between. Subjects allocated more than three times as many punishment points in ObsP than in CompP, but the difference is not significant at the group level (MW, $z = 1.42$; $p = 0.15$) because of large variance differences. The (smaller) difference between punishment allocation in ObsP and BaseP is marginally significant (MW, $z = 1.81$, $p = 0.07$).

Figure 4.2. Average punishment points



Notes. Average number of total punishment points allocated per person in the first 29 periods; lines denote standard errors; BaseP = control treatment, ObsP = observation only, CompP = competition.

Not surprisingly, the observed difference in punishment between ObsP and CompP can be attributed to the groups that contributed relatively less. Across 29 periods, we summed the number of times a group has the higher average contributions of the two; if contributions were on par, neither of the groups was defined as 'winning[57]'. The group that won in the majority of periods is the 'high contribution group'. Sorting into 'high contribution' and 'low contribution' groups reveals that the levels of punishment in the high contribution ObsP and CompP groups are both low, respectively 3.91 and 2.33 (MW, z = 1.00, p = 0.32); in contrast, we find a large difference between average punishment levels in the low contribution groups in ObsP (22.54) compared to CompP (5.91) (MW, z = -1.89, p = 0.06). The low contribution groups in ObsP also punish (marginally significantly) more than the BaseP groups (MW, z = 1.90, p = 0.06).

Result 2: *Punishment is lowest in the competition treatment. Groups with relatively low contribution levels punish more in the observation treatment than in the competition treatment.*

[57] Note that we define winning here in terms of contributions, to avoid taking punishment into account, as opposed to the earlier definition that was formulated in terms of earnings.

4.4.2.2 Punishment efficiency

So far, we have seen that the combination of a competitive setting with a punishment institution (CompP) increases contributions compared to a situation with punishment but without competition (BaseP), and at the same time slightly decreases the number of allocated punishment points. To further analyze the effect of punishment we consider the impact per punishment point, measured as the difference between the average contributions in the punishment treatment and the accompanying treatment without punishment, divided by the average number of punishment points allocated in the punishment treatment. In formula:

$$\rho_x = \frac{averageContributions(xP) - averageContributions(x)}{averagePunishment(xP)}$$

where $x \in \{Base, Obs, Comp\}$. Our data give $\rho_{Base} = 2.50$, $\rho_{Obs} = 1.46$, $\rho_{Comp} = 4.42$. Hence, subjects generate highest contribution growth per punishment point used in the group competition treatment.

Result 3. *Punishment is more effective in the group competition treatment than in the other treatments.*

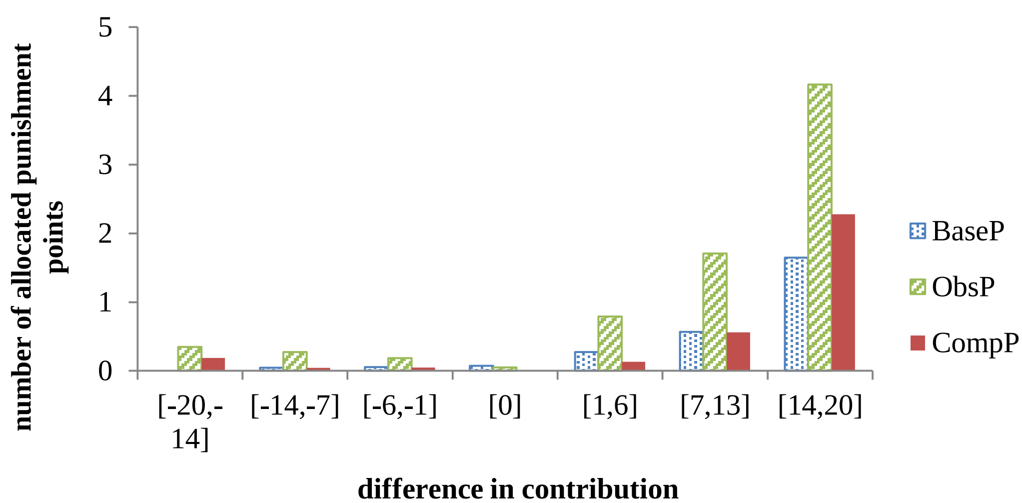
This increased effectiveness may have two causes. Firstly, people may assign fewer punishment points because competition in itself keeps up contributions. We find only weak evidence for this explanation, since competition does not yield higher contributions when there is no punishment (cf. the analysis following figure 4.1 and table 4.2). Alternatively, received punishment points may have a larger impact on subsequent individual contributions through the interaction with group competition. To investigate this, we first consider the individual determinants of punishing; then we analyze the effects of punishment on others' behavior in subsequent periods to establish the effects of received punishment points on contributions.

4.4.2.3 Factors determining punishment behavior

Why do we observe fewer punishment points being allocated in the competition treatment, CompP, compared to the observation treatment without competition, ObsP? A potential explanation for the higher punishment in ObsP is that the differences in contribution across individuals may be larger, which could lead to more punishment. This is not the case: we observe a lower average variance in the contribution of participants per group (of three subjects) in ObsP (8.78 points) than in CompP (9.94 points; MW, $z = -1.74$, $p = 0.08$). On average, then, the difference in contribution between punisher and punished is larger in CompP. We therefore reject this explanation for the difference in punishment.

A second possible explanation for the difference in punishment points is that competition may mitigate punishing in response to the differences in contributions between the punisher and the punished. If this dampening effect is causing the difference, we should on the one hand observe in all three treatments an increase in punishment points with an increase in the difference in contributions, but on the other hand see a more pronounced increase in ObsP than in CompP.

Figure 4.3. Punishment allocation



Notes. Pairwise differences in contribution between punisher and punished, with resulting average punishment points allocated per category, in the competition treatment (CompP), the observation treatment (ObsP), and the control treatment (BaseP).

This is indeed what we observe (see figure 4.3). When the punisher has previously contributed more than the (potentially) punished − i.e., the difference in contributions is positive − the number of allocated punishment points increase with the difference in contribution for all treatments. This correlation is much higher in the observation treatment (ObsP) than in CompP (MW, group-level Spearman correlations between positive deviation in contribution and allocated punishment, $p<0.04$). This observation confirms that group competition dampens the effect that differences in contributions have on the allocation of punishment points.

To better understand the factors determining the individual decision to punish another group member, we use a Tobit regression estimation. To correct for statistical dependencies within statistical groups, robust standard errors are clustered on these groups. For these regression equations we use data from all 30 periods, since a dummy for the final period can account for most of the end game effects. The results are presented in table 4.3. They show that a positive and a negative difference in contribution between the punisher and the punished both significantly increase the number of punishment points allocated. The slope of the increase after a positive deviation in ObsP and CompP is steeper than in the baseline, indicating a stronger reaction to deviations, but not significantly so ($p=0.16$). Aside from these effects the observation treatment dummy is positive and large (but not significant), reflecting that a subject in the observation treatment on average starts punishing at a lower absolute deviation than a subject in the baseline treatment; the competition treatment dummy is negative, but not significant. Whether or not a group had encountered the other group in the previous period does not significantly affect punishment behavior (as it should not, since it was explained to the subjects that encounters are based on a random sequence). There is a negative but non-significant trend over periods (not surprising given the positive trend in contributions over periods (cf. Table 4.1)), except for the last period, where we observe a large increase in punishment points following the drop in contributions in this period[58].

[58] Note that punishment in period 30 is not strategic; see f.i. Nikiforakis (2008) and Vyrastekova, Funaki, Takeuchi (2008).

Table 4.3. Deviation in contribution leads to punishment

Dep. var: punishment points allocated by *i* to *j* in *t*		
Indep vars	**Coefficient**	**Std err**
Contr *i* – contr *j (>0)*	0.64**	0.26
Contr *i* – contr *j (<0)*	0.20*	0.11
Tobservation	1.90	1.45
Tcompetition	-0.91	1.27
deviationXobs	0.19	0.25
deviationXcomp	0.04	0.24
Av. Contr in subgroup	-0.19**	0.09
Group interaction period	0.30	0.35
Period	-0.13***	0.05
Period30	3.96**	1.68
Constant	-7.46***	2.72
# observations (groups)	6838 (22)	
log likelihood	-1589.13	
R2	0.23 ***	

Notes. The table presents the results of a Tobit regression used to explain the allocation of punishment points to *j* by *i* in *t*. *Contr i – contr j (>0)* = positive difference in contribution between punisher and punished; *Contr i – contr j (<0)* = negative difference in contribution between punisher and punished; *Tobservation* = dummy for Obs treatment; *Tcompetition* = dummy for Comp treatment; *deviationXobs (comp) (>0)* = the interaction between the positive difference and a dummy for the Obs (Comp) treatment; Av contr in subgroup = the average contribution in a subgroup of 3; *group interaction period* = a dummy for whether the previous period was a group interaction period. The first line per variable denotes the coefficient (*, **, *** indicating significance at the 0.10, 0.05, and 0.01 level, respectively); the second line denotes the standard error.

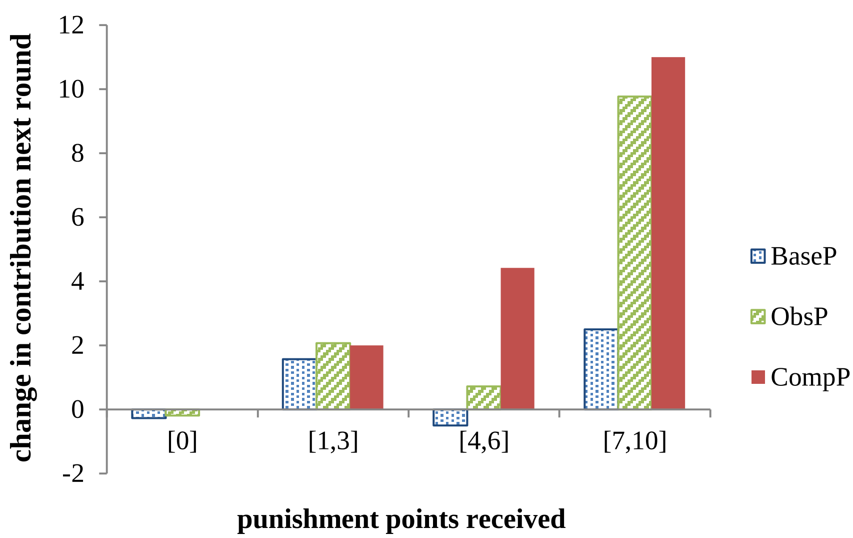
Result 4*: More punishment takes place in ObsP than in CompP.*

A probable reason for this result is that competition extenuates the allocation of punishment points in reaction to differences in contribution.

4.4.2.4 Individual reactions to punishment

Having discussed the decision to punish, we now turn to the effects of punishment and how these vary across treatments. The effects on contributions in the period subsequent to punishment differ across treatments (see figure 4.4). Most noticeably, subjects in BaseP react less to punishment than subjects in the other two treatments. Secondly, taken as a function of the number of punishment points received, the increase in contribution compared to the previous period kicks in at a lower number of received punishment points in the treatment with competition (namely, at 4-6 punishment points instead of at more than 7) than in the other treatments.

Figure 4.4 Reactions to punishment



Notes. Change in contribution in next period as a result of the punishment points received for CompP (competition), ObsP (observation) and BaseP (control).

For a more systematic understanding, we again present the results of a Tobit regression model with robust standard errors clustered on statistical groups (Table 4.4). Here, the dependent variable is the non-negative increase in contribution in the subsequent period[59]. In the baseline treatment the received punishment significantly increases the contribution in the next period; the interaction dummy of the CompP treatment with the number of punishment points received has a large positive coefficient (1.69, p<0.10), but does not differ significantly from the ObsP interaction dummy (p=0.34). This result quantifies the previous observation that impact of punishment points on contribution increases more sharply in the competition treatment and can be compared to the finding that subjects in the competition treatment react more sensitively to punishment (see Figure 4.4). The ObsP treatment dummy is negative and significant compared to the baseline treatment (p<0.05), denoting that in the observation treatment a higher level of punishment is needed to affect behavior. The competition treatment dummy does not differ significantly from the baseline. The negative coefficient of the average contribution of the other group members in the previous period suggests that, other things being equal, people are less inclined to increase their contribution as the others contribute more. Whether group interaction took place in the previous period has no effect.

[59] We exclude decreases in contribution after being punished from this analysis, since these cannot be explained as a reaction to group pressure.

Table 4.4. Increase in contribution

Dep. var: increase in contribution from *t* to *t+1* **Indep vars**	**Coefficient**	**Std err**
Received punishment in *t*	1.14**	0.51
ppxCompP	1.69*	0.96
ppxObsP	1.77	0.55
ObsP	-4.20**	1.95
CompP	-1.60	1.74
Av. contribution others	-1.60***	0.19
Group interaction in *t*	-0.05	0.30
Period *t*	-0.07	0.05
Constant	26.00***	2.44
# observations (groups)	2500 (22)	
log likelihood	-2953.50	
R2	0.24***	

Notes. The model (Tobit regression explaining non-negative increase in contribution, limited between 0 and 20, robust standard errors clustered on group) includes the treatments, the interaction of treatments with the total number of punishment points received in the previous round, and controls for the average contribution of others. *, **, *** indicates significance at the 0.10, 0.05, and 0.01 level, respectively; the second column denotes standard errors.

Result 5: *A punishment point received in the previous period has a larger impact on subsequent contributions in the competition treatment than in the baseline treatment.*

4.4.3 Earnings

Average earnings are an indication of the efficiency of various mechanisms. They do not differ significantly across treatments ($\chi^2(5) = 3.29$, p=0.65); see table 4.5. We constructed a measure of efficiency that normalizes actual earnings by relating them to earnings realized in the social optimum (max *Earnings*) and earnings in the no-contribution Nash equilibrium (min *Earnings*):

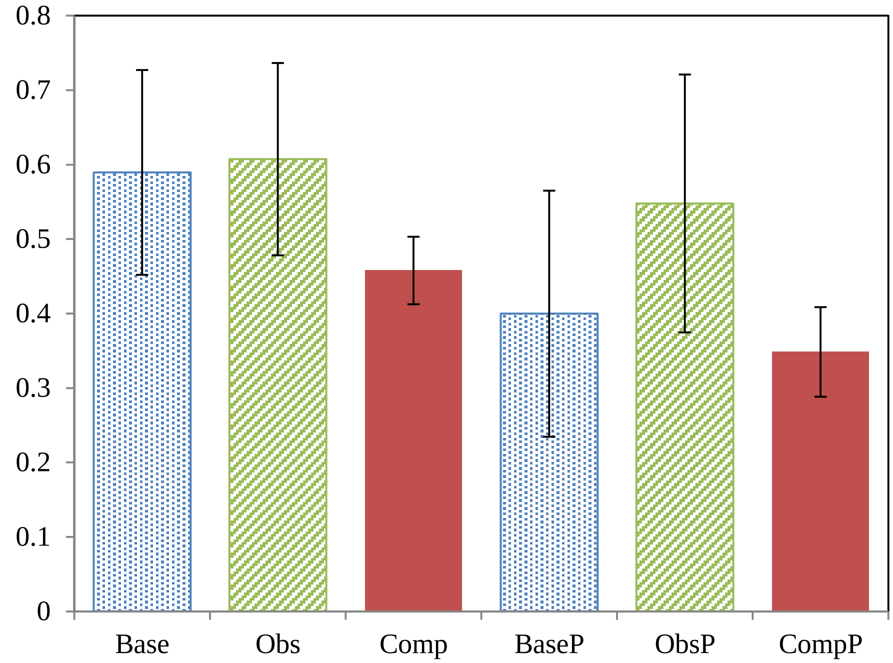
$$\varepsilon = \frac{\max Earnings - actualEarnings}{\max Earnings - \min Earnings}$$

Table 4.5. Average earnings and efficiency

Treatment	Average earnings (29)	SD	Spearman's rho (p<0.01)	% of max	% of min	Efficiency (ε)
Base	18.83	1.27	-0.88	90	108	0.59
Obs	18.77	1.27	-0.90	90	107	0.61
Comp	18.58	0.28	-0.91	95	107	0.46
BaseP	19.49	1.54	0.44	93	112	0.40
ObsP	18.97	1.70	0.60	91	109	0.55
CompP	18.82	0.37	0.57	96	108	0.35

Notes. For each treatment denoted in the first column, the remaining columns show: average earnings over 29 periods; standard deviation; spearman's rho (the correlation between earnings and period number); the percentage of the maximum and minimum earnings; and efficiency for the 6 treatments.

Figure 4.5. Efficiency of treatments



Notes. Average efficiency ((maximum earnings – actual earnings)/(maximum – minimum earnings)) +- se, per treatment. Treatments are control without punishment (Base), Observation (Obs), Competition (Comp), control with punishment (BaseP), Observation with punishment (ObsP), and Competition with punishment (CompP).

For all treatments with punishment, the Spearman's rho of earnings over periods was positive, in contrast with the treatments without punishment. A comparison of the efficiency between the treatments with and without punishment shows that the punishment institution was less efficient (MW Base-BaseP, p<0.001; MW Obs-ObsP, p<0.01; MW Comp-CompP, p<0.001). There is no significant difference between the efficiency of the competition treatments and the observation treatments, either with or without punishment (Obs-Comp: p=0.10; ObsP-CompP: p=0.40. Neither did competition with punishment or observation with punishment increase efficiency compared to the baseline treatment (CompB-Base: p=0.12; ObsP-Base: p=0.99).

Result 6: *Earnings do not differ across treatments. Efficiency in the baseline with punishment treatment is lower than the baseline without punishment treatment; similarly, efficiency in the competition with punishment treatment is lower than in the competition without punishment treatment.*

4.5 Discussion

Both group competition and costly punishment have been put forward as explanations for sustained cooperation in groups, but the interaction of these two mechanisms has not previously been investigated. This chapter experimentally investigates their interplay by systematically comparing how the presence of another group and competition between groups affects contribution levels, punishment and earnings.

Altruistic punishment has been observed widely (Henrich et al., 2006) and competition between groups has taken place throughout the ages (Bowles, 2009). Therefore how people behave when these two institutions occur together is an important question. Our main result is that competition makes punishment more effective. Although competition reduces the number of allocated punishment points, it increases at the same time their impact on contributions in the subsequent period. Observation without financial consequences drives up the contributions to a public good as much as competition does. The fact that this does not result in significantly more efficient outcomes may be due to the nature of the public goods game implemented, specifically the relatively low MPCR, in combination with the higher punishment levels. A longer time span may lead to larger differences in efficiency (Gächter et al., 2008).

We did not find support for the idea that efficiency increases with competition as reported by Puurtinen and Mappes (2009); Sääkasvuori et al., 2011). This may be due to differences between their setup and ours. The linearity of competition effectively increases the MPCR, thus increasing the incentive to contribute, which may explain the efficiency increase reported by Puurtinen and Mappes (2009) and Sääkasvuori et al. (2011). In our experiments, we correct for this change by lowering the MPCR in the competition treatments, and find no significant effect of competition on earnings. The corrected MPCR may have had an effect on punishment, but how exactly punishment depends on the MPCR and other parameters has not yet been extensively studied (Egas and Riedl, 2008). Competition may play a role, too, in the reaction to punishment. Since people are responsive to non-monetary punishment as well, they may be sensitive to other aspects of punishment than the monetary impact (Masclet, 2003). Punishment is more effective when it communicates a transgression of norms, and costliness has been shown to increase the strength of this signal (Xiao, 2013). Therefore, the trade-off that punishers face under competition (by punishing a group member, they decrease their group's chance of winning the competition on the short term) may have increased the perceived strength of the punishment.

Our results may also be considered from an evolutionary group selection perspective. Evolutionary (cultural) group selection models predict that groups in which punishers are common have a selective advantage over groups with lower numbers of punishers, and for this reason may have won the evolutionary battle (Boyd et al., 2003). Recent findings, however, show that within-group punishment does not pay for the individual (i.e., it is probably maladaptive at the individual level to punish free riders; Dreber et al., 2008). Nevertheless, agent-based models suggest that in human prehistoric context the selection effect of group competition may have been strong enough to sustain altruistic punishment (Bowles and Gintis, 2004). On the other hand, group competition has been reported to induce not only behavior that is beneficial to the group welfare. From rent seeking games we know that group contests can turn out to be very destructive for group welfare, especially when punishment opportunities are added (Abbink et al., 2009). Such out-group aggression could have translated into high punishment rates towards in-group free riders in our setting, but we observe the opposite effect. Therefore, our findings are in line with the predictions in Boyd et al. (2003).

One promising direction for further research on competition may be to extend inequality aversion models (Fehr and Schmidt, 1999). In these models agents incorporate the difference between the wellbeing of a reference agent and themselves in their utility function. Diversifying reference agents by in-group and out-group modifiers of altruism and spite may generate testable predictions and spur further experiments (see for instance Yamagishi and Mifune, 2009; Harris et al., 2009). Another way to disentangle subjects' motivations for contributing and punishing in a competitive setting may be to implement a punishment institution in only one of the groups.

When faced with the choice, subjects voluntarily choose a punishment institution after experiencing its monetary advantages (Gürerk et al., 2006). This prompted the question whether such a regime results in winning a competition on earnings when subjects are aware of the competition. Even with our conservative implementation of competition, we show that the interaction between the two mechanisms makes punishment lose its destructive effect on earnings, without losing its deterring force. Therefore group competition removes rather than amplifies the efficiency dilemma of costly punishment.