# Swords without Covenants Do Not Lead to Self-Governance*

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## Abstract

This paper presents an experimental study of two mechanisms for managing common pool resources. Decentralized peer punishment (swords) has been shown to increase cooperation in related social dilemmas, but only with linear private benefits and costs of public goods provision. We investigate the effectiveness of this mechanism for a more realistic nonlinear public goods environment, in isolation and in combination with nonbinding communication and informal agreements (covenants). The results show that swords do not increase cooperation or yield from the public resource, regardless of whether covenants are also possible. Covenants are significantly more effective in solving the social dilemma, and importantly peer punishment is unnecessary if communication is possible.

Keywords: Common Pool Resources, Collective Action, Free Rider, Social Choice, Peer-punishment, Communication, Cheap Talk

JEL Classification: D71, H42

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## 1. Introduction

Social dilemmas arise whenever individuals face a conflict between their personal interests and what is best for the groups to which they belong (Ostrom, 1990). Such conflicts can influence behavior across a wide range of economic, political, social and community life. Research on social dilemmas has sought to identify when external and central authorities are needed to coordinate group efforts toward cooperation, and under what conditions decentralized and peer-based interactions are sufficient to resolve the conflict between group and individual interests.

Empirical research on social dilemmas has identified the importance of peer communication (Balliet, 2010), and monitoring and peer punishment (Fehr and Gaechter, 2000) for improving cooperation without centralized enforcement of property rights or restricted access to group resources. These decentralized solutions to social dilemmas, such as for the management of common pool resources, provide hope for economic and political development without formal and imposed institutions, although researchers have also cautioned that peer-based, local institutions are no panacea (Ostrom et al., 2007). As insights from the academic literature on social dilemmas are applied to the management of the wide range of relevant societal problems in practice, it is important to clarify and refine our understanding of the set of environments where different types of decentralized mechanisms are effective in improving cooperation.

This study reports a laboratory experiment to explore the efficacy of two leading factors that have been shown to improve cooperation, both in isolation and in combination, in certain types of social dilemmas: costly peer punishment (swords) and nonbinding, “cheap talk” communication that often leads to agreements (covenants). Swords, even without covenants, have been shown to improve cooperation in a variety of experiments following Fehr and

Gaechter (2000), but almost entirely focused on a specific class of social dilemmas with linear private and public benefits. This linear structure leads to privately- and socially-optimal outcomes that are at opposite extremes of the range of possible choices. Chaudhuri (2011) provides a recent review.

In the present study we go beyond this linear setting to consider a variation of a common pool resource (CPR) environment first studied by Ostrom, Walker and Gardner (1992), hereafter OWG, who also coined the swords and covenants phrasing to refer to these decentralized management mechanisms. This environment features more realistic nonlinear payoffs that make privately- and socially-optimal outcomes more challenging for participants to identify. Nonlinear payoffs lead to the individuals' private interest and the group's best interest to both have only some but not all effort exerted towards extracting from the resource or contributing to the public good.[1] In stark contrast to results from the simplified linear studies that followed, OWG's original study employing nonlinear returns found that the threat and use of swords fails to reliably increase cooperation.[2] Although this study has been highly influential, this negative result when punishment is used on its own is often overlooked by contemporary researchers studying peer-punishment impacts.

In comparison to swords, covenants (communication) have been shown to effectively enhance cooperation in a wider range of social dilemmas. Nevertheless, relatively free-form

[1] OWG (page 405) argue that "while no formal game or laboratory experiment ever captures all the nuances of field settings, this *n*-person CPR is a far more realistic environment… than many of the dilemma games previously explored."

[2] Ostrom et al. (1994) note that "in only one of the eight experiments do we see the sanctioning mechanism [swords] having a major impact on the level of net yield accrued" (page 178), and although they remark upon "the lack of a significant improvement in net yield accrual with the introduction of a sanctioning mechanism" (page 179) they do not report a statistical test. We extracted from the detail provided in their book the raw data on group contributions and net yield from the public good to conduct such tests. Consistent with the statements quoted above, these tests reveal no significant increase in yield due to sanctioning using either non-parametric Mann-Whitney tests comparing across-sessions ($p$-value=0.22) or within-session increases due to the introduction of sanctioning ($p$-value=0.41), or when using a parametric regression model ($p$-value=0.29). Details are available upon request.

communication has its limits even in simplified environments with linear private and public benefits. Hamman et al. (2011) show that communication alone does not lead to a sustained increase in cooperation if the returns to the public good are relatively low. Instead, delegating decisions about public goods provision to an elected leader is more effective for increasing contributions.[3]

Consistent with OWG and Janssen et al. (2010), the new data reported here indicate that only communication and not peer punishment improves cooperation in this social dilemma.[4] Moreover, our factorial experimental design allows us to conclude that peer punishment is not necessary if communication is possible, and indeed communication actually makes peer punishment redundant. This highlights an advantage of controlled experimentation, which can isolate the marginal impact of each channel of social interaction on cooperation. Field evidence on common pool resource management, such as Coleman (2009), also identifies the importance of monitoring and peer sanctioning in improved outcomes in forests; however, it is difficult to separate the impact of sanctioning from peer communication since communication is often part of the sanctioning process.

Although our main conclusions are similar, this study is not a mere replication of the OWG experiment. It makes a unique contribution by identifying the suitability of specific decentralized mechanisms for improving cooperation in commonly observed field environments. Besides differences in the underlying CPR environment (ours features nonlinear private benefits

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[3] Grossman and Baldassarri (2012) also identify the importance of delegation to elected leaders and in their experiment contributions are substantially higher when group members can elect an individual who can punish low contributors.

[4] Janssen et al. (2010), extend the OWG environment by introducing spatial and temporal resource dynamics in the CPR and find similar results. Costly punishment did not enhance cooperation unless it was combined with communication. Casari and Plott (2003) is the only experiment to find that decentralized peer punishment improves cooperation in a common pool resource environment. They study a simplified laboratory version of the *Carte di Regola* system which existed for centuries in the Italian Alps. In this institution successful punishers receive the "fines" paid by the punished.

while theirs features nonlinear social benefits), as discussed below we also augment the peer punishment mechanism to more standard methods used in the extensive linear public good social dilemma literature, thereby enabling a more direct comparison of results with these more recent studies. This literature has led to the conclusion that peer punishment is broadly and usually effective in raising contributions to the public good, in contrast to OWG's result that peer punishment alone did not improve cooperation. Our experiment demonstrates that OWG's negative result is not due to their restrictive punishment technology or relatively large groups. Stronger, modern peer punishment technology, featuring multiple targets and varying intensity, is also ineffective for enhancing cooperation when used in isolation if the environment features realistic nonlinearities. Adding peer communication, however, leads to significantly higher cooperation and "yield" from the group resource. Furthermore, once the channels of communication open, punishment is not used.

## 2. Swords, Covenants, and the OWG Environment

In this section we summarize the similarities and differences between our experiment and the OWG experiment. Our design is inspired by an environmental (nonpoint source) pollution problem observed in the field.[5] In Cason and Gangadharan (2013) we found that in a similar kind of a nonlinear social dilemma a formal mechanism (such as group tax) leads to more cooperation compared to an informal mechanism (peer punishment). This result led us to revisit the research by OWG to explore whether other informal mechanisms (such as peer communication) would be more successful in such nonlinear social dilemmas. Section 3 presents more details of the new experimental design. Table 1 highlights important aspects of our new social dilemma and the

[5] Nonpoint source pollution comes from diffuse sources whose individual contributions cannot be identified. Examples include nutrient runoff from agricultural production and toxic chemical accumulations from urban runoff.

OWG environment, and the communication and peer punishment institutions used in the two studies. Clearly our goal was not to replicate the seminal OWG experiment, but rather to explore whether the positive results for communication and negative results for peer punishment also hold for a more simplified CPR environment and for the modern communication and peer punishment institutions developed in laboratory research over the past decade.

In OWG, allocations to the public account represent the efforts exerted in extracting from the CPR, so the group return that an individual receives depends on the total allocations to the group by all individuals. OWG therefore add nonlinearities through the group returns. Our environment, by contrast, adds nonlinearities through the private returns since the private benefits of extracting from the CPR are concave. This simplifies the decision problem since the constant marginal group benefit makes their optimal choice independent of the extraction level of others. In other words, in this new study the extraction equilibrium is in *dominant strategies* (Sefton and Steinberg, 1996).[6] A strategy is considered dominant if it leads the individual to earn her highest payoff regardless of what other players do.

In both OWG and our new environment the privately optimal choice equates marginal private benefits with marginal private costs, but the socially optimal choice equates marginal social benefits with marginal social costs. Moreover, due to the nonlinearities in the benefit functions, the privately and socially optimal extraction levels are not on the extreme boundaries of the choice space. Instead, these nonlinearities cause the privately-optimal (self-interested) and socially-optimal (group-oriented) extraction levels into the interior of the choice space. This

[6] Nonlinearities in private returns are observed in several social dilemmas, in the sense that contributing towards the public good or extracting from the common pool has a decreasing marginal per capita return for greater contributions/extractions. A good example of this is when researchers decide how much time to allocate for public good provision, such as administrative duties or refereeing papers. While involvement in these activities has some private benefits, more time spent on these activities leads to decreases in the marginal benefits. Note that decreasing marginal benefits are also consistent with the standard economics assumption of decreasing marginal utility.

means that devoting all or none of the possible efforts to extraction is never optimal, unlike in the linear voluntary contribution mechanism that is widely used to study social dilemmas in experiments.

**Table 1: Summary of Experimental Environments and Decentralized Management Institutions**

| | Ostrom, Walker and Gardner (1992) | This Study |
|---|---|---|
| Marginal payoff to private activity | Constant | Varies with level |
| Marginal payoff to group activity | Varies with level | Constant |
| Group size | 8 | 6 |
| Peer punishment | One target per player<br>Binary (punish or not)<br><br>Punishing fee 5¢ to 40¢<br>Fine received 10¢ to 80¢<br>fee-to-fine ratio 0.25 or 0.50 | Target any and all players<br>Assign 0, 1, …, 5 punishment points per player<br>Punishing fee 50¢ per point<br>Fine received $1.50 per point<br>fee-to-fine ratio 0.333 |
| Communication | Face-to-face, 10 minutes<br><br>One-shot, after 10 periods, or<br>Repeated, every period after period 10 | Anonymous computer chat, 5 minutes<br>Twice, after period 10 and period 20 |
| Nash Equilibrium | Not in Dominant strategies | In Dominant Strategies |

We also employ smaller groups, although our group size of 6 is larger than the 3- to 5-person groups often used in peer punishment laboratory experiments. More importantly, however, the form of peer punishment we use is more typically used in the recent literature that has found peer punishment to be an effective mechanism for improving cooperation in linear public goods settings. It features multiple potential targets and variation in the punishment intensity. By contrast, the ineffective peer punishment employed in OWG was considerably more restrictive. Finally, our new experiment implements communication in a more anonymous and controlled fashion, and our frequency of communication is intermediate between OWG's One-shot and Repeated communication treatments.

Numerous other differences exist in the two experimental designs. For example, OWG implemented 10 baseline periods with neither communication nor peer sanctioning before introducing communication and/or punishment, whereas our experiment introduced peer punishment beginning in period 1. Our subjects also knew in period 1 in the communication treatments that they would have an opportunity to communicate after period 10, while subjects in the OWG experiment did not learn about the communication opportunity until after period 10. OWG also vary the cost of punishment and the frequency of communication across sessions, whereas our design collects more data in a fixed and focused set of treatment conditions.

## 3. Experimental Design Details

We designed an experiment to understand the impact of peer-punishment and nonbinding "cheap talk" communication, individually and jointly, on improving cooperation in nonlinear social dilemmas. In each session subjects interact in groups of 6 and make repeated decisions corresponding to the role of participants facing a social dilemma across 30 periods.

### 3.1. Decision making

Each individual *i* chooses a decision number $E_i$ every period. This corresponds to an amount extracted from the group account or common pool. This choice has an impact on their private payoffs and group payoffs. Private payoffs are represented by a concave benefit function $B(E_i)$ that increases at a decreasing rate up to a maximum level of 125. The experiment implemented the following quadratic functional form for this benefit function:[7]

[7]This functional form is commonly used in the nonpoint source pollution literature (for example, Spraggon, 2002; Cason and Gangadharan, 2013)

$$B(E_i) = 44 - 0.002(125 - E_i)^2$$

The total payoff received by the individual (private plus group payoff) reflects the negative externality that their decisions impose on the group. The group payoff depends on all of the decisions chosen by everyone and is the same for everyone in the group. The external cost or the damage *D* suffered by each of the *M* individuals is proportional to the total extraction by all *M* group members, denoted *E* (without a subscript):

$$D = \alpha E$$

The aggregate total damage suffered by the group is $M \times D$. The damages are endogenous, and individuals themselves suffer from the externality they cause.[8] This framework allows us to examine the absolute and relative effectiveness of mechanisms such as peer punishment and communication for improving cooperation when the actions of individuals generate externalities affecting others in the group. A commonly used example is the linear voluntary contribution mechanism public goods game, which is a version of an *n*-player prisoner's dilemma.

Each individual's payoffs are determined by the benefits from extraction $B(E_i)$ less the damages *D* suffered. The unique Nash equilibrium equates the individual's marginal private benefit $B'(E_i)$ to the marginal private cost of the damages ($\alpha$). Using the value $\alpha$=0.05 employed in the experiment, this privately optimal choice corresponds to an extraction of 112.5 per individual. This leads to the total damages of 202.5, and total payoffs across the six subjects sum to 59.625.

The socially optimal choice equates marginal private benefits with marginal *social* costs of the damages, internalizing the negative externality generated by individuals. The social cost from aggregate total damages for all six individuals in the group is six times larger than

[8]This is similar to the scenario in Cochard et al. (2005). There are many examples in the field where this is observed. For example, the pesticides and fertilizers used by farmers can pollute the water they drink or use for recreation.

individual damages, so the marginal social costs are $6\alpha$=0.3 for the parameters used in the experiment. Therefore, the socially optimal extraction level is obtained if each individual chooses an extraction amount of 50. This level leads to total earnings across the six individuals of 106.5. This socially optimal choice leads to a substantial (79 percent) improvement over Nash equilibrium (privately optimal) total earnings.[9]

### 3.2. Treatments

We conduct four treatments, and collect data from 8 independent groups in each treatment. A total of 192 human subjects participated in the experiment. In all treatments subjects' identities are kept anonymous, although they are given labels that remain the same throughout the session. In the *Baseline* treatment subjects are not given the opportunity to punish each other or to communicate even though they can observe the decisions of their group members at the end of the period as in the other treatments. The purpose of this treatment is to provide a baseline level of cooperation without either peer punishment or communication opportunities.

In the *Swords* treatment, subjects make two decisions in each period, beginning from the first period. In the first stage, subjects choose their decision numbers, which can be observed by the other subjects at the end of that stage. In the second stage subjects are allowed to decrease the payoff of the other members by assigning "deduction points." A punished group member can be assigned between 0 and 5 deduction points by each peer. Each assigned deduction point reduces the punished member's payoffs by 1.5 Experimental dollars and costs the punishing member 0.5 Experimental dollars. These punishment parameters and the instructions for the second stage of

[9] A deviation by one subject to 112.5 (if all 5 others continue to cooperate) raises his earnings by 44%. The 5 "suckers" who continue to cooperate see their earnings fall to 82.4% of the social optimum earnings. Similar gains to and costs from deviating can arise in specific parameterizations of the standard linear public goods game. For example, with groups of size 6 and a marginal per-capita return of 0.3, a subject deviating from the social optimum of full contribution to zero contribution can increase her earnings by 39%, while the suckers who continue to fully contribute earn 83.3% of the social optimum earnings.

the punishment treatment are adapted from Gaechter et al. (2008), who along with many other researchers find that punishment (and this 3-to-1 punishment effectiveness ratio) improves cooperation in a linear public goods game.

Theoretical predictions in the *Swords* treatment are the same as the *Baseline* treatment for agents who have standard own-payoff maximizing preferences. As punishment is costly, individuals who are motivated only by profits would not choose to incur this cost and punish their peers. Realizing this, other agents will not change their behavior and continue to extract more and impose damages on the group. Many studies have however shown that punishment or the threat of punishment helps discipline free riders and leads to higher cooperation amongst group members in certain environments (e.g., Fehr and Gaechter, 2000, 2002; Bowles and Gintis, 2002). We therefore expect subjects to choose decision numbers nearer the socially optimal level in the *Swords* treatment compared to the *Baseline*.

In the third treatment, *Covenants*, subjects are provided the opportunity to communicate with the other 5 participants in their group twice (out of 30 periods) in “chat rooms” on their computers. These chat rooms are open for 5 minutes, and only before the start of period 11 and period 21. Participants are asked to follow some simple rules for this communication—to not identify themselves, be civil to each other and use no profanity—but otherwise they could communicate about anything. They were not instructed to discuss extraction choices. The results from this treatment help determine if a mere exchange of words without any threat of the sword, would be enough to solve the social dilemma and lead subjects to reach cooperative outcomes.

Game theory suggests that if agreements are not binding or enforceable and the Nash equilibrium is unique, as it is in this social dilemma, then peer-communication is not effective as it is just cheap talk because it does not lead to credible ex-ante commitments (Farrell and Rabin, 1996). Communication has however been shown to encourage coordination and cooperation in social dilemma games (Ledyard, 1995; Balliet, 2010), even in challenging settings where subjects only observe others' behavior with a substantial lag (Cason and Khan, 1999). Hence we expect subjects to use communication to obtain more cooperative outcomes. We use communication opportunities sparingly (only twice in a 30 period session), which is twice as often compared to OWG's "one-shot communication" treatment, but it is far less than their "repeated communication" treatment that allowed for communication in every period after period 10. OWG observed that this repeated communication was useful for subjects to discuss defections and extract repeated promises of cooperation, which raised joint yield significantly.

The fourth treatment combines both *Swords* and *Covenants*. Subjects are given the opportunity to communicate twice in the session as in the third treatment and also allowed to punish others in their group in all 30 periods as in the second treatment. As before, theoretical predictions based on the narrow model of purely self-interested objectives suggest that neither punishment nor communication would lead us to the socially optimal outcome. The experimental literature however suggests that an interaction of both these mechanisms could be an effective way of solving the social dilemma problem. This treatment allows us to isolate the marginal impact of these mechanisms on cooperation to increase yield from the public resource and to increase group and individual earnings.

3.3. Procedures

Like many laboratory experiments conducted by social scientists on human subjects, we employ (paid) volunteers drawn from a subject pool of university students, recruited by email using ORSEE (Greiner, 2004). This makes our sample non-representative of the general population, but an appropriate sample for studying social dilemmas would vary from case to case. Some social dilemmas would need to sample farmers in the Brazilian rainforest clearing timber for cultivation, while others would need to sample users of an irrigation ditch in the mountains of Pakistan. Our student participants also face social dilemmas frequently in their everyday lives, such as when they participate in group projects for assessment purposes. Our goal is not to measure how the participants in specific social dilemmas would behave, but rather to draw implications regarding some stylized self-governance mechanisms for these dilemmas in a controlled environment. To measure treatment effects and draw such conclusions, it is actually advantageous to have relatively similar subjects (homogenous on "nuisance" measures not relevant for the research questions) randomly assigned to the various treatment conditions. This raises the signal-to-noise ratio. Therefore, we think it is an advantage that 94% of our subjects are between the ages of 18 and 23 and 100% are university students. We did not explicitly recruit an ethnically and intellectually homogenous set of students. However, 36% were born outside of the U.S. (mostly in Asia) and the subjects represent a wide range of academic majors (the two largest groups being Engineering (24%) and Business (23%)).

The experiment was conducted on computers to minimize interaction between subjects and the experimenter and to limit any uncontrolled interaction across subjects. It was programmed with z-Tree software (Fischbacher, 2007) and was conducted at the Vernon Smith Experimental Economics Laboratory at Purdue University. Although some had participated in other laboratory experiments, all subjects were inexperienced in the sense that they had never participated in a similar experiment with common pool resource and incentives. Subjects interacted anonymously in 6 person fixed groups, however multiple groups under the same treatment conditions were conducted simultaneously in the laboratory, employing 12 to 24 subjects per session.

Subjects were given the equations that determine their private and group payoffs. They were also provided their private payoffs for different decision numbers in a table and their group payoffs for various combinations of decisions numbers in another table. We also employed a graphical user interface to lower subjects' cognitive burden. Every period subjects were required to input at least one "estimate" regarding the decisions made by the other subjects. The decision tool graphs their potential total payoff based on that estimate for every possible extraction level and records and reports this on their screen. They could submit multiple "estimates" regarding others' decisions in each period to re-display new payoff functions, allowing them to perform searches over the strategy space before making a binding choice.[10] After all subjects submitted their choice for the period, they were informed about the choices of the other subjects, the total decision number for the group, and their total payoff for the period. In the treatments in which subjects were allowed to punish, they were informed about the total number of deduction points they received, but not who assigned them, the total number they assigned and their associated payoff reduction. Subjects were required to record this information on hardcopy record sheets at the end of each period.

At the beginning of each experimental session an experimenter read the instructions aloud while subjects followed along on their own copy. The instructions for the *Swords with Covenants* treatment are presented in the Appendix.[11] The number of periods (30) was known by all and announced in the instructions, as was the rule that five periods were randomly chosen at the end of each session for payment. Subjects earned about US$34 on average. Including the

[10] Healy (2006) discusses the advantages of this kind of a decision tool. Several researchers have used variants of this profit calculator, for example, Requate and Waichman (2011), Cason and Gangadharan (2013).

[11] The instructions refer to two subgroups of the six subjects in the total group, in order to be consistent with an earlier experiment in which the two groups' extraction levels had asymmetric impacts on damages that imposed negative externalities on all group members (Cason and Gangadharan, 2013). We kept this wording even though both groups have identical impacts in the present experiment, and this wording should have no bearing on the results here since the group labels were arbitrary and irrelevant for decisions or earnings. This same wording was used in all treatments so it cannot influence our treatment comparisons.

instruction and payment distribution time, sessions usually lasted between 90 and 120 minutes.

## 4. Results

This section is divided into three parts. It first reports the yield from the common pool resource across the four treatments. It then provides additional details of the punishment behavior and communication. The main approach we use in the statistical analysis is simple and conservative. We first calculate the relevant statistic from each independent group of 6 subjects. We then compare these independent observations across treatments using nonparametric Mann-Whitney U tests (abbreviated M-W), which require no statistical assumptions other than independence across observations. In all cases we report two-tailed tests.

### 4.1 Yield from the Common Pool Resource

Higher "decision numbers," as framed for the subjects, lead to greater extraction from the common pool resource. When extraction exceeds the social optimum, the total yield from the resource falls below the best sustainable level. As discussed above, at the Nash equilibrium, which is where all agents choose 112.5, the marginal private benefit equals the marginal private cost. At the social optimum the marginal social benefit equals the marginal private cost, and this occurs when all agents choose 50. We transformed these numbers to a scale that is comparable to OWG, using a realized net *yield* index of benefits provided from the public good. This is simply the aggregate payoff earned by subjects divided by the maximum aggregate payoff earned at the social optimum. At the worst outcome of full extraction (125 each) this yield index is 0.366, and at the social optimum (50 each) the yield index is normalized to 1. At the Nash equilibrium the CPR provides modest returns leading to a yield of 0.56.

**Result 1:** Swords (peer punishment) alone do not significantly increase yield from the CPR.

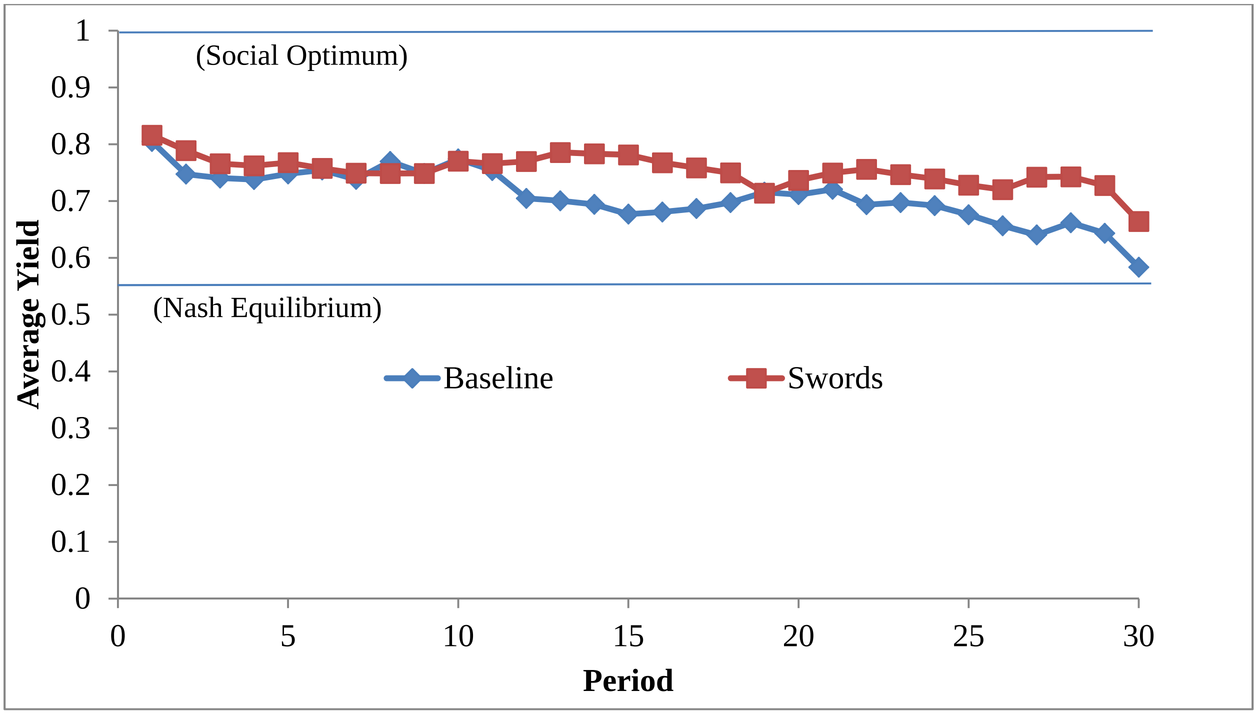


**Figure 1: Average Yield over Time, Treatments without Communication**

Support: Figure 1 displays the time series of average yield for the treatments without any communication opportunities, calculated for the 8 groups in the Swords treatment with peer punishment opportunities and for the 8 groups in the Baseline treatment without peer punishment. These averages are virtually identical across the first 10 periods. Although there is a minor divergence in the later 20 periods, with swords leading to a small increase in yield, this difference between the two treatments is not statistically significant, even when considering only the later periods (M-W *p*-value=0.34 for periods 11-30 only; M-W *p*-value=0.29 for periods 21-30 only; and M-W *p*-value=0.14 for periods 26-30 only).

**Result 2:** Covenants (nonbinding communication) do significantly increase yield, independent of whether punishment is also possible.

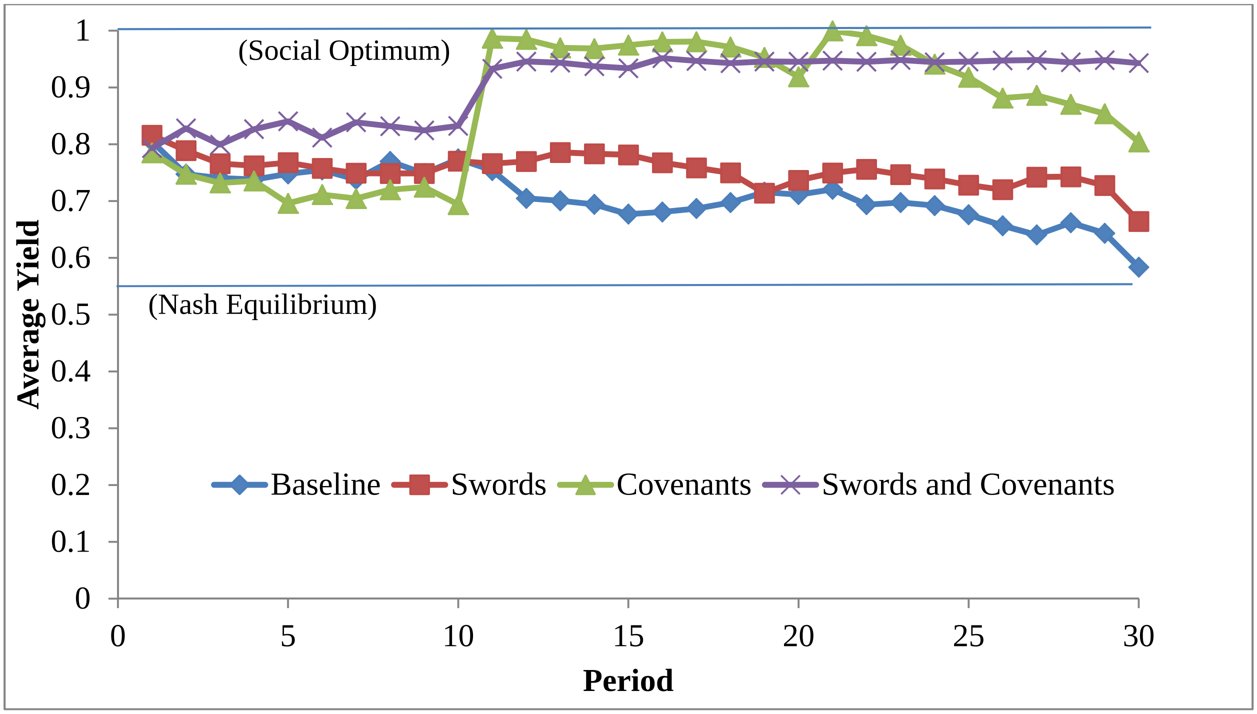


**Figure 2: Average Yield over Time, Including Treatments with Communication**

<u>Support:</u> Figure 2 adds to the previous figure the two Covenants treatments with nonbinding communication. Recall that groups were allowed to communicate for 5 minutes exactly twice in each session—once before period 11 and once before period 21. The impact of this communication is dramatic. Average yield jumps in period 11 in both Covenants treatments, to near the social optimum of 1.[12] Covenants have a large and highly statistically significant impact on yield both with (M-W *p*-value=0.011) and without (M-W *p*-value<0.01) swords.

Figure 3 summarizes the average yield for each individual group of 6 subjects, based on periods 11-30 after communication opportunities are introduced. It illustrates the degree of yield

[12] Although average yield appears higher during periods 1-10 for the Swords and Covenants treatment compared to Swords only, this difference is not statistically significant (M-W *p*-value=0.12). There is also no strong reason to expect any difference since communication was not introduced until period 11, although it is possible that some subjects may have increased their cooperation in periods 1-10 in anticipation of the communication to take place in period 11.

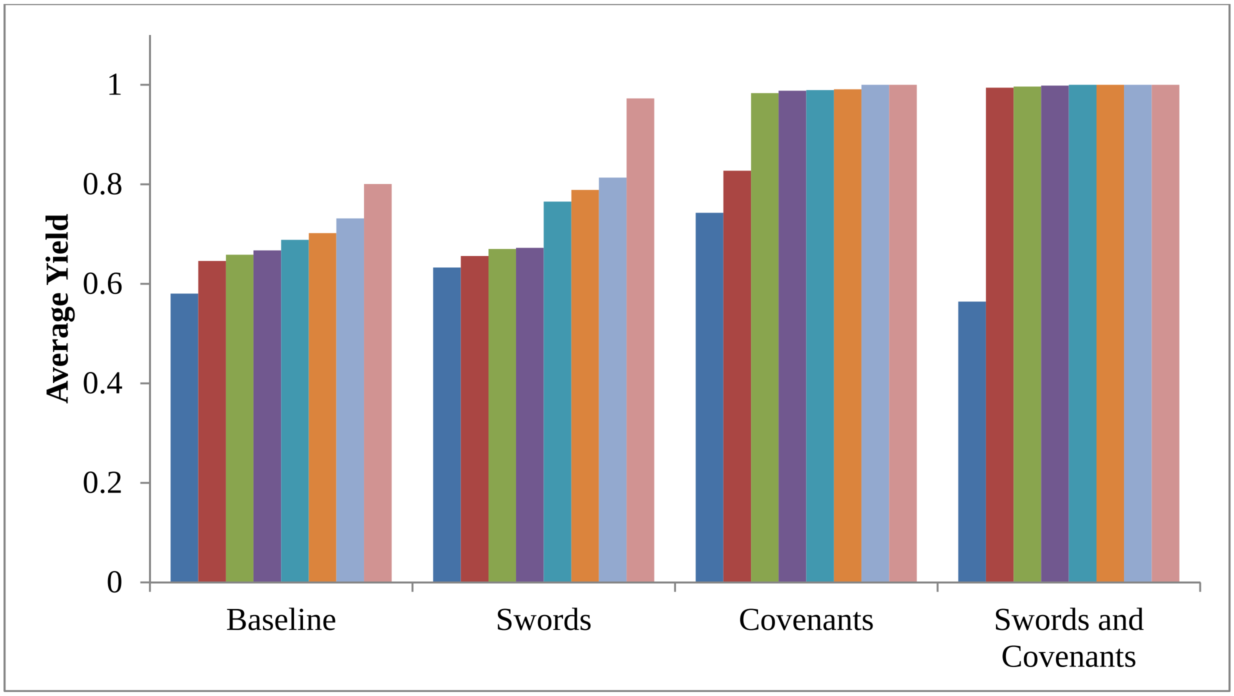


**Figure 3: Average Yield for Individual Groups, Periods 11-30**

heterogeneity across sessions, which is largest for the Swords only and the Covenants only treatments shown in the middle of the figure. It also shows that only one group in the Swords and Covenants treatment failed to cooperate and raise yields. (We discuss this group below when reporting more details of the chat communications.) Six groups in the Covenants only treatment also achieved near-perfect yield, so adding swords (in the Swords and Covenants treatment) does not lead to a significant increase in yield compared to the Covenants only treatment (M-W *p*-value=0.13). A marginal benefit from swords arises only for the final 5 periods (26-30) in the Swords and Covenants treatment (M-W *p*-value=0.043). The threat of swords therefore has some marginal value, as it can help maintain high levels of cooperation through the end periods of this finitely-repeated game.

Efficiency differs from yield because punishment results in a deadweight loss. The punisher incurs 0.5 experimental dollars to assign a deduction point, which reduces the payoff of the punished by 1.5 experimental dollars. Note that this provides an inherent advantage to communication in this experimental environment, since by design communication is costless to implement but punishment is costly both to the punisher and to the punished.[13] The results on yield just summarized, however, are identical to the results for efficiency that accounts for this deadweight loss. Removing the deadweight loss makes the Swords and the Covenants treatments more comparable and we find that swords do not improve efficiency but covenants always do. We omit the details because the results exactly parallel those found for yield.

4.2 Punishment (The Use of Swords)

We next turn to an analysis of how subjects employ peer punishment when it is available.

**Result 3:** During the first 10 periods subjects use swords at a decreasing rate, and when only swords are available subjects use them at a stable and modest level in the second half of the session. By contrast, when covenants are also possible, subjects' use of swords immediately drops and is effectively eliminated throughout all sessions.

Support: Figure 4 displays the time series of average punishment points received by each subject. The downward trend over the first 10 periods is similar in the two treatments—beginning with about 2 points on average in the early periods and declining to about 1 point in periods 5-9. The introduction of communication opportunities in period 11 leads to a large and rapid divergence in the amount of punishment, which then persists throughout the remaining periods. This difference after period 10 is highly statistically significant (M-W $p$-value<0.001). Thus, the possibility of covenants makes swords unnecessary.

[13] This keeps our experiment consistent with the literature on punishment, which almost universally makes punishment costly. Two exceptions are Masclet et al. (2003) and Krieg and Samak (2012). To reduce this inherent advantage of communication, an alternative design could make communication costly and an endogenous choice of the group, as in Isaac and Walker (1991).

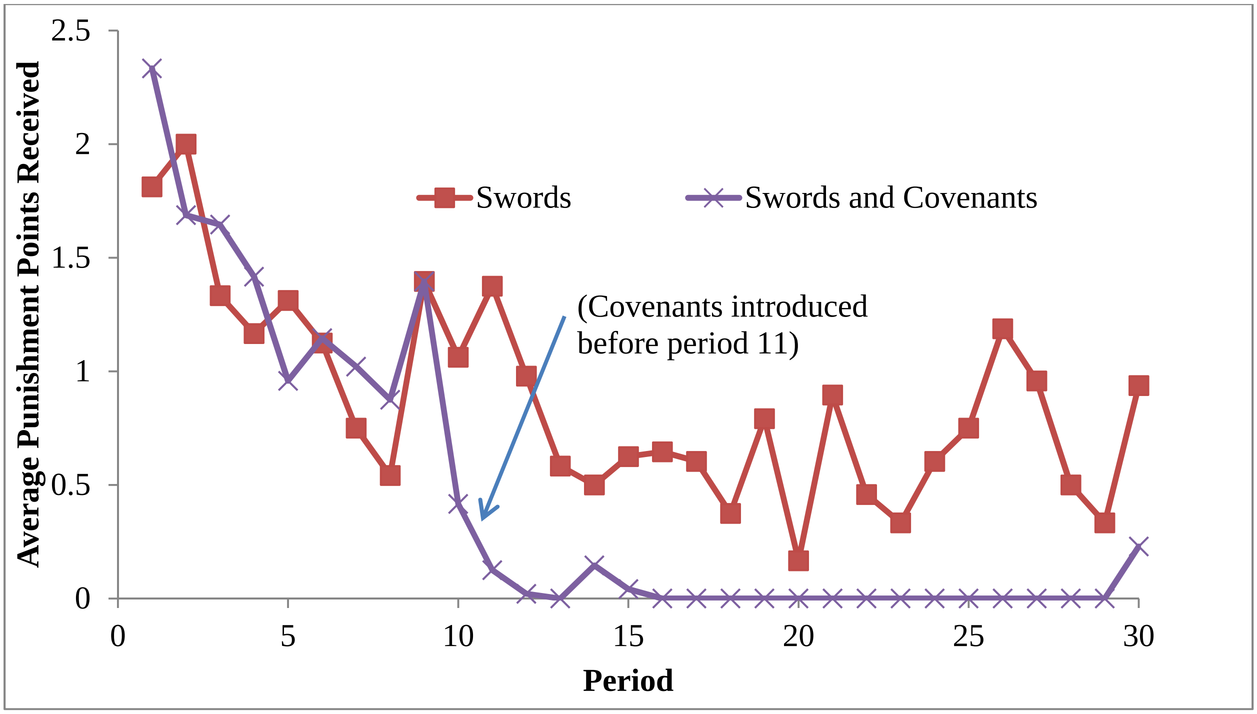


**Figure 4: Average Punishment Points Received by Each Subject, per Period**

Considering that subjects use swords when covenants are not possible, albeit at modest levels, raises the question of why swords are not effective in increasing cooperation and yield (Result 1). To begin to address this question, Panel A of Figure 5 reports the average punishment points received as a function of how much a subject's extraction deviates from the average extraction of others in their group (Fehr and Gaechter, 2000). A subject who, for example, exceeded the average for her group by 8 to 14 units received on an average 1.95 punishment points. The figure indicates that subjects received greater punishment when their extraction exceeds the average chosen by others. This is particularly true for large deviations shown on the far right.

Panel B of Figure 5 summarizes how subjects react to being punished. Modest amounts of punishment lead to only a small change in extraction for the next period. When subjects

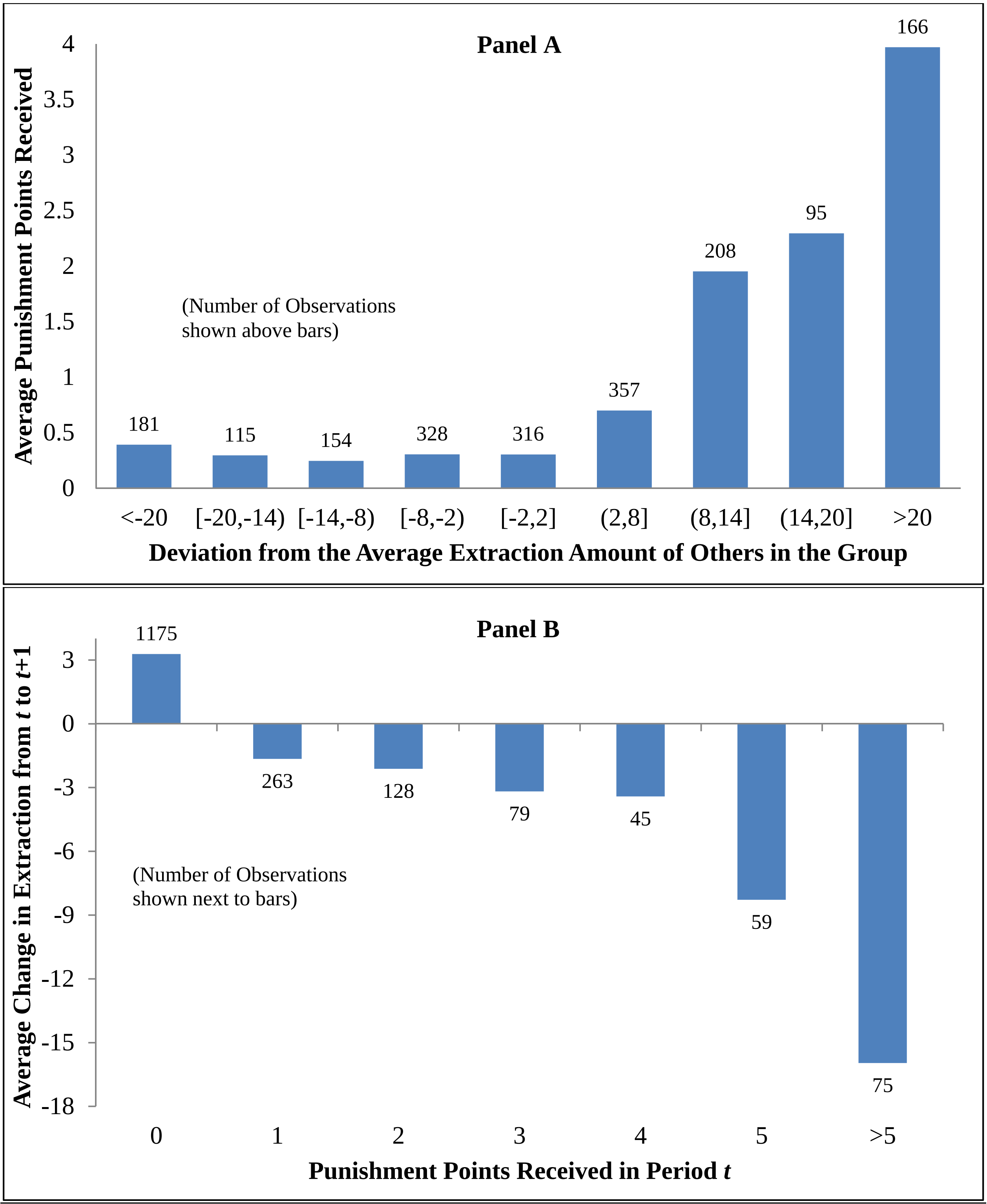


**Figure 5: Panel A reports punishment received by subjects depending on their extraction amount relative to their groups' average; Panel B presents how subjects react to this received punishment, leading to decreased extraction amounts in the subsequent period.**

receive 5 or more punishment points, however, they substantially reduce their extraction. Recall that 5 punishment points reduces the recipient's earnings for the period by 7.5 Experimental dollars, which is 75% of the average Nash equilibrium earnings.

Although swords clearly affect subjects' subsequent choices, Figure 5 suggests that swords are used too infrequently and at levels too low to have a large impact on overall yield. Subjects apparently must receive at least 5 punishment points before they systematically reduce the negative externalities they impose on others by choosing substantially lower extraction. Figure 5 indicates, however, that less than 4 punishment points are received on average even when an individual's extraction exceeds the group mean by over 20. More specifically, for the 166 cases in which subjects chose extraction levels that exceed their group mean by over 20 in the punishment condition, they received 5 or more punishment points only 62 times (37%). Thus, although we implemented a 3-to-1 punishment effectiveness ratio that has been shown to be effective in the linear voluntary contributions game, subjects are infrequently assigned the large punishments required to substantially increase cooperation. This decreased the effectiveness of swords.

### 4.3 Communication (The Use of Covenants)

Nonbinding communication has the greatest and most consistent impact on yields. This is remarkable given that communication opportunities were infrequent, occurring only twice for each group. Our results indicate that frequent communication (as in OWG's "repeated communication" treatment) is unnecessary.

Inspection of the chat transcripts for all 16 groups revealed the following patterns.

**Result 4:** Of the 8 groups who communicated but could not punish, 5 immediately recognized and discussed the optimal group appropriation strategy and 4 of these 5 successfully implemented maximum yield. Another 2 groups identified the optimal group strategy in the second chat opportunity, and 1 implemented it successfully. The eighth group never identified the optimal strategy, but they were successful in keeping yields relatively high.

Consider the following chat transcript excerpt, which is representative of the majority of groups who recognized and successfully restricted extraction to implement the maximum yield. Recall that an extraction choice of 50 per subject is optimal for the group. This is the first communication opportunity available to this group. (...) denotes lines that were excluded.

HI
If we ALL do 50 we can get 17.75 each round (...)
let maximize our payoff (...)
sounds good, 50 for the rest of the periods? (...)
ok. 50 it is
50
great
is 50 the best number to do that?
50 it is
so we put in 50 each time?
we can potentially all walk out of here with 40 bucks real cash if we all do 50 (...)
i hope you are all trustworthy
same here
this will only work if we all do it all the time. The first time someone doesnt do it we all arent going to trust anymore. If we start going higher there is no way anyway will get close to 40 dollars. It is in the best interest of the individual and the group not to cheat
I agree
agreed
i know we should be a team
if we could pinkie promise, I would.
Ok, so 17.75 each!
double pinkie promise

This example illustrates that subjects could identify the group choice that results in the maximum yield and earnings of 17.75 each, and convince others to follow that strategy. They also recognized the importance of being trustworthy, and the consequences of trust breaking down. These groups frequently promised cooperation, and the implications of defection.

Those implications of defection could additionally involve the use of swords in the treatment with Swords and Covenants, and while this was discussed in their chats it was rarely needed, as shown above in Figure 4.

**Result 5:** Of the 8 groups who communicated and could also punish their peers, 5 immediately recognized and successfully implemented the optimal group appropriation strategy. Another 2 groups took longer but also identified and implemented the optimal yield strategy.

The following chat transcript was representative of the majority of groups who quickly recognized and implemented strategies to extract the optimal yield. Note the reference to punishment (described in the instructions as "deduction points") for defections from the optimal group strategy.

> ANY IDEAS?
> If everyone chooses 50 everytime, and no one assigns deduction points, we will all get a payout of 17.75 for every period
> So lets do that
> OKAY SOUNDS GOOD TO ME
> OK
> sounds good to me
> I'm cool with that
> SURE
> If anyone thinks its cool to choose 125 to boost their points, just assign all your deduction points their way
> haha I agree (...)

In spite of this warning, one subject in this group chose an extraction of 110 in period 11, while all 5 others in his group chose the agreed-upon level of 50. This defecting subject received 6 deduction points from his peers, which lowered his payoff that period to 16.55—below the 17.75 possible from cooperation at the socially optimal yield. This subject never defected again, indicating that this one use of punishment was very effective. This punishment to implement the optimal extraction was typically not needed in most groups, since defections were rare.

All 8 groups discussed punishment, however, in their first chat opportunity. In particular, 3 of the 8 groups agreed to punish those who deviated from the decision number they had agreed upon. Another 4 groups explicitly specified that they should not assign deduction points to each other, and they did not threaten to use deduction points if there was a deviation from their extraction level agreement.

While 7 of the 8 groups in the Swords and Covenants treatment did implement the socially optimal outcome, the eighth group that never identified the optimal strategy to raise payoffs, essentially played the Nash equilibrium. Although the chat from this group indicated that they understood that "we need to work all together (...) basically we can work all together to maximize own profit" they did not identify a strategy to improve yield and raise their payoffs. This group encouraged each other to not assign deduction points, and they did stick to this agreement to not punish each other. But apparently they did not recognize their ability to cooperate to reduce extraction to raise their earnings.

## 5. Discussion

The primary goal of this paper was to examine the effectiveness of two institutional features relevant to self-governance. Peer punishment (swords) and agreements reached through communication (covenants) have been repeatedly identified as key drivers for improving cooperation in social dilemmas. Our paper breaks new ground by comparing the performance of these swords and covenants mechanisms for a more realistic nonlinear public goods environment, where the private benefits of cooperation are nonlinear and the punishment technology is consistent with the recent literature that establishes robust impacts of peer punishment in simplified linear environments. Compared to Ostrom et al. (1992), the punishment mechanism in this paper is designed to be potentially stronger as we allow for multiple targets of punishment and varying intensity of punishment. The communication mechanism that we employ is however weaker than in their environment as it is anonymous and less frequent. Yet we find that covenants are significantly more effective than swords. The use of punishment without communication does not improve cooperation, while allowing communication always increases cooperation and yield significantly. Moreover, swords are unnecessary if covenants are possible.

Our results contrast starkly with the literature on peer punishment in the voluntary contributions mechanism, which features linear private and public benefits that lead to socially optimal and privately optimal (Nash equilibrium) outcomes at the extreme boundaries of the available choice space. Studies using that environment have provided relatively robust evidence that punishment is effective for improving cooperation even without communication. Combined with our results, however, and the ineffectiveness of peer punishment alone seen in the complex environment studied in Janssen et al. (2010), a different picture emerges. Peer punishment may *only* be effective if the social dilemma is sufficiently simple in structure. This suggests that different environments may require the development of different decentralized mechanisms for self-governance. Our findings from a new and richer nonlinear environment underscore the importance of communication in social dilemmas.

Our experiment has implications for understanding decision making in social dilemmas in the field. It highlights the importance of group discussion for identifying and implementing rules of self-governance. This may be particularly so for relatively complex but also common social dilemmas, such as air and water pollution, the management of fisheries and forests, managing international refugees, or costly political participation. Communication is important because it creates group identity, allows for the emergence of an ad-hoc group leader who is non-myopic, allows for group members to exert peer pressure, and provides an opportunity for group learning and trial-and-error that leads to a better understanding of the decision problem. When punishment (without communication) is the mechanism groups must depend on, the only signals participants can send to encourage cooperation is through punishment. Sometimes this is a particularly noisy signal, and our results suggest that participants do not use it effectively to significantly improve cooperation when the environment becomes more complex. Increased complexity appears to require the greater richness of natural communication for decentralized solutions to social dilemmas.

In this experiment communication was introduced exogenously, which allows us to identify directly its causal impact on cooperation. Given the important role of communication, future work should examine if communication can arise endogenously in groups and whether individuals constructively use the opportunity to open the lines of communication. This can provide insight into how best to initiate communication and negotiation in global social dilemmas in which it may be difficult for individuals or political groups to begin a dialog that can lead to an interchange of ideas and identify solutions in increasingly complex environments.

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**Appendix: EXPERIMENT INSTRUCTIONS (Swords with Covenants Treatment)**

This is an experiment in the economics of decision making. The instructions are simple and if you follow them carefully and make good decisions you will earn considerable money that will be paid to you privately in cash. All earnings on your computer screens are in Experimental Dollars. These Experimental Dollars will be converted to real Dollars at the end of the experiment, at a rate of _______ Experimental Dollars = 1 real Dollar. At the beginning of the experiment everyone will begin with an initial balance of ________ real Dollars.

Today's session will be conducted using the computer network located here in this laboratory. This part of the session will last for 30 periods. Attached to these instructions you will find a sheet labeled Personal Record Sheet, which will help you keep track of your earnings based on the decisions you might make. You are not to reveal this information to anyone. It is your own private information.

**Your Choices**

You have been assigned to a group of six (yourself and five other) participants. This will be your group for the entire session (all 30 periods). Within these 30 periods you will have an opportunity to communicate with the other 5 participants in your group twice in "chat rooms" that will open on your computer. These chat rooms will be open for 5 minutes each, and only before the start of period 11 and period 21. In sending messages back and forth between you and the other 5 people we request that you follow two simple rules: (1) Be civil to each other and use no profanity and (2) Do not identify yourself.

In **Stage 1** each period you (and the others in your group) will be asked to choose a number and to enter it into the computer. This is your **Decision Number** and it must be between 0 and 125.

Your Total Payoff for Stage 1 each period is the sum of your Private Payoff and your Group Payoff:

Total Payoff = Private Payoff + Group Payoff

Your Private Payoff depends only on your own Decision Number. The formula describing your Private Payoff is

Your Private Payoff = $44 – 0.002(125\text{-}D)^2$,

where $D$ is your decision number. So that you do not have to worry about how to interpret this formula, Table 1 in these instructions shows the Private Payoff for a wide range of possible

Decision Numbers. For example if your Decision Number is 60 Table 1 shows that your Private Payoff would be 35.55 Experimental Dollars. Or if you had chosen 30 your Private Payoff would be 25.95 Experimental Dollars. Notice that the higher your Decision Number the higher your Private Payoff.

The Group Payoff depends on the total decision numbers chosen by everyone in the group and is the same for everyone in the group. In your 6-person group there are 3 BLUE individuals and 3 ORANGE individuals. You will be randomly assigned to one of these colors, and will remain this type of individual throughout this experiment. Denote the summed decision numbers for the 3 BLUE individuals as BLUE SUM, and the summed decision numbers for the 3 ORANGE individuals as ORANGE SUM. The computer will calculate the total weighted sum of the decision numbers chosen by all 6 individuals as

TOTAL WEIGHTED SUM = [0.3(BLUE SUM)+0.3(ORANGE SUM)].

Your group payoff will be **negative one-sixth** of this TOTAL WEIGHTED SUM:

Your Group Payoff = – (1/6)[TOTAL WEIGHTED SUM]

= – (1/6)[0.3(BLUE SUM)+0.3(ORANGE SUM)]

Notice that the impact of the Decision Numbers depends on the type of individual in the group. So that you do not need to worry about how to interpret these formulas, Table 2 in these instructions shows your Group Payoff for a wide range of combinations of BLUE and ORANGE SUM numbers. Notice that your Decision Number affects either the BLUE SUM or ORANGE SUM amounts, depending on your color.

Suppose, for example, that you are a BLUE type and your Decision Number is 60 while the other 2 BLUE type individuals total decision numbers add to 105. Then the total BLUE SUM is 60+105=165. Suppose further that the 3 ORANGE type individuals total ORANGE SUM is 150. For this example the TOTAL WEIGHTED SUM is (0.3×165)+(0.3×150)=94.5. Table 2 shows that your Group Payoff would be -15.8 Experimental Dollars, which is the number found at the intersection of the BLUE SUM row labeled 165 and the ORANGE SUM column labeled 150. Notice that higher SUMS reduce your Group Payoff.

**Choosing your Decision Number**

Your task in Stage 1 each period is to choose your Decision Number. You may use the formulas or tables in these instructions to help you make your choice. You may also find it useful to use your computer to investigate how different choices that you and others in your group affect your Total Payoff for the period.

When we start the computers to begin the experiment, your screen will look similar to the one shown in Figure 1 below. (It may look slightly different depending on whether you are a BLUE or ORANGE type of individual in the experiment.) You do not know what others in your group will choose for their decision numbers in the current period, but on the upper right part of this screen you can enter in guesses for the SUMS chosen by the other people in your group (not counting your own Decision Number). After you do this, click “Enter Guess.” The computer will require you to enter at least one guess at the start of each period.

After you do this, your screen will look similar to Figure 2. The computer will draw a graph indicating your potential Total Payoff (including both your Private Payoff and your Group Payoff) for every possible Decision Number you might choose, based on your guess about the other group members’ choices. At this point you can enter a possible Decision Number for yourself. The screen will display your payoff on this graph with a red dot. You can enter in different Decision Numbers if you wish to see how your Total Payoff changes. Your different possible choices and guesses will be recorded in the upper left part of your computer screen.

At this point you can go back to change your guess by clicking the “Enter New Guess” button on the lower right of the screen. This returns you to a screen similar to Figure 1, except that your previous guesses and possible Decision Numbers will be shown in the table on the top left. You can continue to enter many guesses and Decision Numbers to explore how they affect your Total Payoff.

When you are ready to submit your actual Decision Number, click the “Submit Final Decision Number” button on the bottom of your screen. This will take you to a screen like Figure 3, to submit your final Decision Number for the period.

**The Second Stage each Period**

In the second stage you will see the Decision Numbers chosen for the five other individuals in your group, labeled with their color and labels Triangle, Circle and Square. These (anonymous) individuals will keep these color and symbol labels throughout the experiment today. Moreover, in this stage you can decide whether to **decrease** the payoff of these other group members by assigning **deduction points**. These other group members can also decrease your payoff if they wish to. This is shown on the second stage input screen, in Figure 4.

**Your Decision Number** is displayed **on the left of the first row**, while the decision numbers of the other people with the same color type as you are shown in the lower two rows. The decision numbers of the three other people of the other color type are shown in the **upper right** of this input screen.

You will have to decide how many deduction points to assign to **each** of these other five group members. You must enter a number for each of them. If you do not wish to change the payoff of a specific group member then you must enter 0. You can **assign up to 5 points to each group member**.

You will incur costs from assigning deduction points. Every deduction point you assign costs you 0.50 Experimental Dollars. For example, if you assign 2 deduction points to one member, this costs you 1 Experimental Dollars; if, in addition, you assign 4 deduction points to another member this costs you an additional 2 Experimental Dollars. In total for this example you will have assigned 6 points and your **total costs** therefore amount to 3 Experimental Dollars.

After you have assigned points to each of the other five group members you can click the button "**Calculate**" (see Figure 4). On the screen you will then see the total costs of your assigned points. As long as you have not yet clicked the **Submit Deduction Points** button, you can still change your decision. To recalculate the costs after a change of your assigned points, simply press the "Calculate" button again.

If you assign 0 deduction points to a particular group member (i.e., enter "0"), you will not alter his or her payoff. However, if you assign **one deduction point** to a group member you will **decrease** the payoff of this group member by **1.50 Experimental Dollars**. If you assign a group member **2 deduction points** you will **decrease** the group member's payoff by **3 Experimental Dollars**, and so on. Each deduction point that you assign to another group member will reduce his or her payoff by 1.50 Experimental Dollars. Similarly, each deduction point assigned to you by another group member will reduce your first stage payoff by 1.50 Experimental Dollars:

**Costs of received deduction points = 1.50 × Sum of received deduction points.**

How much the payoff at the second stage is decreased depends on the sum of deduction points received. For instance, if somebody receives **a total** of **3 deduction points** (from all other group members in this period), his or her payoff would be decreased by **4.50 Experimental**

**Dollars**. If somebody receives a total of **4 deduction points,** his or her payoff is reduced by **6 Experimental Dollars**.

Your total payoff from the two stages is therefore calculated as follows:

| |
|---|
| **Total payoff at the end of the second stage = period payoff =**<br>= Payoff from the first stage – 1.50 × (sum of received deduction points)<br>– 0.50 × (sum of deduction points you have assigned) |

After all participants have made their decision, your payoff from the period will be displayed on a screen such as the one shown in Figure 5. After you have viewed the payoff screen the period is over and the next period commences. Recall that 30 periods will be conducted in this part of the experiment.

**Recording Rules**

During every period you should write down the information shown on your results screen on your Personal Record Sheet. The screen where you choose deduction points shows the Decision Numbers you should record, and the final payoff screen shows your Deduction Points and payoffs. Be sure to record your total payoff for each period in the rightmost column. At the end of the experiment we will randomly select 5 periods from this part of the experiment for payment. You will sum up the earnings from these 5 periods and divide this amount by the conversion rate to determine your total earnings for this part in real Dollars.

**Summary**

- You and the 5 others in your group chose a Decision Number each period
- Your Total Payoff before Deduction Points for each period is the sum of your Private Payoff and your Group Payoff
- You may use the Tables or your computer to determine how different choices affect your Total Payoff
- You may assign up to 5 Deduction Points to each of the other individuals in your group. Each Point you assign costs you 0.50 Experimental Dollars.
- These other individuals can assign Deduction Points to you. Each Point assigned to you reduces your payoff by 1.50 Experimental Dollars
- You will interact with the same 5 other individuals for 30 decision periods in this part
- You will chat with the 5 other individuals for 5 minutes before the start of periods 11 and 21
- Results and payoffs should be recorded on your Record Sheet at the end of each period


Period
1 out of 20
Guess of Blue Sum (not including you)
Guess of Orange Sum
Your Decision Number
Potential Payoff
Your are a Blue Type
Guess for Blue Sum [ 0 , 250 ]
0.00
(not including your Decision Number)
Guess for Orange Sum [ 0 , 375 ]
0.00
Enter Guess
Enter Final Decision Number
Enter New Guess

**Figure 1:**

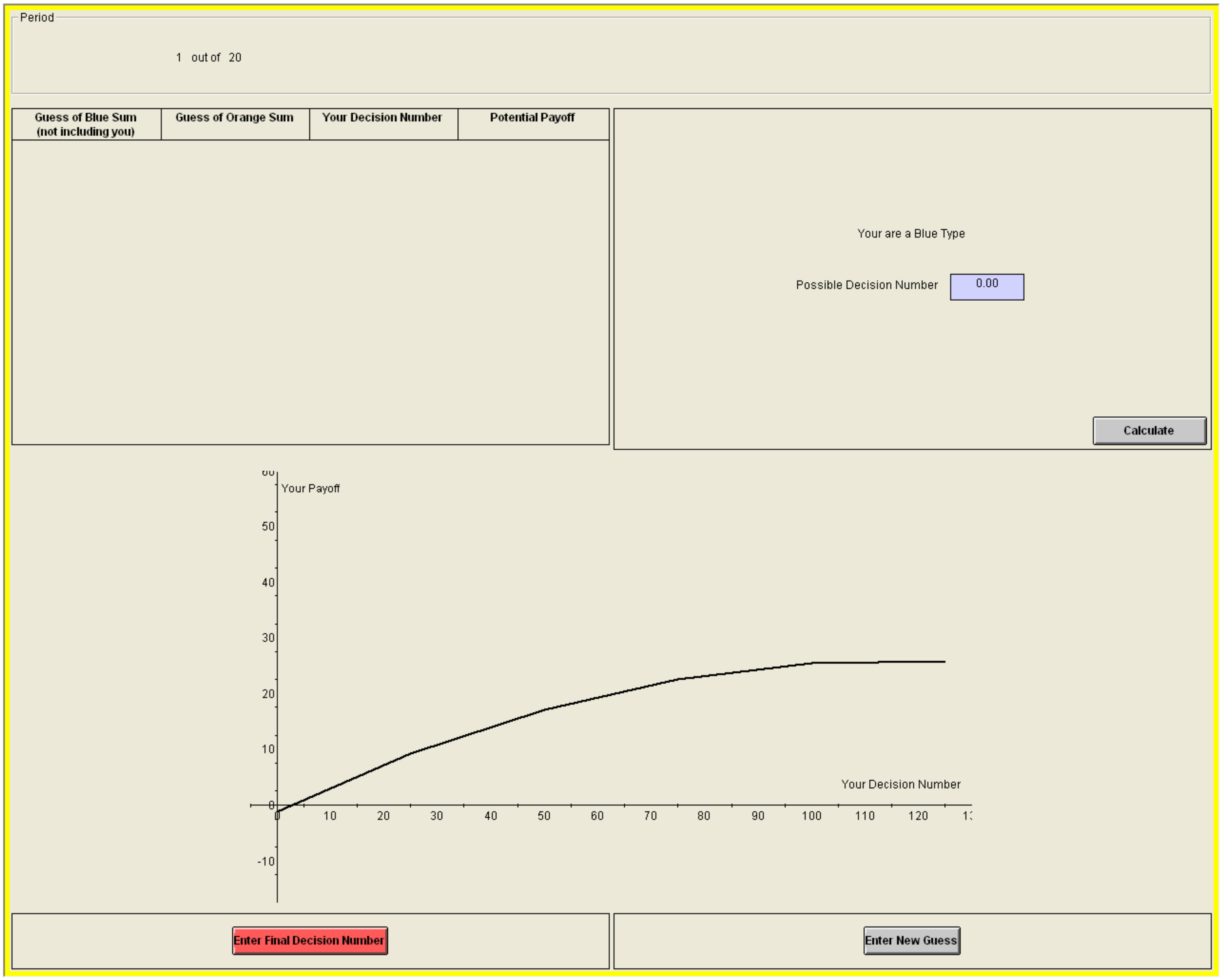
Period
1 out of 20
Guess of Blue Sum (not including you)
Guess of Orange Sum
Your Decision Number
Potential Payoff
Your are a Blue Type
Possible Decision Number
0.00
Calculate
Your Payoff
Your Decision Number
Enter Final Decision Number
Enter New Guess

**Figure 2:**


Period
1 out of 20
Guess of Blue Sum (not including you)
Guess of Orange Sum
Your Decision Number
Potential Payoff
Your are a Blue Type
Enter Your Decision Number for this Period
0.00
Enter New Guess
Submit Final Decision Number

**Figure 3:**

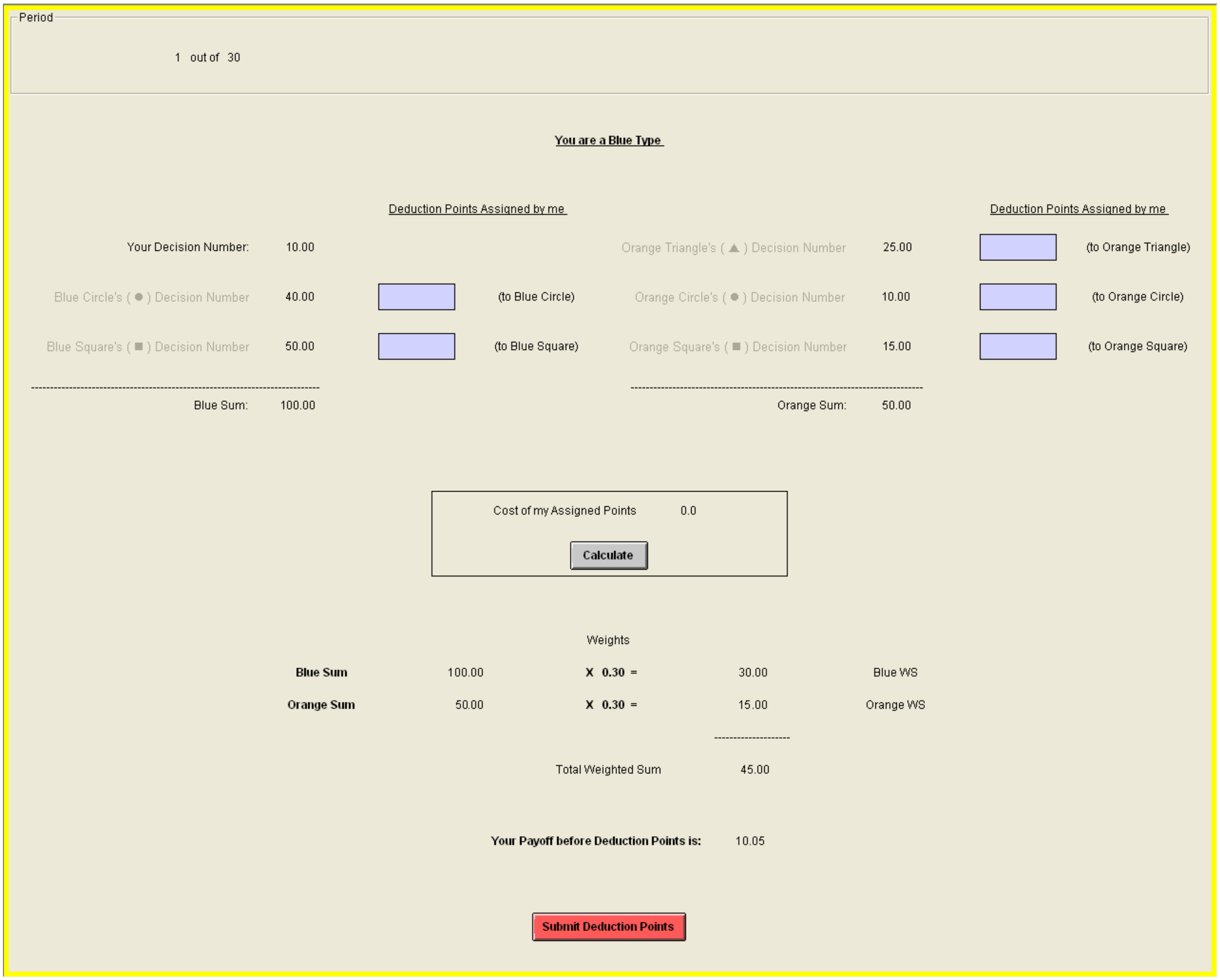
Period
1 out of 30
You are a Blue Type
Deduction Points Assigned by me
Deduction Points Assigned by me
Your Decision Number: 10.00
Orange Triangle's ( ▲ ) Decision Number 25.00
(to Orange Triangle)
Blue Circle's ( ● ) Decision Number 40.00
(to Blue Circle)
Orange Circle's ( ● ) Decision Number 10.00
(to Orange Circle)
Blue Square's ( ■ ) Decision Number 50.00
(to Blue Square)
Orange Square's ( ■ ) Decision Number 15.00
(to Orange Square)
Blue Sum: 100.00
Orange Sum: 50.00
Cost of my Assigned Points 0.0
Calculate
Weights
Blue Sum 100.00 X 0.30 = 30.00 Blue WS
Orange Sum 50.00 X 0.30 = 15.00 Orange WS
Total Weighted Sum 45.00
Your Payoff before Deduction Points is: 10.05
Submit Deduction Points

**Figure 4:**


Period
1 out of 30
You are a Blue Type
Your Payoff after the First Stage 12.35
Amount of Received Deduction Points 3.00
Payoff Reduction through Deduction Points -4.50
Amount of Assigned Deduction Points 3.00
Your Cost of Assigning Deduction Points -1.50
Your Payoff for the Period is 6.35
Continue

**Figure 5:**

| Table 1: Private Payoff for Different Decision Numbers | | | | |
|---|---|---|---|---|
| Decision Number | Private Payoff | | Decision Number | Private Payoff |
| 0 | 12.75 | | 64 | 36.56 |
| 2 | 13.74 | | 66 | 37.04 |
| 4 | 14.72 | | 68 | 37.50 |
| 6 | 15.68 | | 70 | 37.95 |
| 8 | 16.62 | | 72 | 38.38 |
| 10 | 17.55 | | 74 | 38.80 |
| 12 | 18.46 | | 76 | 39.20 |
| 14 | 19.36 | | 78 | 39.58 |
| 16 | 20.24 | | 80 | 39.95 |
| 18 | 21.10 | | 82 | 40.30 |
| 20 | 21.95 | | 84 | 40.64 |
| 22 | 22.78 | | 86 | 40.96 |
| 24 | 23.60 | | 88 | 41.26 |
| 26 | 24.40 | | 90 | 41.55 |
| 28 | 25.18 | | 92 | 41.82 |
| 30 | 25.95 | | 94 | 42.08 |
| 32 | 26.70 | | 96 | 42.32 |
| 34 | 27.44 | | 98 | 42.54 |
| 36 | 28.16 | | 100 | 42.75 |
| 38 | 28.86 | | 102 | 42.94 |
| 40 | 29.55 | | 104 | 43.12 |
| 42 | 30.22 | | 106 | 43.28 |
| 44 | 30.88 | | 108 | 43.42 |
| 46 | 31.52 | | 110 | 43.55 |
| 48 | 32.14 | | 112 | 43.66 |
| 50 | 32.75 | | 114 | 43.76 |
| 52 | 33.34 | | 116 | 43.84 |
| 54 | 33.92 | | 118 | 43.90 |
| 56 | 34.48 | | 120 | 43.95 |
| 58 | 35.02 | | 122 | 43.98 |
| 60 | 35.55 | | 124 | 44.00 |
| 62 | 36.06 | | 125 | 44.00 |

Amounts shown are rounded to the nearest hundreth.

Table 2: Individual Amounts of Group Payoff for Different BLUE and ORANGE SUM Numbers (NT)

| | | ORANGE SUM | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 | 165 | 180 | 195 | 210 | 225 | 240 | 255 | 270 | 285 | 300 | 315 | 330 | 345 | 360 | 375 |
| | 0 | 0 | -0.75 | -1.5 | -2.25 | -3 | -3.75 | -4.5 | -5.25 | -6 | -6.75 | -7.5 | -8.25 | -9 | -9.75 | -10.5 | -11.3 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 |
| | 15 | -0.75 | -1.5 | -2.25 | -3 | -3.75 | -4.5 | -5.25 | -6 | -6.75 | -7.5 | -8.25 | -9 | -9.75 | -10.5 | -11.3 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 |
| | 30 | -1.5 | -2.25 | -3 | -3.75 | -4.5 | -5.25 | -6 | -6.75 | -7.5 | -8.25 | -9 | -9.75 | -10.5 | -11.3 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 |
| | 45 | -2.25 | -3 | -3.75 | -4.5 | -5.25 | -6 | -6.75 | -7.5 | -8.25 | -9 | -9.75 | -10.5 | -11.3 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 |
| | 60 | -3 | -3.75 | -4.5 | -5.25 | -6 | -6.75 | -7.5 | -8.25 | -9 | -9.75 | -10.5 | -11.3 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 |
| | 75 | -3.75 | -4.5 | -5.25 | -6 | -6.75 | -7.5 | -8.25 | -9 | -9.75 | -10.5 | -11.3 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 |
| | 90 | -4.5 | -5.25 | -6 | -6.75 | -7.5 | -8.25 | -9 | -9.75 | -10.5 | -11.3 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 |
| | 105 | -5.25 | -6 | -6.75 | -7.5 | -8.25 | -9 | -9.75 | -10.5 | -11.3 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 |
| | 120 | -6 | -6.75 | -7.5 | -8.25 | -9 | -9.75 | -10.5 | -11.3 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 |
| | 135 | -6.75 | -7.5 | -8.25 | -9 | -9.75 | -10.5 | -11.3 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 |
| | 150 | -7.5 | -8.25 | -9 | -9.75 | -10.5 | -11.3 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 | -26.3 |
| | 165 | -8.25 | -9 | -9.75 | -10.5 | -11.3 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 | -26.3 | -27 |
| BLUE | 180 | -9 | -9.75 | -10.5 | -11.3 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 | -26.3 | -27 | -27.8 |
| SUM | 195 | -9.75 | -10.5 | -11.3 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 | -26.3 | -27 | -27.8 | -28.5 |
| | 210 | -10.5 | -11.3 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 | -26.3 | -27 | -27.8 | -28.5 | -29.3 |
| | 225 | -11.3 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 | -26.3 | -27 | -27.8 | -28.5 | -29.3 | -30 |
| | 240 | -12 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 | -26.3 | -27 | -27.8 | -28.5 | -29.3 | -30 | -30.8 |
| | 255 | -12.8 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 | -26.3 | -27 | -27.8 | -28.5 | -29.3 | -30 | -30.8 | -31.5 |
| | 270 | -13.5 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 | -26.3 | -27 | -27.8 | -28.5 | -29.3 | -30 | -30.8 | -31.5 | -32.3 |
| | 285 | -14.3 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 | -26.3 | -27 | -27.8 | -28.5 | -29.3 | -30 | -30.8 | -31.5 | -32.3 | -33 |
| | 300 | -15 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 | -26.3 | -27 | -27.8 | -28.5 | -29.3 | -30 | -30.8 | -31.5 | -32.3 | -33 | -33.8 |
| | 315 | -15.8 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 | -26.3 | -27 | -27.8 | -28.5 | -29.3 | -30 | -30.8 | -31.5 | -32.3 | -33 | -33.8 | -34.5 |
| | 330 | -16.5 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 | -26.3 | -27 | -27.8 | -28.5 | -29.3 | -30 | -30.8 | -31.5 | -32.3 | -33 | -33.8 | -34.5 | -35.3 |
| | 345 | -17.3 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 | -26.3 | -27 | -27.8 | -28.5 | -29.3 | -30 | -30.8 | -31.5 | -32.3 | -33 | -33.8 | -34.5 | -35.3 | -36 |
| | 360 | -18 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 | -26.3 | -27 | -27.8 | -28.5 | -29.3 | -30 | -30.8 | -31.5 | -32.3 | -33 | -33.8 | -34.5 | -35.3 | -36 | -36.8 |
| | 375 | -18.8 | -19.5 | -20.3 | -21 | -21.8 | -22.5 | -23.3 | -24 | -24.8 | -25.5 | -26.3 | -27 | -27.8 | -28.5 | -29.3 | -30 | -30.8 | -31.5 | -32.3 | -33 | -33.8 | -34.5 | -35.3 | -36 | -36.8 | -37.5 |

## Personal Record Sheet

| | My Color Decision Numbers | | | Other Color Decision Numbers | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period Number | My Decision Number | Circle's Decision Number | Square's Decision Number | Triangle's Decision Number | Circle's Decision Number | Square's Decision Number | BLUE SUM | ORANGE SUM | TOTAL WEIGHTED SUM | Payoff before Deduction | Received Deduct Points | Payoff Deduction Received | Chosen Deduction Points | Cost of Assigned Points | Period Total Payoff |
| 1 | | | | | | | | | | | | | | | |
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