How Large Should the "Bullets" be? Dissecting the Role of Unilateral and Tie Punishment in the Provision of Public Goods

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How Large Should the "Bullets" be? Dissecting the Role of Unilateral and Tie Punishment in the Provision of Public Goods*

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Abstract

This paper evaluates the role of centralized punishment in boosting contribution to the provision of public goods. To avoid the race to the bottom in the provision of public goods, this centralized punishment mechanism relies on the use of the *unilateral* and *tie* punishment imposed on the lowest contributor(s). In this paper, we aim to examine how severe this unilateral and tie punishment should be to achieve the full-contribution equilibrium. Specifically, we are interested in investigating the size of the "bullets" that the "hired gun" should carry. We theoretically derive a range of punishment mechanisms which would lead to full contribution and which are also experimentally tested. Our experimental results generally substantiate the theoretical prediction except for the more lenient punishment parameters. This discrepancy is successfully explained by individual evolutionary learning.

Keywords: Public Goods Provision, Centralized Punishment Mechanism, Unilateral Punishment, Tie Punishment, Individual Evolutionary Learning

JEL Classification: C63; C72; C92; D7; D83; H41

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1 Introduction

Not all law/rule brokers are punished as law/rule enforcement naturally is subject to resource constraints. For instance, not every car on road exceeding the speed limit gets a speeding ticket. It is more common that the ticket is issued to the fastest car going over the limit. Tax authorities are prone to pursue tax evasion cases against big corporations rather than small businesses. Law enforcement agencies often devote the resources to prosecuting the most heinous crimes (e.g., murder) instead of misdemeanors. It is a common practice to punish the largest deviator. One being the second largest deviator therefore dodges sanction. Intuitively, the competition of not being the largest deviator should eventually drive out any deviations and lead to a socially optimal outcome.

Following this line of reasoning, Andreoni and Gee (2012) proposed the hired gun mechanism to overcome the free rider problem in a voluntary contribution setting. It is a centralized and automatic mechanism which punishes the lowest contributor to an extent that she would rather have been the second lowest. It has been shown to be effective in promoting contribution (Andreoni and Gee 2012, 2015). An overlooked but paramount issue is what the right size of punishment is. If punishment is too small, it is not enough to discourage free-ride. On the opposite side, unnecessarily large punishment results in societal welfare loss.

We adopt the hired gun mechanism as the centerpiece to explore what the right size of punishment is. The punishment in the hired gun mechanism consists of the unilateral punishment, which aims to discourage people from being the lowest contributor, and the tie punishment, which is to prevent people from coordinating on a tie at a below full-contribution level. We generalize the mechanism by introducing flexibility of these two components and derive a wide range of classes of effective mechanisms with various sizes of punishment. We also run experiments to test the generalized mechanism. The experimental results are mostly consistent with the theory with the exception of the mechanism with lenient punishment parameters. This discrepancy between theory and experimental results is successfully explained by individual evolutionary learning (IEL hereafter). The results from IEL simulations without sample size and time horizon constraints square with the experimental results.

The free rider problem in public good provision has received the lion's share of attention in the literature. It is a classic social dilemma where collective interests are at odds with individual interests, leading to a non-socially optimal outcome. Mounting studies have explored the mechanisms to mitigate free riding in public goods provision. Exhausting this literature is beyond the scope of this paper, we only focus on the strand of literature on the use of punishment to promote cooperation.

There has been a burgeoning literature on punishment mechanisms in improving cooperation in public goods provision (see Chaudhuri (2011) for an excellent survey). Depending on the administration body of punishment, there are informal punishment and formal punishment. Informal punishment, which is also commonly referred to as peer-to-peer punishment, is usually administrated by fellow group members. Though it is costly to exercise such punishments, people are willing to punish free-riders, which results in higher contribution levels (Fehr and Gächter 2000, 2002; Cason and Gangadharan 2015). This finding has been replicated by dozens of studies later on (surveyed by Chaudhuri (2011)). Despite its effectiveness, informal punishment system suffers from some drawbacks. The punishment exerted by peers may trigger revenge or anti-social punishment. Its existence has been supported by various experimental studies (Denant-Boemont, Masclet, and Noussair 2007; Herrmann, Thöni, and Gächter 2008; Nikiforakis 2008). This is commonplace in reality as well. That is probably why there are laws in place to protect whistleblowers from retaliation (e.g., Whistleblower Protection Act in United States). In addition to revengeful punishment, there could be second-order free-riding problem (Panchanathan and Boyd 2004; Fowler 2005; Gross et al. 2016). As punishment is only costly to the punisher and benefits the whole group, individuals could free ride on others who do punish free-riders. Despite the drawbacks, the merits of peer punishment are obvious. It is self-autonomous and that the cost of its implementation is relatively low.

Formal punishment or centralized punishment mechanism provides an alternative to solve free rider problems in social dilemmas. Its "state" nature and that it is usually exercised according to pre-set rules make it clear of anti-social punishment and second-order free ride problems existed in informal punishment systems. Moreover, the concentration of power in a centralized body is a hallmark of civilization (Mann 1986). That being said, it is usually substantially costly to set up a centralized punishment system (court system, police force). That is probably why centralized punishment systems have received much less attention than informal punishment systems in the literature.

There are a handful of experimental studies exploring the centralized systems. Putterman, Tyran, and Kamei (2011) ask subjects to vote on formal punishment systems which could improve or worsen cooperation in public goods games. They find that people mostly learn to choose the system that helps to resolve the free-rider problem. Markussen, Putterman, and Tyran (2014) and Kamei, Putterman, and Tyran (2015) explore the choice between informal and formal sanction systems. It is shown that people prefer informal sanctions if implementing formal sanctions is costly. If it is one's choice to design the formal sanction system, the low-cost and deterrent formal sanctions are preferred. The abovementioned formal sanctions are meted out on all deviators and thus are absolute punishment systems. The relative punishment system instead only punishes the largest deviator. The punishment exerted is dependent on the group's contributions. Yamagishi (1986) and Andreoni and Gee (2012) propose formal punishment systems which only target the lowest contributor. They show that these mechanisms are successful in mitigating free-rider problems. Kamijo et al. (2014) compare the use of absolute and relative punishment systems theoretically and experimentally. They find that the relative punishment system results in equal or higher contributions than that in absolute punishment systems.

A key question in relation to the formal punishment mechanism is what the right size of punishment is. If the punishment is too lenient, the sanction system fails to improve cooperation (Tyran and Feld 2006). It obviously hurts societal welfare if the punishment is too harsh. The punishment in Yamagishi (1986) depends on the punishment fund raised by the group. In Andreoni and Gee (2012), the punishment meted out on the lowest contributor depends on the contribution difference between the lowest and the second lowest contributions. Kamijo et al. (2014) use a fixed penalty in the centralized punishment systems. In addition to punishment size considerations, a good centralized sanction system should be low cost to implement as the low-cost and deterrent sanction system is preferred by voters (Markussen, Putterman, and Tyran 2014; Kamei, Putterman, and Tyran 2015). The hired gun mechanism proposed by Andreoni and Gee (2012) is a relatively low-cost centralized mechanism. Its implementation only relies on the information on the lowest and second lowest contributions. It punishes the lowest contributor to the extent that she would rather have been the second lowest contributor. In other words, the system does not require monitoring all norm violators and instead only the largest and the second largest violator. It thus reduces the cost of monitoring.

We adopt the hired gun mechanism as the framework to address an important but overlooked question, i.e., what the right size of punishment is. We add to the thin literature on the centralized punishment mechanisms. Specifically, we contribute to the literature in the following ways: Firstly, to the best of our knowledge, our study is the first one to explore the right size of punishment in such a low-cost and relative punishment mechanism; Secondly, we go beyond specifying a limited number of punishment conditions (e.g., no, mild and severe sanction conditions in Tyran and Feld (2006)). We theoretically derive a wide range of classes of punishment mechanisms which would lead to full contribution equilibrium. It points to a possibility of using less punishment compared to Andreoni and Gee (2012) to achieve the same full contribution outcome. Thirdly, we employ the individual evolutionary learning model to successfully explain the discrepancy between theory and experimental results. The reason behind the discrepancy is that the theory assumes people to be fully rational and smart. That is to say, people are perceived to be able to play the dominant strategy even if it is very difficult to identify such a strategy. This is not the case in the actual play of the game. As a matter of fact, if the best strategy is too difficult to identify, people evolve to play the second best strategy. In a broader sense, the same reasoning could be extended to many other contexts in explaining the discrepancy between theory and empirically results.

The rest of this paper proceeds as follows. Section 2 details our generalized model of the hired gun mechanism, followed by the experimental design and procedures in section 3. Section 4 discusses the results and section 5 concludes the paper.

2 Theoretical background

2.1 The model

In this section, we start by introducing the hired gun mechanism proposed by Andreoni and Gee (2012), followed by our generalization of the model.

In the classic linear public goods game, players form a group of n and each is endowed with w. All group members decide independently and simultaneously how much of w to contribute to the public goods. Each unit contributed to the public goods generates a payoff of α ($0 \leq \alpha < 1$) for each group member regardless of each individual's contributed amount. α is referred as marginal per capita return (MPCR). Suppose player i contributes g_i $(0 \leq g_i \leq w)$, her payoff π_i can be expressed as:

$$\pi_i = w - g_i + \alpha \sum_{j=1}^{n} g_j \tag{1}$$

Given that $\partial \pi_i / \partial g_i = -1 + \alpha < 0$, the dominant strategy would be not to contribute at all, which leads to the zero-contribution inefficient equilibrium. Everyone would be better off if all group members contribute the whole endowment. It is referred as the socially optimal outcome, which is usually hard to achieve.

Andreoni and Gee (2012) proposed the hired gun mechanism, which has been shown to be effective in promoting contribution. The idea is to punish the lowest contributor just enough so that she would rather have been the second lowest contributor. Define the set of contributors as S and $L(g) \subset S$ as a set of contributors with the lowest contributions. The size of $L(g)$ could range from 1 to n. For example, if $g_z \leq g_j$ holds for all j, $z \in L(g)$. Also let g_y be the second lowest contribution. That is to say, $y \notin L(g)$ and that $g_y \leq g_j$ holds for all $j \notin L(g)$. For a player who contributes g_i when the choice vector is g of all players, the hired gun mechanism administers the punishment $P(g_i, g)$ as follows:

$$P(g_i, g) = \begin{cases} 1, & if\ L(g) = S\ and\ \ g_i < w \\ 0, & if\ L(g) = S\ and\ \ g_i = w \\ g_y - g_i + 1, & if\ L(g) \subset S\ and\ \ i \in L(g) \\ 0, & if\ L(g) \subset S\ and\ \ i \notin L(g) \end{cases} \tag{2}$$

Equation (2) depicts the punishment rule: 1) If all contributors are tied at a below full-contribution level, all are punished by 1 unit; 2) If all contributors contribute the full endowment, no one is punished; 3) If there is no tie, only the lowest contributor is punished and the punishment amount equals the difference between the second lowest and the lowest contribution plus 1 unit. It is straightforward that full contribution is the unique equilibrium, reasoned from the repeated elimination of dominated strategies.

The punishment could be dissected into two parts: the unilateral punishment and the tie punishment. The former is to discourage people from being the lowest contributor, that is, for $P(g_i, g) = g_y - g_i + 1\ if\ L(g) \subset S\ and\ i \in L(g)$, the 1 unit punishment on top of the difference between the second lowest and the lowest contribution is defined as the '*unilateral*' punishment. The '*tie*' punishment is to discourage people from settling at a below full-contribution tie, that is, for $P(g_i, g) = 1,\ if\ L(g) = S\ and\ g_i < w$, the 1 unit punishment is defined as the tie punishment. Andreoni and Gee (2012) assume both the unilateral punishment and the tie punishment to be 1 unit for convenience and realism. We relax this assumption by allowing the unilateral and the tie punishment to be different and by removing the minimum 1 unit restriction. The two parts of punishment in principle have different roles. We are interested in whether or not and to what extent these two parts are connected and that if it is possible to achieve full contribution with less punishment. Should the answer be yes, there might exist a class of such mechanisms which are effective in promoting contribution and wherein punishment is minimized to reduce potential welfare loss. Let u $(u \geq 0)$ be the unilateral punishment and t $(t \geq 0)$ be the tie punishment. Equation (2) could be rewritten as:

$$P(g_i, g) = \begin{cases} t, & if\ L(g) = S\ and\ g_i < w \\ 0, & if\ L(g) = S\ and\ g_i = w \\ g_y - g_i + u, & if\ L(g) \subset S\ and\ i \in L(g) \\ 0, & if\ L(g) \subset S\ and\ i \notin L(g) \end{cases} \tag{3}$$

2.2 The equilibrium

Following the spirit of Andreoni and Gee (2012), we also adopt the repeated elimination of dominated strategies to reach equilibrium. Let Δ_{-1} be the payoff change from decreasing contribution by 1 unit and Δ_{+1} be the payoff change from increasing contribution by 1 unit. It is informative and tractable, and without loss of generality, to start with 2 players. We next discuss the equilibrium outcome from different off-equilibrium starting points.

Starting at a below full-contribution tie. This is the case where $L(g) = S\ and\ g_i < w$ in (3). Both players receive a punishment $P = t$. Increasing contribution by 1 unit incurs a loss of $1 - \alpha$ based on (1) but avoids the punishment t. Decreasing contribution by 1 unit increases payoff by $1 - \alpha$ and avoids the punishment t, but a punishment $(1 + u)$ kicks in. That is to say,

$$\Delta_{+1} = t + \alpha - 1 \tag{4}$$

$$\Delta_{-1}= t-\alpha-u \tag{5}$$

To encourage people only to move contribution upward, it is necessary to have

$$\Delta_{+1}> 0 \Rightarrow t > 1- \alpha \tag{6}$$

$$\Delta_{+1}> \Delta_{-1}\Rightarrow u > 1- 2\alpha \tag{7}$$

If (6) and (7) are both satisfied, players would have incentive to increase contribution to break from the tie. It would be informative to construct a payoff matrix with two players starting from a tie. Each player has 3 strategies: decreasing contribution by 1 unit, remaining the same or increasing contribution by 1 unit. The payoff matrix is as follows:

$$\begin{array}{cccc} & -1 & 0 & 1 \\ -1 & (1-2\alpha,1-2\alpha) & (t-\alpha-u,t-\alpha) & (t-1-u,t-1) \\ 0 & (t-\alpha,t-\alpha-u) & (0,0) & (t-1+\alpha-u,t-1+\alpha) \\ 1 & (t-1,t-1-u) & (t-1+\alpha,t-1+\alpha-u) & (2\alpha-1,2\alpha-1) \end{array} \tag{8}$$

Starting from non-tie. If the initial difference in contribution is more than 1 unit, it is straightforward that the higher contributor will decrease contribution and the lower contributor will increase contribution as doing so would improve the payoff for both before the relative position of contributions changes. Therefore, we discuss the case where the difference in contribution has been shortened to 1 unit. As $t > 1- \alpha$ according to (6), the higher contributor does not have incentive to decrease contribution by 1 to reach a tie. For the lower contributor, the change in payoff from 1 unit contribution increase is $\Delta_{+1\_lower}= \alpha+u-t$. If $\Delta_{+1\_lower}= \alpha+u-t<0$, which means the lower contributor is better off by staying put rather than increasing contribution by 1 unit to reach a tie. If $\Delta_{+1\_lower}= \alpha+u-t>0$, which suggests that the lower contributor should increase contribution by 1 unit. Besides the option of increasing contribution by 1 unit to reach a tie, the lower contributor could also increase contribution by 2 units to avoid any kind of punishment. The resulting payoff change $\Delta_{+2\_lower}= 2\alpha+u-1>0$ always holds according to (7). The lower contributor is thus better off by increasing contribution by 2 units rather than remaining status quo. All in all, the lower contributor has incentive to increase contribution.

To summarize, in the 2-player case, as long as $t > 1- \alpha$ and $u > 1-2\alpha$, the game will end up with the full contribution equilibrium. In other words, the tie punishment and the unilateral punishment need to be harsh enough to reach the full contribution equilibrium. The same reasoning applies to the case with more than two players. It is straightforward to see that increasing the group size does not change the theoretical prediction. Therefore, we only discuss the two-player case in the next subsection for simplicity.

2.3 Violations

In this subsection, we discuss the situations where (6) and (7) are not satisfied simultaneously.

$t < 1 - \alpha$ & $u < 1 - 2\alpha$ This corresponds to the case where both the tie punishment and the unilateral punishment are lenient. When $\alpha > 0.5$, it is impossible to satisfy $u < 1 - 2\alpha$ as it violates the assumption $u \geq 0$. When $\alpha < 0.5$, it is possible to satisfy $0 < u < 1 - 2\alpha$. It leads to $\Delta_{+1} < 0$ and $\Delta_{-1} > \Delta_{+1}$. Δ_{-1} could be either positive or negative: 1) $\Delta_{-1} = t - \alpha - u > 0$, it means $u < t - \alpha$. In the tie case, players are better off by decreasing 1-unit contribution to break from the tie. In the non-tie case (the difference in contribution has been shorten to 1 unit), $\Delta_{+1\_lower} = \alpha + u - t < 0$ & $\Delta_{+2\_lowest} = 2\alpha + u - 1 < 0$, which means the lowest contributor is better off by staying at status quo rather than increasing contribution to a tie or to be the second lowest contributor. Besides the possible change in relative payoff positions caused by actions of the lowest contributor, that of the second lowest contributor could also cause such changes. If the second lowest contributor decreases contribution by 1 unit and the resulting payoff change is $\Delta_{-1\_second\ lower} = 1 - \alpha - t > 0$, which means the second lowest contributor has incentive to decrease contribution to a tie. Eventually, the game ends up with the zero-contribution equilibrium; 2) $\Delta_{-1} = t - \alpha - u < 0$, it leads to $u > t - \alpha$. Together with $\Delta_{+1} < 0$, it suggests that players are better off by staying at tie rather than breaking from the tie. If the game starts with the non-tie case, $\Delta_{+1\_lower} = \alpha + u - t > 0$ and the lowest contributor has incentive to increase contribution to a tie. In other words, the game becomes a coordination game.

$t < 1 - \alpha$ & $u > 1 - 2\alpha$ The tie punishment is lenient and the unilateral punishment is harsh enough. It leads to $\Delta_{-1} < \Delta_{+1} < 0$, which means deviating from the tie in either direction tends to decrease one's payoff. In a non-tie situation $\Delta_{+1\_lower} = \alpha + u - t > 1 - \alpha - t > 0$, which indicates that the lowest contributor always has incentive to increase contribution to a tie. Therefore, it ends up with a coordination problem.

$t > 1 - \alpha$ & $u < 1 - 2\alpha$ The tie punishment is harsh enough and the unilateral punishment is lenient. As discussed earlier, it is possible to satisfy $u < 1 - 2\alpha$ only if $\alpha < 0.5$. These two conditions of t and u lead to $0 < \Delta_{+1} < \Delta_{-1}$, i.e., players are better off by deviating 1 unit negatively from the tie. In the non-tie case $\Delta_{+1\_lower} = \alpha + u - t < 0$, which means the lowest contributor is better off by staying at the lowest rather than increasing contribution to a tie. It is straightforward to see that the higher contributor is better off by staying where she is rather than decreasing contribution to a tie ($\Delta_{-1\_higher} = 1 - \alpha - t < 0$). In other words, the dominant strategy is not a single universal strategy, it is mixed in the sense that it varies according to the starting situation.

[Insert figure 1 here]

Figure 1 summarizes and illustrates all possible cases described above for various parameter values for the unilateral punishment (u) and the tie punishment (t), with $\alpha = 1/3$ in the left panel and $\alpha = 2/3$ in the right panel. Area Cs in both panels represent the required condition for an effective hired-gun mechanism where the unique full contribution Nash equilibrium is achieved. Area As indicate the case where the game degenerates into a coordination problem. Area B in the left panel represents the mixed (varying) dominant strategies depending on the starting situation. The blank area in the left panel represents the situations where the game ends up with the zero-contribution equilibrium. Table 1 summarizes the games outcomes and parameter conditions.

[Insert table 1 here]

3 Experimental design and procedures

3.1 Design and predictions

In Andreoni and Gee (2012), contribution showed a tendency to converge to the full contribution equilibrium where the hired gun mechanism was implemented. They had an endowment of 5 with contributions being integers and $u = 1, t = 1$. The relatively small choice set of contributions might have had impacts on equilibrium convergence. For instance, it might be easier for people to happen to play the equilibrium strategy without realizing it. It would be more difficult to guess it right with a relatively large choice set. Evidence of equilibrium convergence with a large choice set would further substantiate the effectiveness of the hired gun mechanism. In light of this, we run our treatments with an endowment of 20 to expand the choice set. We also replicate the hired gun treatment in Andreoni and Gee (2012) as our ***control*** treatment, where the endowment is 5 and $u = 1, t = 1$. Likewise, similar to Andreoni and Gee (2012) we set α to $2/3$. We vary the unilateral punishment (u) and the tie punishment (t) across treatments in the following way: 1) Treatment ***Rescale***: we only rescale the endowment to 20, but keep $u = 1$ and $t = 1$ (normalized based on the size of endowment, the same logic applies hereafter) the same as Andreoni and Gee (2012); 2) Treatment ***Coordination***: $u = 1$ and $t = 0$; 3) Treatment LoTNoU (low t no u): $u = 0$ and $t = 0.5$. Treatment Control is the same as treatment Rescale except that the endowment is 5 instead of 20.

[Insert figure 2 here]

Figure 2 positions the 4 treatments in the game outcome map based on the relationship between t and u. Treatment Control, Rescale and LoTNoU locate in area C where the conditions for an effective hired gun mechanism are satisfied. The predicted outcome would be full contribution in these 3 treatments. Treatment Coordination locates in area A where the game becomes a coordination game. Table 2 outlines the theoretical predictions.

[Insert table 2 here]

3.2 Procedures

The experiment was conducted at Nanyang Technological University, Singapore. Subjects were recruited through mass university emails and were from various majors. The experiment was programmed in Z-tree (Fischbacher 2007). There were 4 sessions for each treatment. Each session has a size of 12 with the exception of one being 8. In total, there were 188 participants in 16 sessions for the experiment.

The between-subject design was implemented, that is, no subjects participated more than 1 session. We followed the procedure in Andreoni and Gee (2012) closely, including the instructions. All instructions used are available in the supplementary appendix. Instructions were read out aloud at the beginning of the session and questions were answered privately. Subjects had to answer some control questions correctly before proceeding to the real experiment. Subjects played the public goods game for 20 periods in total. The first 10 periods were the public good game without the hired-gun mechanism. Starting period 11, subjects played the game with the introduction of the hired gun mechanism for another 10 periods. They were randomly re-matched from period to period within the session. Subjects were informed of each individual's contribution and earnings in the group including. 1 out of 20 periods was randomly selected for payment. After 20 periods, subjects filled in a post-experiment questionnaire before collecting payments. The average payment for this experiment was around 15 Singapore Dollars (equivalent to around 11 US Dollars).

4 Results

4.1 Experimental results

We start with descriptive results, followed by econometric analysis. Figure 3 depicts the mean contribution over time across treatments. Note that subjects played the same standard linear public goods game in the first 10 periods in all treatments. The only difference is that the endowment in the Control treatment is 5 tokens instead of 20 tokens in the other 3 treatments. Though the first 10 periods are not the focus of this study, we present the results for completeness. The decaying trend is consistent with the classic findings in the literature (e.g., Houser and Kurzban 2002; Fischbacher and Gaechter 2010). Contributions across treatments are remarkably similar, which makes it fair to speculate that there is no substantial difference in individual idiosyncrasy across treatments. Obviously, difference in the amount of endowment does not affect the contribution.

[Insert figure 3 here]

The introduction of the hired gun mechanism in period 11 boosts contribution substantially regardless of the size of the unilateral and the tie punishment. Such a boost in contribution squares with findings in Andreoni and Gee (2012). In the Control treatment replicating Andreoni and Gee (2012) with 5-token endowment, the same trend converging to the full contribution equilibrium emerges. In the Rescale treatment with 20-token endowment but the same unilateral and tie punishment ($u = 1, t = 1$) as Andreoni and Gee (2012), the upward trend still appears but it becomes less obvious. The contribution percentage and trend are very similar in the Control and Rescale treatments. The slightly slower convergence speed in the Rescale treatment might result from the larger choice set (21 vs 6 for the number of choices available). The results in these two treatments are in line with theoretical predictions. This evidence further substantiates the robustness of the hired gun mechanism.

Contribution in the Coordination treatment is consistent over time in the last 10 periods. The theory predicts it to be a coordination outcome but it fails to predict the specific contribution level that people will coordination on. It, to a large degree, depends on the staring contribution level. Contribution being consistent over time might be a piece of evidence supporting the coordination outcome. The theory prediction does not find its support in the LoTNoU treatment. The predicted outcome is contribution converging to the full contribution equilibrium. In contrast, contribution shows a decaying trend over time especially in the last few periods. We will explore the possible explanations for this in later parts.

Table 3 reports the regression analysis of contribution by treatment in the last 10 periods where the hired gun mechanism is introduced. Multilevel mixed-effects linear estimation is adopted and that observations are clustered by session and by subject. The dependent variable is defined as the percentage of endowment contributed. Explanatory variables include period (*Period*), a dummy variable taking value 1 if the payoff in the previous period was the group's minimum and the group did not tie at full contribution and taking value 0 otherwise (*If_min_profit_notiefull_t-1*), a dummy variable taking value 1 if the payoff in the previous period was the group's maximum and the group did not tie at full contribution and taking value 0 otherwise (*If_max_profit_notiefull_t-1*), a dummy variable indicating if there was a tie in the previous period (*Tie_t-1*), a dummy variable taking value 1 if one was punished in the previous period and 0 otherwise (*Ifpunish_t-1*), overall belief about others' contribution for the last 10 periods (*Belief*) and gender taking value 1 for male and 0 otherwise (*Gender*). In an attempt to follow the exact procedure of Andreoni and Gee (2012), which did not elicit belief during the experiment, we only elicited belief at the end of the experiment to avoid any potential effects on contribution and that the variable has been normalized as a percentage of endowment.

[Insert table 3 here]

Period does not have significant effects on contribution in the Control, Rescale and Coordination treatments, which is consistent with findings in figure 3. The negative coefficient speaks to the decaying trend in the LoTNoU treatment. Being the group minimum payoff or the group maximum payoff in the previous period has significantly positive effects on contribution in both the Rescale and LoTNoU treatments. The highest contributors increase contribution might be because they expect others to do so. Since in the Rescale treatment the lowest contributor is punished in the way that her payoff is lower than the second lowest contributor, the second lowest contributor has the maximum payoff in the group. Model (2) suggests that the second lowest contributor tends to increase her contribution, possibly expecting that the lowest will increase hers as well. Those who have the group maximum payoff in the LoTNoU treatment are the lowest and the second lowest contributors as the unilateral punishment is zero. Those people on average tend to increase contribution in the next period.

The positive effect of being tie in the previous period is universal except in the Coordination treatment. This is expected in that there is tie punishment in all except in the Coordination treatment. The presence of tie punishment creates a pull to the full contribution equilibrium as the theory predicts. The significant and negative sign of *Ifpunish_t-1* suggests that the lowest contributor tends to decrease contribution in the next period, which might explain the declining trend in the LoTNoU treatment. We explore possible explanations for the lowest contributor's behavior in later parts. None of the variables discussed above has significant effects in the Coordination treatment. The hired gun mechanism does not seem to pull contribution to the full contribution level like other treatments, which is what the theory predicts. Belief is significant and positive in the Coordination treatment, which very much squares with the nature of coordination games. Model (4) provides further evidence that the treatment Coordination ends up with a coordination outcome.

4.2 Simulations: Individual Evolutionary Learning (IEL)

Following the discussion on the game outcome theoretically and empirically, we explore the evolution path under the hired gun mechanism with different parameters. The evolution path is interesting for several reasons. Firstly, contribution in the LoTNoU treatment has a decaying trend instead of converging to the full contribution equilibrium as the theory predicts. The individual evolutionary learning model is an attempt to explain this deviation from the theory. Secondly, the theory cannot predict the speed of convergence, it would be intriguing to learn about the convergence path and speed in general. Thirdly, the experiments shed light on how people actually behave in the hired gun context but they are bounded by the number of subjects and periods one could use. Simulation provides a robustness check using a longer horizon and a larger sample.

We adopt the individual evolutionary learning (IEL) approach (see more details in Arifovic and Maschek 2006; Arifovic and Ledyard 2012, 2011). IEL has been shown to be successful in explaining all the five stylized facts in public goods games simultaneously (Arifovic and Ledyard 2012). The idea of IEL is that subjects carry a finite set of remembered strategies, which are evaluated and replicated in a certain way, and the better strategies have better chances of being carried forward to future periods. As a result, subjects evolve to play the optimal strategies over time.

Following the definition of IEL in Arifovic and Ledyard (2012), we let X^i be subject i's action space, $I^i(x_t)$ be the information revealed to i at the end of period t, A_t^i be i's remembered set of strategies (contribution levels) in period t and ψ_t^i be the probability measure on A_t^i. A_t^i has a dimension of J, which represents the subject's memory capacity. In period t, each subject chooses a strategy (a contribution level) randomly from A_t^i based on the probability measure ψ_t^i and ends up with the action $x_t^i = a_{j,t}^i$ ($j \in \{1, \ldots J\}$). A^i and ψ^i are updated from period to period. At the end of period t, subjects use a process to compute A_{t+1}^i, ψ_{t+1}^i based on A_t^i, ψ_t^i, $I^i(x_t)$. Experimentation, replication and selection are the three crucial steps in this process. We next describe this process to explain how the decision is made at $t + 1$ based on what happened at t.

The process starts with experimentation. Experimentation introduces a dash of randomness into the remembered strategy set, which contributes to some level of diversity in the process. For each strategy in A_t^i ($a_{j,t}^i, j = 1, \ldots J$), a new strategy (contribution) from X^i is randomly chosen with probability ρ to replace the existing strategy $a_{j,t}^i$. The new strategy has a normal distribution $N\left(a_{j,t}^i, \sigma\right)$. In other words, the mean of the normal distribution where the new contribution is drawn from equals the value of the existing strategy $a_{j,t}^i$ to be replaced. This normal distribution has a standard deviation σ. ρ and σ are free parameters which could be set to various numbers in the simulations.

Replication follows experimentation. It reinforces strategies that would have been relatively high-paying in the past. It is also an opportunity for the potentially better strategies to replace less-paying ones. The key is to identify potentially good strategies. A strategy $a_{j,t}^i$ is evaluated based on the corresponding payoff if $a_{j,t}^i$ had been played at t regardless of the strategy actually played. Let $p^i(a_{j,t}^i | I^i(x_t))$ be subject i's payoff at t if she had played strategy $a_{j,t}^i$ given the information $\mathrm{I}^i(x_t)$, $p^i(a_{j,t}^i | I^i(x_t))$ is used to screen good strategies. For each strategy in A_t^i ($a_{j,t}^i, j = 1, \ldots J$), $a_{j,t}^i$ is replicated in the following way. Two strategies in A_t^i are randomly selected with replacements and that the selection uses uniform probability. Let those two selected strategies be $a_{k,t}^i$ and $a_{l,t}^i$, the strategy set for period $t + 1$ is updated as follows:

$$a^i_{j,t+1} = \begin{cases} a^i_{k,t}, & if\ p^i(\ a^i_{k,t}|I^i(x_t)) \geq\ p^i(\ a^i_{l,t}|I^i(x_t)) \\ a^i_{l,t}, & if\ p^i\left(\ a^i_{k,t}\middle|I^i(x_t)\right) <\ p^i(\ a^i_{l,t}|I^i(x_t)) \end{cases} \tag{9}$$

The replication repeats for $j = 1, \ldots J$. It is straightforward that strategies with more replicates at t, and those that would have resulted in higher payoffs had they been used at t, are more likely to be carried forward into $t + 1$. If the information $I^i(x_t)$, i.e., other group members' contribution at t, makes strategy $a^i_{j,t}$ a high paying strategy, this strategy tends to have more replicates in the strategy set. In other words, this strategy is favorably remembered and thus has higher chance of being actually played. As a result, the replication process averages over the past periods. In the long term, the remembered strategy set consists of best-response strategies.

Selection happens after replication and is the last step in the process. Each strategy $a^i_{k,t+1}$ in A^i_{t+1} is selected with a probability $\psi^i_{k,t+1}$. The probability is decided by its relative fitness in the strategy set, which is measured by the proportional payoff.

$$\psi^i_{k,t+1} = \frac{p^i(\ a^i_{k,t+1}|I^i(x_t))}{\sum_{j=1}^{J} p^i(\ a^i_{j,t+1}|I^i(x_t))} \tag{10}$$

Those 3 steps constitute the process describing how an IEL subject proceeds from t to $t + 1$. The last piece missing is the initial values in period 1, A^i_1 and ψ^i_1. Following the practice in Arifovic and Maschek (2006), Arifovic and Ledyard (2011) and Arifovic and Ledyard (2012), we also use the same simple initialization in period 1. Every strategy forming A^i_1 is drawn randomly with uniform probability from the action space X^i. Each strategy in A^i_1 stands an equal chance of being selected in period 1. That is to say, $\psi^i_{k,1} = \frac{1}{J}\ for\ all\ k.$

We now have a complete picture of the IEL model from the very beginning. We set the free parameters $\rho = 1, J = 5, \sigma = 1\ (Endowment = 5), \sigma = 4\ (Endowment = 20)$[1] in our simulations. Figure 4 shows the simulation results for all treatments with 1000 repetitions and $t = 80$. As we use the same simple initialization across treatments, the contribution always starts at 50% of endowment. There is a decaying trend in the linear public goods game and that contributions converge to zero in the long run. This phenomenon is robust regardless of the size of endowment.

[1] Rescaling the standard deviation according to the size of endowment is realistic.

[Insert figure 4 here]

Endowment size plays a role in evolution trend when the hired-gun mechanism is introduced. Contributions in the Control treatment (5-token HG when $t = 1 \& u = 1$ in figure 4) converge much more quickly to the full contribution than that in the Rescale treatment (20-token HG when $t = 1 \& u = 1$ in figure 4). It indicates that if subjects start at the same medium contribution level (50%), smaller endowment size results in faster convergence to the equilibrium in the hired-gun mechanism. This is intuitive as the smaller set of choices available associated with the smaller endowment makes it easier to find the dominant strategy and thus leads to a quicker convergence to the equilibrium. The difference in convergence speed is not as obvious in experiments as that in simulations. It might be because the starting contribution level is already very high (91%) for both treatments in experiments, which limits the presence of different convergence speeds.

There is not much difference in the evolution trend between the Rescale (20-token HG when $t = 1 \ \& \ u = 1$) and the Coordination treatments (20-token HG when $t = 0 \ \& \ u = 1$) in simulations. This is consistent with experimental results. Note that the difference between these two treatments in the removal of tie punishment in the Coordination treatment. The removal of tie punishment theoretically would make people coordinate on a certain contribution level depending on the starting point and the game therefore ends up with a tie. However, this is not the case in simulations. It might be because in reality achieving successful coordination is difficult, which is a solid finding in the literature (Devetag and Ortmann 2007). It turns out tie also rarely exists in both of our simulation data and experimental observations (only 1 out of 470 groups under the hired-gun mechanism).

Intriguingly there is a decaying trend in the LoTNoU treatment (20-token HG when $t = 0.5 \ \& \ u = 0$). It is in line with experiment results but at odds with theoretical predictions. Recall that the game is predicted to end up with a full contribution equilibrium. This divergence from theory might result from subjects' difficulty in locating the dominant strategy. Subjects are assumed to be rational and smart in the sense that they are always able to find the dominant strategy and that the decision environment is irrelevant. For instance, suppose 1 out of 5 strategies is the dominant strategy in situation A, 1 out of 20 strategies is the dominant strategy in situation B, theoretically there would not be any difference in the outcome as the dominant strategy will be played in both situations. However, this might not be the case empirically. In situation B, subjects might not be able to pick up the dominant strategy over the choice set. In the same spirit, if it is not easy for subjects to locate the "right" choice, they would end up with playing the less optimal strategy. This is indeed the case in the LoTNoU treatment.

We use an example where the contributions in the group are not a tie to illustrate what might have happened in the LoTNoU treatment. Let the contribution difference between the lowest and the second lowest be j_1, the contribution difference between the second lowest and the third lowest be j_2, the change in the lowest contributor's contribution be k, the change in the lowest contributor's payoff resulting from the contribution change k be Δ. It is straightforward that one is never better off by decreasing contribution when one is already the lowest contributor. Therefore, we assume $k > 0$. There are several possibilities of k: 1) The lowest contributor can increase contribution but remain the lowest contributor, i.e., $k < j_1, \Delta = \alpha k > 0$; 2) She can increase contribution to the second lowest contributor's contribution, i.e., $k = j_1, \Delta = \alpha j_1 - j_2$; 3) She can increase contribution so that she becomes the second lowest contributor, i.e., $k > j_1, \Delta = j_1 + u - k(1-\alpha)$. In the second case, if $j_2 < \alpha j_1$, increasing contribution by exact j_1 would make her better off rather than staying put. In the third case, if $k > (j_1 + u)/(1-\alpha)$, increasing contribution by k would make her worse off. Therefore, any one condition from (11) to (13) would be a sufficient condition to ensure increasing k is a dominant strategy.

$$k < j_1 \tag{11}$$

$$k = j_1 \;\&\; j_2 < \alpha j_1 \tag{12}$$

$$j_1 < k < \frac{j_1 + u}{1 - \alpha} \tag{13}$$

When u is small, the range in (13) becomes small. If this is the case, the lowest contributor could easily increase her contribution too much, which in turn decreases her payoff. Figure 5 is a pseudocolor (checkerboard) plot of contributions in the 20th period with $\sigma = 1$, $w = 5$ and 100 repetitions. In the pseudocolor plot, both the tie punishment t (*x-axis*) and the unilateral punishment u (*y-axis*) are in increments of 0.02. The color represents contribution percentage as indicated in the color bar on the right. It seems that the proper size of both u and t are necessary for a high contribution outcome. It might be the case that for a small choice set associated with the 5-token endowment, it is relatively easy to find the dominant strategy. Therefore, both harsh enough tie punishment and unilateral punishment are needed to discourage people from settling at below full-contribution ties and being the lowest contributor. When u is sufficiently small, increasing k runs the risk of k being too much and therefore it backfires. The blue band at the bottom supports this conjecture.

[Insert figure 5 here]

Figure 6 plots the contributions in the 40th period with $\sigma = 4$, $w = 20$ and 100 repetitions.[2] When endowment increases to 20, the tie punishment no longer matters that much and that the contribution level is substantially affected by the unilateral punishment. This could be due to the fact that a large choice set associated with 20-token endowment makes ties rare and therefore subjects do not have many chances to learn to avoid the tie punishment empirically. As a result, tie punishment loses its function. Similar to the 5-token case, the lowest band at the bottom colored with darker blue indicates lower contributions when u is very small. There are also clear cut-offs at $u = 1 - \alpha$ and $u = \alpha$. It is consistent with (13) that the range of k is sensitive to the size of u, which affects contribution levels.

[Insert figure 6 here]

5 Conclusion

In this paper, we explore the right size of punishment in the context of the centralized punishment modelled after the hired gun mechanism proposed by Andreoni and Gee (2012). We are interested in the hired gun mechanism because it is effective in promoting cooperation and that it is relative low-cost to implement. The hired gun mechanism punishes the lowest contributor to the extent that the person would rather have been the second lowest contributor. The suggested punishment involves two components; a unilateral punishment and a tie punishment. The former is imposed to discourage people from wanting to be the lowest contributor and the latter is added on to prevent people from coordinating on a tie at a below full-contribution level. There is essentially a range of values for the relative magnitude of these two components that would sustain full contribution equilibrium. We aim to examine how severe the unilateral and tie punishment should be to achieve the full-contribution equilibrium. Specifically, we are interested in investigating the size of the "bullets" that the "hired gun" should carry. We vary the magnitude of the unilateral and tie punishment in such a way that full contribution equilibrium sustains. We derive theoretically a class of punishment mechanisms which would lead to full contribution equilibrium, which are tested by experiments. We also run an experimental treatment wherein we only eliminate the tie punishment but keep the unilateral punishment intact so that the voluntary contribution game is transformed into a coordination game. Our experimental results generally substantiate the theoretical prediction on the full cooperation equilibrium and the coordination outcome, except for the more lenient punishment parameters. This discrepancy is successfully explained by individual evolutionary learning.

We conclude by suggesting some promising directions for future research. It would be interesting to explore if the generalized mechanism applies to other types of public goods games, such as public goods

[2] We use the same standard deviation parameters as that in the IEL simulations. Since it takes longer to converge to the equilibrium for the 20-token endowment situations, we prolong the time frame to 40 periods.

games with provision points, public goods games with asymmetric payoffs, sequential public goods games, etc. One could also study endogenously chosen hired gun mechanisms. Subjects deicide endogenously on the size of the unilateral punishment and the tie punishment. It would be interesting to see what the parameters of the hired gun mechanism end up with and if the endogenously chosen mechanism has different effects compared to the exogenously mechanism.

References

Andreoni, James, and Laura K. Gee. 2012. "Gun for Hire: Delegated Enforcement and Peer Punishment in Public Goods Provision." *Journal of Public Economics* 96 (11–12). Elsevier B.V.: 1036–46. doi:10.1016/j.jpubeco.2012.08.003.

———. 2015. "Gunning for Efficiency with Third Party Enforcement in Threshold Public Goods." *Experimental Economics* 18 (1): 154–71. doi:10.1007/s10683-014-9392-1.

Arifovic, Jasmina, and John Ledyard. 2011. "A Behavioral Model for Mechanism Design: Individual Evolutionary Learning." *Journal of Economic Behavior & Organization* 78 (3). Elsevier B.V.: 374–95. doi:10.1016/j.jebo.2011.01.021.

———. 2012. "Individual Evolutionary Learning, Other-Regarding Preferences, and the Voluntary Contributions Mechanism." *Journal of Public Economics* 96 (9–10). Elsevier B.V.: 808–23. doi:10.1016/j.jpubeco.2012.05.013.

Arifovic, Jasmina, and Michael K. Maschek. 2006. "Revisiting Individual Evolutionary Learning in the Cobweb Model - An Illustration of the Virtual Spite-Effect." *Computational Economics* 28 (4): 333–54. doi:10.1007/s10614-006-9053-3.

Cason, Timothy N., and Lata Gangadharan. 2015. "Promoting Cooperation in Nonlinear Social Dilemmas through Peer Punishment." *Experimental Economics* 18 (1): 66–88. doi:10.1007/s10683-014-9393-0.

Chaudhuri, Ananish. 2011. "Sustaining Cooperation in Laboratory Public Goods Experiments: A Selective Survey of the Literature." *Experimental Economics* 14 (1): 47–83. doi:10.1007/s10683-010-9257-1.

Denant-Boemont, Laurent, David Masclet, and Charles N. Noussair. 2007. "Punishment, Counterpunishment and Sanction Enforcement in a Social Dilemma Experiment." *Economic Theory* 33 (1): 145–67. doi:10.1007/s00199-007-0212-0.

Devetag, Giovanna, and Andreas Ortmann. 2007. "When and Why? A Critical Survey on Coordination Failure in the Laboratory." *Experimental Economics* 10 (3): 331–44. doi:10.1007/s10683-007-9178-9.

Fehr, Ernst, and Simon Gächter. 2000. "Cooperation and Punishment in Public Goods Experiments." *The American Economic Review* 90 (4): 980–94.

———. 2002. "Altruistic Punishment in Humans." *Nature* 415 (6868): 137–40. doi:10.1038/415137a.

Fischbacher, Urs. 2007. "Z-Tree: Zurich Toolbox for Ready-Made Economic Experiments." *Experimental Economics* 10 (2): 171–78. doi:10.1007/s10683-006-9159-4.

Fischbacher, Urs, and Simon Gaechter. 2010. "Heterogeneous Social Preferences and the Dynamics of Free Riding in Public Goods." *American Economic Review* 100 (1): 541–56.

Fowler, James H. 2005. "Human Cooperation: Second-Order Free-Riding Problem Solved?" *Nature* 437 (7058): E8–E8. doi:10.1038/nature04201.

Gross, Jörg, Zsombor Z. Méder, Sanae Okamoto-Barth, and Arno Riedl. 2016. "Building the Leviathan – Voluntary Centralisation of Punishment Power Sustains Cooperation in Humans." *Scientific Reports* 6 (June 2015). Nature Publishing Group: 20767. doi:10.1038/srep20767.

Herrmann, Benedikt, Thöni Christian, and Simon Gächter. 2008. "Antisocial Punishment across Societies." *Science* 319 (5868): 1362–67.

Houser, Daniel, and Robert Kurzban. 2002. "Revisiting Kindness and Confusion in Public Goods Experiments." *American Economic Review* 92 (4): 1062–69.

Kamei, Kenju, Louis Putterman, and Jean-Robert Tyran. 2015. "State or Nature? Endogenous Formal versus Informal Sanctions in the Voluntary Provision of Public Goods." *Experimental Economics* 18 (1): 38–65. doi:10.1007/s10683-014-9405-0.

Kamijo, Y., T. Nihonsugi, A. Takeuchi, and Y. Funaki. 2014. "Sustaining Cooperation in Social Dilemmas: Comparison of Centralized Punishment Institutions." *Games and Economic Behavior* 84. Elsevier Inc.: 180–95. doi:10.1016/j.geb.2014.01.002.

Mann, Michael. 1986. *The Sources of Social Power, Vol. I: A History of Power from the Beginning to 1760 AD*.

Markussen, Thomas, Louis Putterman, and Jean Robert Tyran. 2014. "Self-Organization for Collective Action: An Experimental Study of Voting on Sanction Regimes." *Review of Economic Studies* 81 (1): 301–24. doi:10.1093/restud/rdt022.

Nikiforakis, Nikos. 2008. "Punishment and Counter-Punishment in Public Good Games: Can We Really Govern Ourselves?" *Journal of Public Economics* 92 (1–2): 91–112.

doi:10.1016/j.jpubeco.2007.04.008.

Panchanathan, Karthik, and Robert Boyd. 2004. "Indirect Reciprocity Can Stabilize Cooperation without the Second-Order Free Rider Problem." *Nature* 432 (7016): 499–502. doi:10.1038/nature02978.

Putterman, Louisa, Jean Robert Tyran, and Kenjua Kamei. 2011. "Public Goods and Voting on Formal Sanction Schemes." *Journal of Public Economics* 95 (9–10). Elsevier B.V.: 1213–22. doi:10.1016/j.jpubeco.2011.05.001.

Tyran, Jean Robert, and Lars P. Feld. 2006. "Achieving Compliance When Legal Sanctions Are Non-Deterrent." *Scandinavian Journal of Economics* 108 (1): 135–56. doi:10.1111/j.1467-9442.2006.00444.x.

Yamagishi, Toshio. 1986. "The Provision of a Sanctioning System as a Public Good." *Journal of Personality and Social Psychology* 51 (1): 110–16. doi:10.1037/0022-3514.51.1.110.

Tables and Figures

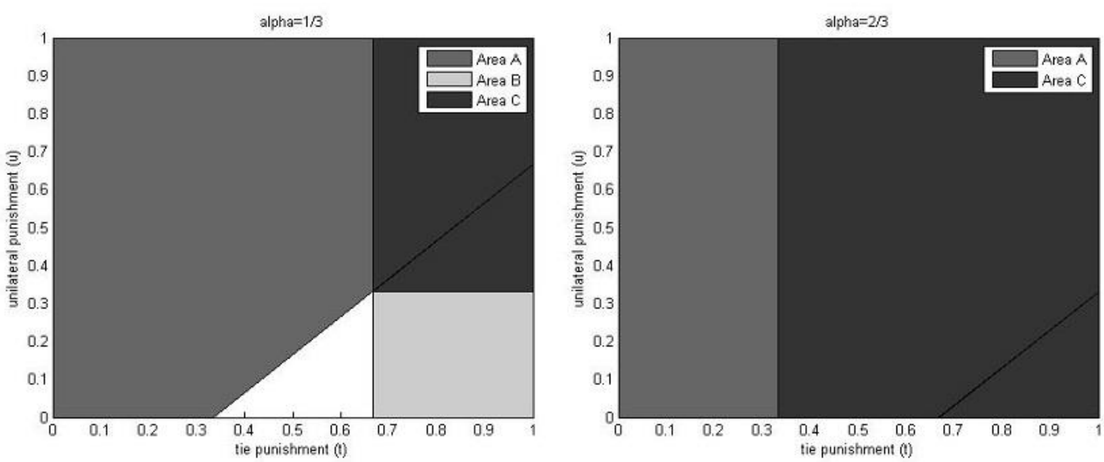

Figure 1. Game outcomes conditioned on t and u for different α

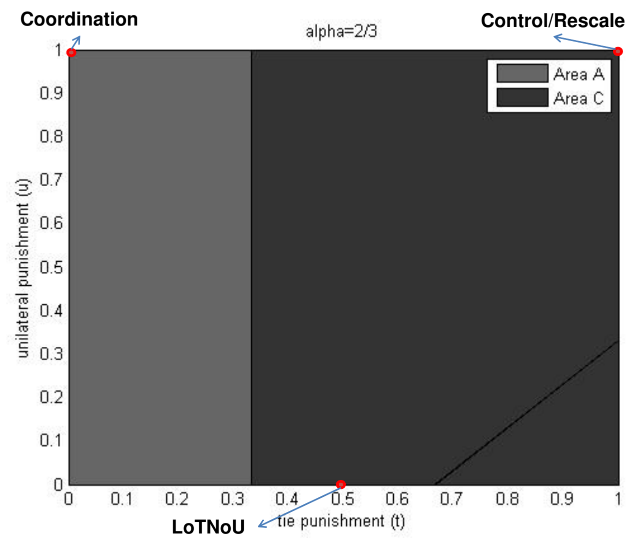

Figure 2. The treatments

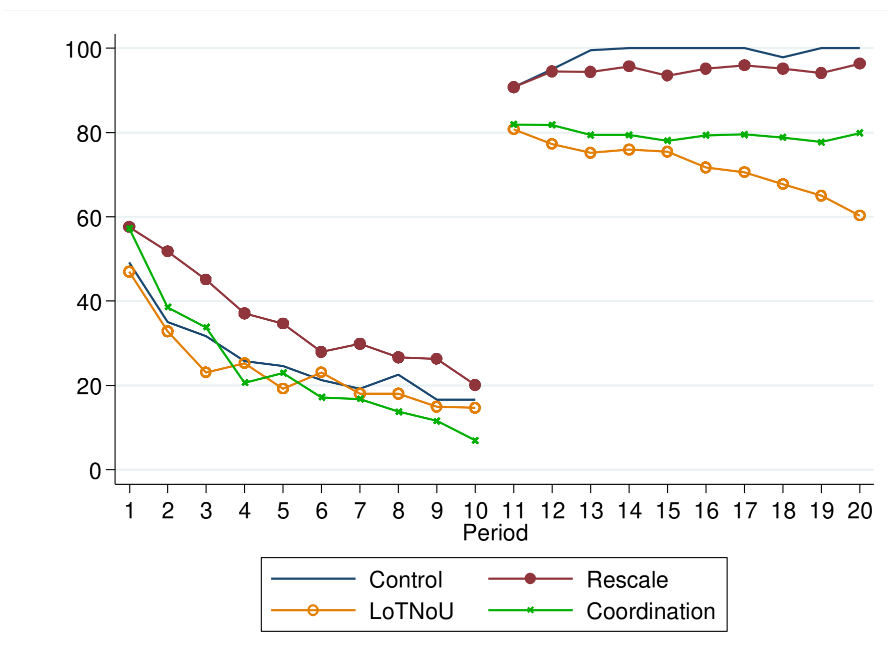

Figure 3. Mean contribution over time

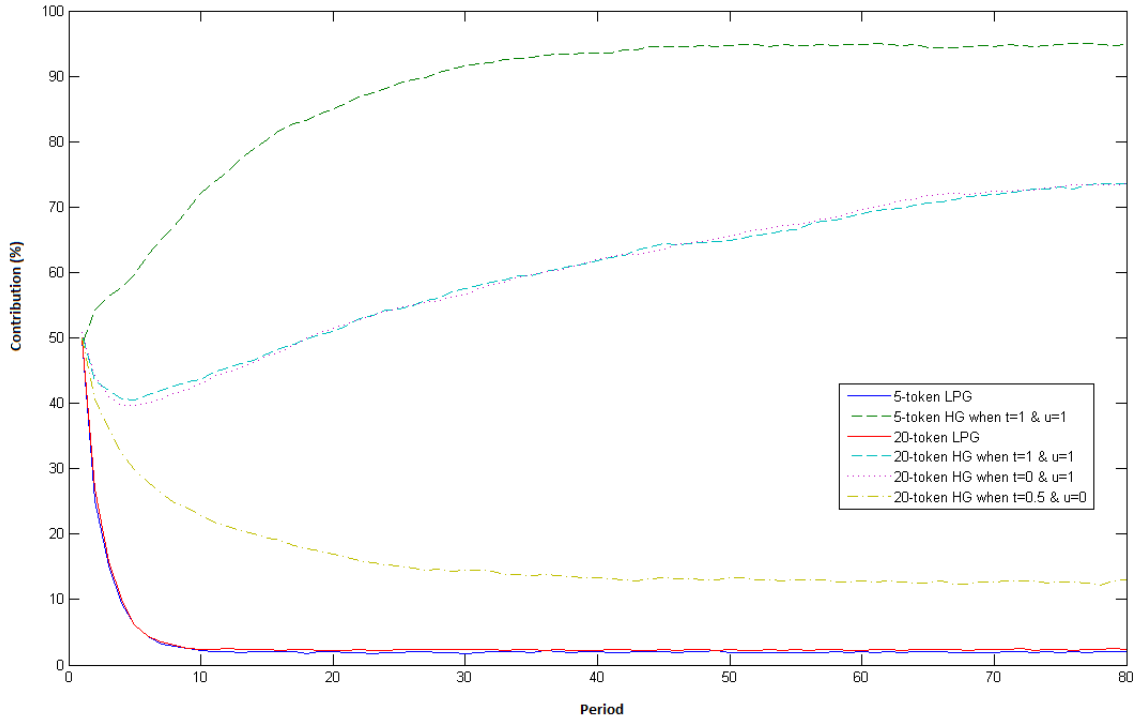

Figure 4. Simulation results with 1000 repetitions

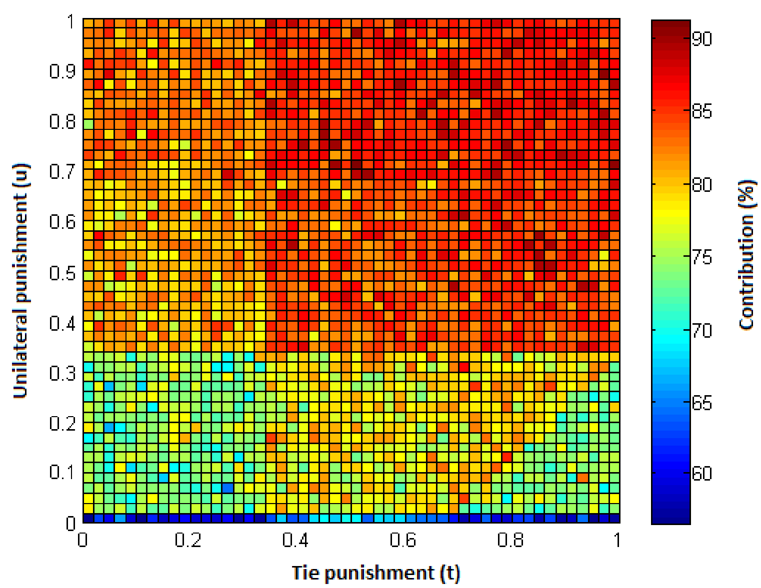

Figure 5. Contribution with 5-token endowment in the 20th period (100 repetitions)

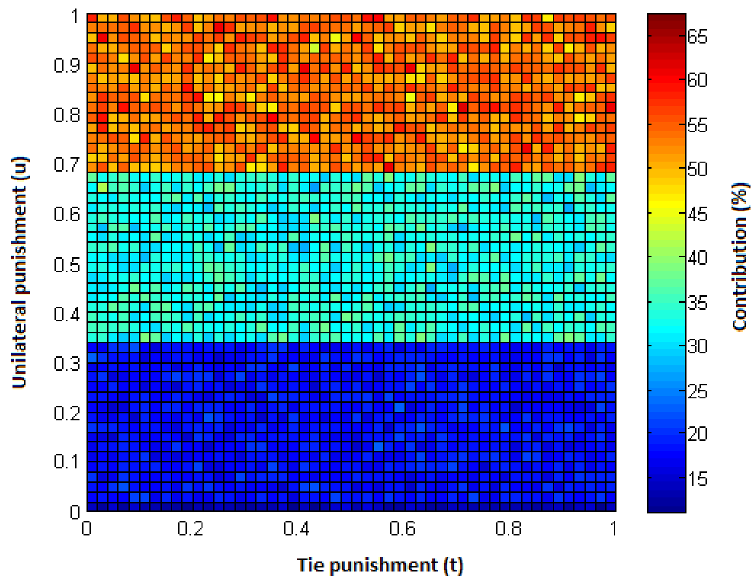

Figure 6. Contribution with 20-token endowment in the 40th period (100 repetitions)

Table 1. Game outcomes conditioned on t and u

Area	t	u	Outcome
A	$t < 1 - \alpha$	$u > t - \alpha$	Coordination
B (only if $\alpha < 0.5$)	$t > 1 - \alpha$	$u < 1 - 2\alpha$	Mixed strategies
C	$t > 1 - \alpha$	$u > 1 - 2\alpha$	Full contribution
Blank (only if $\alpha < 0.5$)	$t < 1 - \alpha$	$u < t - \alpha$	Zero contribution

Table 2. Predictions across treatments

Treatment	Endowment	t	u	Predicted outcome
Control	5	1	1	Full contribution
Rescale	20	1	1	Full contribution
LoTNoU	20	0.5	0	Full contribution
Coordination	20	1	0	Coordination

Table 3. Determinants of contribution: Multilevel mixed-effects linear estimation

Dependent variable: contribution percentage				
	Control	Rescale	LoTNoU	Coordination
	(1)	(2)	(3)	(4)
Period	0.00163	0.00287	-0.0160***	-0.00283
	(0.00195)	(0.00212)	(0.00323)	(0.00256)
If_min_profit_notiefull_t-1	-0.0399*	0.0433**	0.123***	-0.00107
	(0.0209)	(0.0220)	(0.0224)	(0.0181)
If_max_profit_notiefull_t-1	0.0103	0.0634***	0.0686***	-0.00416
	(0.0202)	(0.0235)	(0.0238)	(0.0202)
Tie_t-1	0.0510**	0.0605**	0.141***	0.0164
	(0.0202)	(0.0252)	(0.0450)	(0.0286)
Ifpunish_t-1	0.0261	-0.0110	-0.0718***	-0.0254
	(0.0317)	(0.0237)	(0.0252)	(0.0227)
Belief	-0.00679	0.223	0.158	0.280***
	(0.0335)	(0.199)	(0.0997)	(0.0866)
Gender	-0.00272	0.0276	-0.0115	-0.0789***
	(0.00973)	(0.0246)	(0.0463)	(0.0256)
Constant	0.927***	0.615***	0.749***	0.648***
	(0.0475)	(0.195)	(0.133)	(0.120)
Observations	480	480	480	440
Log. Likelihood	446.6	292.6	51.99	185.9
Chi-squared	39.71	19.20	91.45	26.51

Standard errors in parentheses
* p<0.10 ** p<0.05 *** p<0.01

Supplementary Appendix

Instructions

1. Treatment Control

General Information

Welcome to all of you! You are now taking part in an interactive study on decision making. **Please pay attention to the information provided here and make your decisions carefully. If at any time you have questions to ask, please raise your hand and we will attend to you in private.**

Please note that **unauthorized communication is prohibited**. Failure to adhere to this rule would force us to stop this study and you will be asked to leave the experiment without pay. You have the right to withdraw from the experiment at any point in time, and if you decide to do so your payments earned during this study will be forfeited.

By participating in this study, you will be able to earn a considerable amount of money in addition to your show-up fee of $5. The amount of your earnings depends on the decisions you and others make.

At the end of this session, your earnings will be paid to you privately and in cash. It would be contained in an envelope (indicated with your unique user ID). You will need to sign a claim card given to you and exchange your claim card with your payment.

General Instructions

Each of you will be given **a unique user ID** and it **will be clearly stated on your computer screen**. At the end of the study, you will be asked to fill in your user ID and other information, pertaining to your earnings from this study, in the claim card. **Please fill in the correct user ID to make sure that you will get the correct amount of payment**.

Rest assured that your **anonymity will be preserved** throughout the study. You will **never be aware of** the personal information of other participants **during or after** the study. Similarly, other participants will also **never be aware** of your personal identities **during or after** the study. You will only be identified by your user ID in our data collection. All information collected will **strictly be kept confidential** for the sole purpose of this study.

Specific Instructions

You have been organized into groups of 4 people. Each group will consist of 4 different randomly assigned persons in each period. There will be 20 periods in this session. In each period you will be required to make some decisions and what you earn from each decision will depend on what you and the other 3 people in your group decide.

Once all your decisions in the 20 periods have been made, we will randomly select one of the 20 periods as the period that counts. We will use the period-that-counts to determine your actual earnings. Note, since all periods are equally likely to be chosen, you should make your decision in each period as if it will be the period-that-counts.

First, we will describe the instructions for the first 10 periods.

First 10 Periods: Investment Decision

At the beginning of each period you will be randomly assigned to a new group of 4 players, and you will be given an automatic payment of $0.40.

In each period you will be choosing how to divide 5 tokens between two investment opportunities:

THE RED INVESTMENT

Each token you invest in the RED investment will earn you a return of $1.20.

Example: Suppose you invest 4 tokens in the RED investment, then you would earn $ 4.80 from this investment.

Example: Suppose you invest 0 token in the RED investment, then you would earn $ 0.00 from this investment.

THE BLUE INVESTMENT

What you earn from the BLUE investment will depend on the total number of tokens that you and the other 3 members of your group invest in the BLUE investment. The more the group invests in the BLUE investment, the more each member of the group earns. Each token you invest in the BLUE investment will earn you and all your group members a return of $0.8.

The process is best explained by a number of examples.

Example: Suppose that you decided to invest no tokens in the BLUE investment but that the 3 other members invest a total of 9 tokens. Then your earnings from the BLUE investment would be $7.20 (which is 9 tokens multiplied by $0.80). Everyone else in your group would also earn $ 7.20.

Example: Suppose that you invest 2 tokens in the BLUE investment and that the 3 other members of your group invest a total of 9 tokens. This makes a group total of 11 tokens. Your return from the BLUE investment would be $8.80 (which is 11 tokens multiplied by $0.80). The other 3 members of the group would also get a return of $ 8.80.

Example: Suppose that you invest 3 tokens in the BLUE investment and the other 3 members invest nothing. Then you, and everyone else in the group, would get a return from the BLUE investment of $2.40 (which is 3 tokens multiplied by $ 0.80).

As you can see, every token invested in the BLUE investment will earn $0.80 for every member of the group, not just the person who invests it there. *It does not matter who invests tokens in the BLUE investment. Everyone will get a return from every token invested there—whether they invest tokens in the BLUE investment or not.*

YOUR TASK

Your task is to decide how many of your tokens to invest in the RED investment and how many to invest in the BLUE investment. You are free to invest some of your tokens in the RED investment and some in the BLUE investment. Alternatively, you can invest all of them into the RED investment or all of them into the BLUE investment.

Earnings

Once you and the other 3 members of your group have made your decisions, you will receive an **Earnings Statement** for that period. You will be given anonymous details of all your group's investments and earnings.

Your earnings have been computed using the following simple formula:

1st Stage Earnings = ($1.20)*(Your investment to the RED investment) + ($0.80)*(Total group investments to the BLUE investment)

For example imagine you invested 4 to the BLUE investment, your other group members invest 2, 3, and 3 to the BLUE investment.

In this example 1st stage earnings are computed as follows:

1st Stage Earnings = ($1.20)*(5-4) + ($0.80)*(4 + 2 + 3+ 3)

1st Stage Earnings = ($1.20)*(1) + ($0.80)*(12)

1st Stage Earnings = $1.20+$9.60

1st Stage Earnings = $ 10.80

Your earnings will be your 1st Stage earnings plus your $0.40 automatic payment. You will also be given a summary of your current and previous earnings. **You must make your investment decisions without knowing what the others in your group are deciding. *Do not discuss your decision with any other participant*.**

Your Group

For each decision period you will be in a group of 4 people in the room today. **After each decision period we will randomly re-match you with a new group of 4 people in the room.** As a result, each decision you make will be with a new group of 4 participants. The probability that you will ever be in the same group of 4 participants again is extremely remote. After 10 periods of this one stage investment decision, you will be given directions for another type of decision.

Things to remember

- You will be in a group of 4 people
- You will have automatic earnings of $0.40 each period
- You will have 5 tokens to invest each period
- Each token you invest in the RED investment earns you $1.20
- Each token you invest in the BLUE investment earns you and every member of your group $0.80
- There will be a total of 10 decision periods.
- The groups will be randomly re-matched every decision period.
- Please feel free to use the calculator, and scratch paper provided to help you with your calculations.

If you have any questions about the instructions please raise your hand and someone will come and speak with you privately about your question.

Thank you. Please wait to be told when you can begin making decisions for the first 10 periods.

Next 10 Periods: Two Stage Investment Decision

The investment decision is exactly the same as the decision you made in the first 10 periods. At the beginning of each period you will be randomly assigned to a new group of 4 players, and you will be given an automatic payment of $0.40. In each period you will be choosing how to divide 5 tokens between two investment opportunities:

THE RED INVESTMENT

Each token you invest in the RED investment will earn you a return of $1.20.

THE BLUE INVESTMENT

Each token you invest in the BLUE investment will earn you a return of $0.80 for you and all the members of your group.

Administrator

In these 10 periods your group will be overseen by a *computer-simulated* Administrator, the Administrator will examine the number of tokens you invest in the BLUE investment. The computer-simulated Administrator may take a deduction from your payoff according to these rules:

1) Only the lowest investor (or investors in case of a tie) to the BLUE investment will have a deduction taken from their payoff by the Administrator.

2) The size of the deduction will depend on the investment choices of your group members. The deduction will be the difference between the payoff of the lowest investor *and* the payoff of the second lowest investor to the BLUE investment in your group plus $1.20.

3) If there is a tie for the lowest investor, all those who tied will have the deduction taken from their payoff.

4) If all 4 members of your group tie for the lowest investor, then all of you will have $1.20 taken from your payoffs.

5) If all members of your group allocate the whole of their 5 tokens to the BLUE investment, then no one will have a deduction taken from their payoffs.

Thus, with the Administrator the only way you can avoid having a deduction is to avoid being the lowest investor to the BLUE investment. With the Administrator, the only way everyone in the group can avoid a deduction is if everyone invests all 5 tokens to the BLUE investment.

Earnings:

Example: Suppose that you invest 3 tokens in the RED investment and 2 tokens in the BLUE investment. Suppose that the 3 other members of your group invest 4, 4, and 1 tokens in the BLUE investment respectively. This makes a group total of 11 tokens. Your return from the BLUE investment would be $8.80. The other 3 members of the group would also get a return of $8.80 from the BLUE investment. Your initial payoff from this stage would be: 3*($1.20) + (2+ 4+ 4+ 1)*($0.80)=$12.40

You invested 2 tokens to the BLUE investment, while another player invested only 1 token, so you are **not** the lowest investor to the BLUE investment. Thus, you will **not** have a payoff deduction. Your earnings for Stage 2 of this period will be your initial earnings of $12.40.

Example: Suppose that you invest 3 tokens in the RED investment and 2 tokens in the BLUE investment. Suppose that the 3 other members of your group invest 3, 4, and 2 tokens in the BLUE investment respectively. This makes a group total of 11 tokens. Your return from the BLUE investment would be $8.80. The other 3 members of the group would also get a return of $8.80 from the BLUE investment. Your initial payoff from this stage would be: 3*($1.20) + (2+ 3+ 2+ 1)*($0.80)=$12.40

You invested 2 tokens to the BLUE investment, so you and the other player that invested 2 tokens tied for being the lowest investors to the BLUE investment. Thus, you (and the other player that invested only 2 in the BLUE investment) will have a payoff deduction. The size of the deduction will be $1.20 plus the difference between your initial earnings and the next lowest investor in the BLUE investment. The next lowest investor in your group invested 3 tokens in the BLUE investment and earned $11.20. In this example that would mean your deduction would be $1.20+ ($12.40-$11.20)= $2.40. Your Stage 2 net earnings will be your initial earnings of $12.40 minus your deduction of $2.40, which in total equals $10.00. You will be told that you were the lowest investor when your period earnings are reported to you.

Example: Suppose that you invest 0 tokens in the RED investment and 5 tokens in the BLUE investment. Suppose that the 3 other members of your group invest 5, 5, and 5 tokens in the BLUE investment respectively. This makes a group total of 20 tokens. Your return from the BLUE investment would be $16.00. The other 3 members of the group would also get a return of $16.00 from the BLUE investment.

Everyone invested all their 5 tokens to the BLUE investment, so there is no lowest investor to the BLUE investment. In this specific case even though there is a computer simulated Administrator, no one will have a payoff deduction. Your payoff for Stage 2 of this period will be $16.00.

Your earnings for the last 10 periods are computed by the following formula:

Earnings = ($1.20)*(Your investment to the RED investment) + ($0.80)*(Total group investments to the BLUE investment) – (Payoff Deduction if you are the lowest investor to the BLUE investment)

Your Group

For each decision period you will be in a group of 4 people in the room today. As a result, each period you will be with a new group of 4 participants. The probability that you will ever be in the same group of 4 participants again is extremely remote.

Your Earnings

Once all your decisions in the 20 periods have been made, we will randomly select one of the 20 periods as the period that-counts. We will use the period-that-counts to determine your actual earnings. Note, since all periods are equally likely to be chosen, you should make all your decision in each period as if it will be the period-that-counts.

Things to Remember

- You will be in a group of 4 people
- You will have automatic earnings of $0.40 each period
- You will have 5 tokens to invest each period
- Each token you invest in the RED investment earns you $1.20

- Each token you invest in the BLUE investment earns you and every member of your group $0.80
- The groups will be randomly re-matched every decision period.
- You group will be monitored by a computer-simulated Administrator
    - The Administrator will be responsible for taking a deduction from the earnings of the lowest investor in the BLUE investment.
    - The deduction will equal to (the earnings of the lowest BLUE investor) – (the earnings of the second lowest BLUE investor) + $1.20.
    - If several people are tied for the lowest investor, all will receive a deduction from their earnings.
    - If all people in the group invest all 5 tokens in the BLUE investment, then no one will receive a deduction.
- Please feel free to use the calculator, and scratch paper provided to help you with your calculations.

If you have any questions about the instructions please raise your hand and someone will come and speak with you privately about your question

Thank you. Please wait to be told when you can begin making decisions for the next 10 periods.

2. Treatment Rescale

General Information

Welcome to all of you! You are now taking part in an interactive study on decision making. **Please pay attention to the information provided here and make your decisions carefully. If at any time you have questions to ask, please raise your hand and we will attend to you in private.**

Please note that **unauthorized communication is prohibited**. Failure to adhere to this rule would force us to stop this study and you will be asked to leave the experiment without pay. You have the right to withdraw from the experiment at any point in time, and if you decide to do so your payments earned during this study will be forfeited.

By participating in this study, you will be able to earn a considerable amount of money in addition to your show-up fee of $5. The amount of your earnings depends on the decisions you and others make.

At the end of this session, your earnings will be paid to you privately and in cash. It would be contained in an envelope (indicated with your unique user ID). You will need to sign a claim card given to you and exchange your claim card with your payment.

General Instructions

Each of you will be given **a unique user ID** and it **will be clearly stated on your computer screen**. At the end of the study, you will be asked to fill in your user ID and other information, pertaining to your earnings from this study, in the claim card. **Please fill in the correct user ID to make sure that you will get the correct amount of payment**.

Rest assured that your **anonymity will be preserved** throughout the study. You will **never be aware of** the personal information of other participants **during or after** the study. Similarly, other participants will also **never be aware** of your personal identities **during or after** the study. You will only be identified by your user ID in our data collection. All information collected will **strictly be kept confidential** for the sole purpose of this study.

Specific Instructions

You have been organized into groups of 4 people. Each group will consist of 4 different randomly assigned persons in each period. There will be 20 periods in this session. In each period you will be required to make some decisions and what you earn from each decision will depend on what you and the other 3 people in your group decide.

Once all your decisions in the 20 periods have been made, we will randomly select one of the 20 periods as the period that counts. We will use the period-that-counts to determine your actual earnings. Note, since all periods are equally likely to be chosen, you should make your decision in each period as if it will be the period-that-counts.

First, we will describe the instructions for the first 10 periods.

First 10 Periods: Investment Decision

At the beginning of each period you will be randomly assigned to a new group of 4 players, and you will be given an automatic payment of $0.40.

In each period you will be choosing how to divide 20 tokens between two investment opportunities:

THE RED INVESTMENT

Each token you invest in the RED investment will earn you a return of $0.30.

Example: Suppose you invest 16 tokens in the RED investment, then you would earn $ 4.80 from this investment.

Example: Suppose you invest 0 token in the RED investment, and then you would earn $ 0.00 from this investment.

THE BLUE INVESTMENT

What you earn from the BLUE investment will depend on the total number of tokens that you and the other 3 members of your group invest in the BLUE investment. The more the group invests in the BLUE investment, the more each member of the group earns. Each token you invest in the BLUE investment will earn you and all your group members a return of $0.2.

The process is best explained by a number of examples.

Example: Suppose that you decided to invest no tokens in the BLUE investment but that the 3 other members invest a total of 36 tokens. Then your earnings from the BLUE investment would be $7.20 (which is 36 tokens multiplied by $0.20). Everyone else in your group would also earn $7.20.

Example: Suppose that you invest 8 tokens in the BLUE investment and that the 3 other members of your group invest a total of 36 tokens. This makes a group total of 44 tokens. Your return from the BLUE investment would be $8.80 (which is 44 tokens multiplied by $0.20). The other 3 members of the group would also get a return of $ 8.80.

Example: Suppose that you invest 12 tokens in the BLUE investment and the other 3 members invest nothing. Then you, and everyone else in the group, would get a return from the BLUE investment of $2.40 (which is 12 tokens multiplied by $ 0.20).

As you can see, every token invested in the BLUE investment will earn $0.20 for every member of the group, not just the person who invests it there. *It does not matter who invests tokens in the BLUE investment. Everyone will get a return from every token invested there—whether they invest tokens in the BLUE investment or not.*

YOUR TASK

Your task is to decide how many of your tokens to invest in the RED investment and how many to invest in the BLUE investment. You are free to invest some of your tokens in the RED investment and some in the BLUE investment. Alternatively, you can invest all of them into the RED investment or all of them into the BLUE investment.

Earnings

Once you and the other 3 members of your group have made your decisions, you will receive an **Earnings Statement** for that period. You will be given anonymous details of all your group's investments and earnings.

Your earnings have been computed using the following simple formula:

1st Stage Earnings = ($0.30)*(Your investment to the RED investment) + ($0.20)*(Total group investments to the BLUE investment)

For example imagine you invested 16 to the BLUE investment, your other group members invest 8, 12, and 12 to the BLUE investment.

In this example 1st stage earnings are computed as follows:

1st Stage Earnings = ($0.30)*(20-16) + ($0.20)*(16+ 8 + 12+ 12)

1st Stage Earnings = ($0.30)*(4) + ($0.20)*(48)

1st Stage Earnings = $1.20+$9.60

1st Stage Earnings = $ 10.80

Your earnings will be your 1st Stage earnings plus your $0.40 automatic payment. You will also be given a summary of your current and previous earnings. **You must make your investment decisions without knowing what the others in your group are deciding.** ***Do not discuss your decision with any other participant*****.**

Your Group

For each decision period you will be in a group of 4 people in the room today. **After each decision period we will randomly re-match you with a new group of 4 people in the room.** As a result, each decision you make will be with a new group of 4 participants. The probability that you will ever be in the same group of 4 participants again is extremely remote. After 10 periods of this one stage investment decision, you will be given directions for another type of decision.

Things to remember

- You will be in a group of 4 people
- You will have automatic earnings of $0.40 each period
- You will have 20 tokens to invest each period
- Each token you invest in the RED investment earns you $0.30
- Each token you invest in the BLUE investment earns you and every member of your group $0.20
- There will be a total of 10 decision periods.
- The groups will be randomly re-matched every decision period.
- Please feel free to use the calculator, and scratch paper provided to help you with your calculations.

If you have any questions about the instructions please raise your hand and someone will come and speak with you privately about your question.

Thank you. Please wait to be told when you can begin making decisions for the first 10 periods.

Next 10 Periods: Two Stage Investment Decision

The investment decision is exactly the same as the decision you made in the first 10 periods. At the beginning of each period you will be randomly assigned to a new group of 4 players, and you will be given an automatic payment of $0.40. In each period you will be choosing how to divide 20 tokens between two investment opportunities:

THE RED INVESTMENT

Each token you invest in the RED investment will earn you a return of $0.30.

THE BLUE INVESTMENT

Each token you invest in the BLUE investment will earn you a return of $0.20 for you and all the members of your group.

Administrator

In these 10 periods your group will be overseen by a *computer-simulated* Administrator, the Administrator will examine the number of tokens you invest in the BLUE investment. The computer-simulated Administrator may take a deduction from your payoff according to these rules:

1) Only the lowest investor (or investors in case of a tie) to the BLUE investment will have a deduction taken from their payoff by the Administrator.

2) The size of the deduction will depend on the investment choices of your group members. The deduction will be the difference between the payoff of the lowest investor *and* the payoff of the second lowest investor to the BLUE investment in your group plus $0.30.

3) If there is a tie for the lowest investor, all those who tied will have the deduction taken from their payoff.

4) If all 4 members of your group tie for the lowest investor, then all of you will have $0.30 taken from your payoffs.

5) If all members of your group allocate the whole of their 20 tokens to the BLUE investment, then no one will have a deduction taken from their payoffs.

Thus, with the Administrator the only way you can avoid having a deduction is to avoid being the lowest investor to the BLUE investment. With the Administrator, the only way everyone in the group can avoid a deduction is if everyone invests all 20 tokens to the BLUE investment.

Earnings:

Example: Suppose that you invest 12 tokens in the RED investment and 8 tokens in the BLUE investment. Suppose that the 3 other members of your group invest 16, 16, and 4 tokens in the BLUE investment respectively. This makes a group total of44 tokens. Your return from the BLUE investment would be $8.80. The other 3 members of the group would also get a return of $8.80 from the BLUE investment. Your initial payoff from this stage would be: 12*($0.30) + (8+ 16+ 16+ 4)*($0.20) =$12.40

You invested 8 tokens to the BLUE investment, while another player invested only 4 token, so you are **not** the lowest investor to the BLUE investment. Thus, you will **not** have a payoff deduction. Your earnings for Stage 2 of this period will be your initial earnings of $12.40.

Example: Suppose that you invest 12 tokens in the RED investment and 8 tokens in the BLUE investment. Suppose that the 3 other members of your group invest 12, 16, and 8 tokens in the BLUE investment respectively. This makes a group total of 44 tokens. Your return from the BLUE investment would be $8.80. The other 3 members of the group would also get a return of $8.80 from the BLUE investment. Your initial payoff from this stage would be: 12*($0.30) + (12+ 8+ 16+ 8)*($0.20)=$12.40

You invested 8 tokens to the BLUE investment, so you and the other player that invested 8 tokens tied for being the lowest investors to the BLUE investment. Thus, you (and the other player that invested only 8 in the BLUE investment) will have a payoff deduction. The size of the deduction will be $0.30 plus the difference between your initial earnings and the next lowest investor in the BLUE investment. The next lowest investor in your group invested 12 tokens in the BLUE investment and earned $11.20. In this example that would mean your deduction would be $0.3+ ($12.40-$11.20)= $1.5. Your Stage 2 net earnings will be your initial earnings of $12.40 minus your deduction of $2.40, which in total equals $10.9. You will be told that you were the lowest investor when your period earnings are reported to you.

Example: Suppose that you invest 0 tokens in the RED investment and 20 tokens in the BLUE investment. Suppose that the 3 other members of your group invest 20, 20, and 20 tokens in the BLUE investment respectively. This makes a group total of 80 tokens. Your return from the BLUE investment would be $16.00. The other 3 members of the group would also get a return of $16.00 from the BLUE investment.

Everyone invested all their 20 tokens to the BLUE investment, so there is no lowest investor to the BLUE investment. In this specific case even though there is a computer simulated Administrator, no one will have a payoff deduction. Your payoff for Stage 2 of this period will be $16.00.

Your earnings for the last 10 periods are computed by the following formula:

Earnings = ($0.30)*(Your investment to the RED investment) + ($0.20)*(Total group investments to the BLUE investment) – (Payoff Deduction if you are the lowest investor to the BLUE investment)

Your Group

For each decision period you will be in a group of 4 people in the room today. As a result, each period you will be with a new group of 4 participants. The probability that you will ever be in the same group of 4 participants again is extremely remote.

Your Earnings

Once all your decisions in the 20 periods have been made, we will randomly select one of the 20 periods as the period that-counts. We will use the period-that-counts to determine your actual earnings. Note, since all periods are equally likely to be chosen, you should make all your decision in each period as if it will be the period-that-counts.

Things to Remember

- You will be in a group of 4 people
- You will have automatic earnings of $0.40 each period
- You will have 20 tokens to invest each period
- Each token you invest in the RED investment earns you $0.30

- Each token you invest in the BLUE investment earns you and every member of your group $0.20
- The groups will be randomly re-matched every decision period.
- You group will be monitored by a computer-simulated Administrator
  - The Administrator will be responsible for taking a deduction from the earnings of the lowest investor in the BLUE investment.
  - The deduction will equal to (the earnings of the lowest BLUE investor) – (the earnings of the second lowest BLUE investor) + $0.30.
  - If several people are tied for the lowest investor, all will receive a deduction from their earnings.
  - If all people in the group invest all 20 tokens in the BLUE investment, then no one will receive a deduction.
- Please feel free to use the calculator, and scratch paper provided to help you with your calculations.

If you have any questions about the instructions please raise your hand and someone will come and speak with you privately about your question

Thank you. Please wait to be told when you can begin making decisions for the next 10 periods.

3. Treatment LoTNoU

General Information

Welcome to all of you! You are now taking part in an interactive study on decision making. **Please pay attention to the information provided here and make your decisions carefully. If at any time you have questions to ask, please raise your hand and we will attend to you in private.**

Please note that **unauthorized communication is prohibited**. Failure to adhere to this rule would force us to stop this study and you will be asked to leave the experiment without pay. You have the right to withdraw from the experiment at any point in time, and if you decide to do so your payments earned during this study will be forfeited.

By participating in this study, you will be able to earn a considerable amount of money in addition to your show-up fee of $5. The amount of your earnings depends on the decisions you and others make.

At the end of this session, your earnings will be paid to you privately and in cash. It would be contained in an envelope (indicated with your unique user ID). You will need to sign a claim card given to you and exchange your claim card with your payment.

General Instructions

Each of you will be given **a unique user ID** and it **will be clearly stated on your computer screen**. At the end of the study, you will be asked to fill in your user ID and other information, pertaining to your earnings from this study, in the claim card. **Please fill in the correct user ID to make sure that you will get the correct amount of payment**.

Rest assured that your **anonymity will be preserved** throughout the study. You will **never be aware of** the personal information of other participants **during or after** the study. Similarly, other participants will also **never be aware** of your personal identities **during or after** the study. You will only be identified by your user ID in our data collection. All information collected will **strictly be kept confidential** for the sole purpose of this study.

Specific Instructions

You have been organized into groups of 4 people. Each group will consist of 4 different randomly assigned persons in each period. There will be 20 periods in this session. In each period you will be required to make some decisions and what you earn from each decision will depend on what you and the other 3 people in your group decide.

Once all your decisions in the 20 periods have been made, we will randomly select one of the 20 periods as the period that counts. We will use the period-that-counts to determine your actual earnings. Note, since all periods are equally likely to be chosen, you should make your decision in each period as if it will be the period-that-counts.

First, we will describe the instructions for the first 10 periods.

First 10 Periods: Investment Decision

At the beginning of each period you will be randomly assigned to a new group of 4 players, and you will be given an automatic payment of $0.40.

In each period you will be choosing how to divide 20 tokens between two investment opportunities:

THE RED INVESTMENT

Each token you invest in the RED investment will earn you a return of $0.30.

Example: Suppose you invest 16 tokens in the RED investment, then you would earn $ 4.80 from this investment.

Example: Suppose you invest 0 token in the RED investment, and then you would earn $ 0.00 from this investment.

THE BLUE INVESTMENT

What you earn from the BLUE investment will depend on the total number of tokens that you and the other 3 members of your group invest in the BLUE investment. The more the group invests in the BLUE investment, the more each member of the group earns. Each token you invest in the BLUE investment will earn you and all your group members a return of $0.2.

The process is best explained by a number of examples.

Example: Suppose that you decided to invest no tokens in the BLUE investment but that the 3 other members invest a total of 36 tokens. Then your earnings from the BLUE investment would be $7.20 (which is 36 tokens multiplied by $0.20). Everyone else in your group would also earn $7.20.

Example: Suppose that you invest 8 tokens in the BLUE investment and that the 3 other members of your group invest a total of 36 tokens. This makes a group total of 44 tokens. Your return from the BLUE investment would be $8.80 (which is 44 tokens multiplied by $0.20). The other 3 members of the group would also get a return of $ 8.80.

Example: Suppose that you invest 12 tokens in the BLUE investment and the other 3 members invest nothing. Then you, and everyone else in the group, would get a return from the BLUE investment of $2.40 (which is 12 tokens multiplied by $ 0.20).

As you can see, every token invested in the BLUE investment will earn $0.20 for every member of the group, not just the person who invests it there. *It does not matter who invests tokens in the BLUE investment. Everyone will get a return from every token invested there—whether they invest tokens in the BLUE investment or not.*

YOUR TASK

Your task is to decide how many of your tokens to invest in the RED investment and how many to invest in the BLUE investment. You are free to invest some of your tokens in the RED investment and some in the BLUE investment. Alternatively, you can invest all of them into the RED investment or all of them into the BLUE investment.

Earnings

Once you and the other 3 members of your group have made your decisions, you will receive an **Earnings Statement** for that period. You will be given anonymous details of all your group's investments and earnings.

Your earnings have been computed using the following simple formula:

1st Stage Earnings = ($0.30)*(Your investment to the RED investment) + ($0.20)*(Total group investments to the BLUE investment)

For example imagine you invested 16 to the BLUE investment, your other group members invest 8, 12, and 12 to the BLUE investment.

In this example 1st stage earnings are computed as follows:

1st Stage Earnings = ($0.30)*(20-16) + ($0.20)*(16+ 8 + 12+ 12)

1st Stage Earnings = ($0.30)*(4) + ($0.20)*(48)

1st Stage Earnings = $1.20+$9.60

1st Stage Earnings = $ 10.80

Your earnings will be your 1st Stage earnings plus your $0.40 automatic payment. You will also be given a summary of your current and previous earnings. **You must make your investment decisions without knowing what the others in your group are deciding.** ***Do not discuss your decision with any other participant*.**

Your Group

For each decision period you will be in a group of 4 people in the room today. **After each decision period we will randomly re-match you with a new group of 4 people in the room.** As a result, each decision you make will be with a new group of 4 participants. The probability that you will ever be in the same group of 4 participants again is extremely remote. After 10 periods of this one stage investment decision, you will be given directions for another type of decision.

Things to remember

- You will be in a group of 4 people
- You will have automatic earnings of $0.40 each period
- You will have 20 tokens to invest each period
- Each token you invest in the RED investment earns you $0.30
- Each token you invest in the BLUE investment earns you and every member of your group $0.20
- There will be a total of 10 decision periods.
- The groups will be randomly re-matched every decision period.
- Please feel free to use the calculator, and scratch paper provided to help you with your calculations.

If you have any questions about the instructions please raise your hand and someone will come and speak with you privately about your question.

Thank you. Please wait to be told when you can begin making decisions for the first 10 periods.

Next 10 Periods: Two Stage Investment Decision

The investment decision is exactly the same as the decision you made in the first 10 periods. At the beginning of each period you will be randomly assigned to a new group of 4 players, and you will be given an automatic payment of $0.40. In each period you will be choosing how to divide 20 tokens between two investment opportunities:

THE RED INVESTMENT

Each token you invest in the RED investment will earn you a return of $0.30.

THE BLUE INVESTMENT

Each token you invest in the BLUE investment will earn you a return of $0.20 for you and all the members of your group.

Administrator

In these 10 periods your group will be overseen by a *computer-simulated* Administrator, the Administrator will examine the number of tokens you invest in the BLUE investment. The computer-simulated Administrator may take a deduction from your payoff according to these rules:

1) Only the lowest investor (or investors in case of a tie) to the BLUE investment will have a deduction taken from their payoff by the Administrator.

2) The size of the deduction will depend on the investment choices of your group members. The deduction will be the difference between the payoff of the lowest investor *and* the payoff of the second lowest investor to the BLUE investment in your group.

3) If there is a tie for the lowest investor, all those who tied will have the deduction taken from their payoff.

4) If all 4 members of your group tie for the lowest investor, then all of you will have $0.15 taken from your payoffs.

5) If all members of your group allocate the whole of their 20 tokens to the BLUE investment, then no one will have a deduction taken from their payoffs.

Thus, with the Administrator the only way you can avoid having a deduction is to avoid being the lowest investor to the BLUE investment. With the Administrator, the only way everyone in the group can avoid a deduction is if everyone invests all 20 tokens to the BLUE investment.

Earnings:

Example: Suppose that you invest 12 tokens in the RED investment and 8 tokens in the BLUE investment. Suppose that the 3 other members of your group invest 16, 16, and 4 tokens in the BLUE investment respectively. This makes a group total of 44 tokens. Your return from the BLUE investment would be $8.80. The other 3 members of the group would also get a return of $8.80 from the BLUE investment. Your initial payoff from this stage would be: 12*($0.30) + (8+ 16+ 16+ 4)*($0.20) =$12.40

You invested 8 tokens to the BLUE investment, while another player invested only 4 token, so you are **not** the lowest investor to the BLUE investment. Thus, you will **not** have a payoff deduction. Your earnings for Stage 2 of this period will be your initial earnings of $12.40.

Example: Suppose that you invest 12 tokens in the RED investment and 8 tokens in the BLUE investment. Suppose that the 3 other members of your group invest 12, 16, and 8 tokens in the BLUE investment respectively. This makes a group total of 44 tokens. Your return from the BLUE investment would be $8.80. The other 3 members of the group would also get a return of $8.80 from the BLUE investment. Your initial payoff from this stage would be: 12*($0.30) + (12+ 8+ 16+ 8)*($0.20)=$12.40

You invested 8 tokens to the BLUE investment, so you and the other player that invested 8 tokens tied for being the lowest investors to the BLUE investment. Thus, you (and the other player that invested only 8 in the BLUE investment) will have a payoff deduction. The size of the deduction will be $the difference between your initial earnings and the next lowest investor in the BLUE investment. The next lowest investor in your group invested 12 tokens in the BLUE investment and earned $11.20. In this example that would mean your deduction would be $12.40-$11.20= $1.20. Your Stage 2 net earnings will be your initial earnings of $12.40 minus your deduction of $1.20, which in total equals $11.20. You will be told that you were the lowest investor when your period earnings are reported to you.

Example: Suppose that you invest 0 tokens in the RED investment and 20 tokens in the BLUE investment. Suppose that the 3 other members of your group invest 20, 20, and 20 tokens in the BLUE investment respectively. This makes a group total of 80 tokens. Your return from the BLUE investment would be $16.00. The other 3 members of the group would also get a return of $16.00 from the BLUE investment.

Everyone invested all their 20 tokens to the BLUE investment, so there is no lowest investor to the BLUE investment. In this specific case even though there is a computer simulated Administrator, no one will have a payoff deduction. Your payoff for Stage 2 of this period will be $16.00.

Your earnings for the last 10 periods are computed by the following formula:

Earnings = ($0.30)*(Your investment to the RED investment) + ($0.20)*(Total group investments to the BLUE investment) – (Payoff Deduction if you are the lowest investor to the BLUE investment)

Your Group

For each decision period you will be in a group of 4 people in the room today. As a result, each period you will be with a new group of 4 participants. The probability that you will ever be in the same group of 4 participants again is extremely remote.

Your Earnings

Once all your decisions in the 20 periods have been made, we will randomly select one of the 20 periods as the period that-counts. We will use the period-that-counts to determine your actual earnings. Note, since all periods are equally likely to be chosen, you should make all your decision in each period as if it will be the period-that-counts.

Things to Remember

- You will be in a group of 4 people
- You will have automatic earnings of $0.40 each period
- You will have 20 tokens to invest each period
- Each token you invest in the RED investment earns you $0.30
- Each token you invest in the BLUE investment earns you and every member of your group $0.20
- The groups will be randomly re-matched every decision period.
- You group will be monitored by a computer-simulated Administrator

- The Administrator will be responsible for taking a deduction from the earnings of the lowest investor in the BLUE investment.
- The deduction will equal to (the earnings of the lowest BLUE investor) – (the earnings of the second lowest BLUE investor).
- If several people are tied for the lowest investor, all will receive a deduction from their earnings.
- If all people in the group invest all 20 tokens in the BLUE investment, then no one will receive a deduction.

- Please feel free to use the calculator, and scratch paper provided to help you with your calculations.

If you have any questions about the instructions please raise your hand and someone will come and speak with you privately about your question

Thank you. Please wait to be told when you can begin making decisions for the next 10 periods.

4. Treatment Coordination

General Information

Welcome to all of you! You are now taking part in an interactive study on decision making. **Please pay attention to the information provided here and make your decisions carefully. If at any time you have questions to ask, please raise your hand and we will attend to you in private.**

Please note that **unauthorized communication is prohibited**. Failure to adhere to this rule would force us to stop this study and you will be asked to leave the experiment without pay. You have the right to withdraw from the experiment at any point in time, and if you decide to do so your payments earned during this study will be forfeited.

By participating in this study, you will be able to earn a considerable amount of money in addition to your show-up fee of $5. The amount of your earnings depends on the decisions you and others make.

At the end of this session, your earnings will be paid to you privately and in cash. It would be contained in an envelope (indicated with your unique user ID). You will need to sign a claim card given to you and exchange your claim card with your payment.

General Instructions

Each of you will be given **a unique user ID** and it **will be clearly stated on your computer screen**. At the end of the study, you will be asked to fill in your user ID and other information, pertaining to your earnings from this study, in the claim card. **Please fill in the correct user ID to make sure that you will get the correct amount of payment**.

Rest assured that your **anonymity will be preserved** throughout the study. You will **never be aware of** the personal information of other participants **during or after** the study. Similarly, other participants will also **never be aware** of your personal identities **during or after** the study. You will only be identified by your user ID in our data collection. All information collected will **strictly be kept confidential** for the sole purpose of this study.

Specific Instructions

You have been organized into groups of 4 people. Each group will consist of 4 different randomly assigned persons in each period. There will be 20 periods in this session. In each period you will be required to make some decisions and what you earn from each decision will depend on what you and the other 3 people in your group decide.

Once all your decisions in the 20 periods have been made, we will randomly select one of the 20 periods as the period that counts. We will use the period-that-counts to determine your actual earnings. Note, since all periods are equally likely to be chosen, you should make your decision in each period as if it will be the period-that-counts.

First, we will describe the instructions for the first 10 periods.

First 10 Periods: Investment Decision

At the beginning of each period you will be randomly assigned to a new group of 4 players, and you will be given an automatic payment of $0.40.

In each period you will be choosing how to divide 20 tokens between two investment opportunities:

THE RED INVESTMENT

Each token you invest in the RED investment will earn you a return of $0.30.

Example: Suppose you invest 16 tokens in the RED investment, then you would earn $ 4.80 from this investment.

Example: Suppose you invest 0 token in the RED investment, and then you would earn $ 0.00 from this investment.

THE BLUE INVESTMENT

What you earn from the BLUE investment will depend on the total number of tokens that you and the other 3 members of your group invest in the BLUE investment. The more the group invests in the BLUE investment, the more each member of the group earns. Each token you invest in the BLUE investment will earn you and all your group members a return of $0.2.

The process is best explained by a number of examples.

Example: Suppose that you decided to invest no tokens in the BLUE investment but that the 3 other members invest a total of 36 tokens. Then your earnings from the BLUE investment would be $7.20 (which is 36 tokens multiplied by $0.20). Everyone else in your group would also earn $7.20.

Example: Suppose that you invest 8 tokens in the BLUE investment and that the 3 other members of your group invest a total of 36 tokens. This makes a group total of 44 tokens. Your return from the BLUE investment would be $8.80 (which is 44 tokens multiplied by $0.20). The other 3 members of the group would also get a return of $ 8.80.

Example: Suppose that you invest 12 tokens in the BLUE investment and the other 3 members invest nothing. Then you, and everyone else in the group, would get a return from the BLUE investment of $2.40 (which is 12 tokens multiplied by $ 0.20).

As you can see, every token invested in the BLUE investment will earn $0.20 for every member of the group, not just the person who invests it there. *It does not matter who invests tokens in the BLUE investment. Everyone will get a return from every token invested there—whether they invest tokens in the BLUE investment or not.*

YOUR TASK

Your task is to decide how many of your tokens to invest in the RED investment and how many to invest in the BLUE investment. You are free to invest some of your tokens in the RED investment and some in the BLUE investment. Alternatively, you can invest all of them into the RED investment or all of them into the BLUE investment.

Earnings

Once you and the other 3 members of your group have made your decisions, you will receive an **Earnings Statement** for that period. You will be given anonymous details of all your group's investments and earnings.

Your earnings have been computed using the following simple formula:

1st Stage Earnings = ($0.30)*(Your investment to the RED investment) + ($0.20)*(Total group investments to the BLUE investment)

For example imagine you invested 16 to the BLUE investment, your other group members invest 8, 12, and 12 to the BLUE investment.

In this example 1st stage earnings are computed as follows:

1st Stage Earnings = ($0.30)*(20-16) + ($0.20)*(16+ 8 + 12+ 12)

1st Stage Earnings = ($0.30)*(4) + ($0.20)*(48)

1st Stage Earnings = $1.20+$9.60

1st Stage Earnings = $ 10.80

Your earnings will be your 1st Stage earnings plus your $0.40 automatic payment. You will also be given a summary of your current and previous earnings. **You must make your investment decisions without knowing what the others in your group are deciding. *Do not discuss your decision with any other participant*.**

Your Group

For each decision period you will be in a group of 4 people in the room today. **After each decision period we will randomly re-match you with a new group of 4 people in the room.** As a result, each decision you make will be with a new group of 4 participants. The probability that you will ever be in the same group of 4 participants again is extremely remote. After 10 periods of this one stage investment decision, you will be given directions for another type of decision.

Things to remember

- You will be in a group of 4 people
- You will have automatic earnings of $0.40 each period
- You will have 20 tokens to invest each period
- Each token you invest in the RED investment earns you $0.30
- Each token you invest in the BLUE investment earns you and every member of your group $0.20
- There will be a total of 10 decision periods.
- The groups will be randomly re-matched every decision period.
- Please feel free to use the calculator, and scratch paper provided to help you with your calculations.

If you have any questions about the instructions please raise your hand and someone will come and speak with you privately about your question.

Thank you. Please wait to be told when you can begin making decisions for the first 10 periods.

Next 10 Periods: Two Stage Investment Decision

The investment decision is exactly the same as the decision you made in the first 10 periods. At the beginning of each period you will be randomly assigned to a new group of 4 players, and you will be given an automatic payment of $0.40. In each period you will be choosing how to divide 20 tokens between two investment opportunities:

THE RED INVESTMENT

Each token you invest in the RED investment will earn you a return of $0.30.

THE BLUE INVESTMENT

Each token you invest in the BLUE investment will earn you a return of $0.20 for you and all the members of your group.

Administrator

In these 10 periods your group will be overseen by a *computer-simulated* Administrator, the Administrator will examine the number of tokens you invest in the BLUE investment. The computer-simulated Administrator may take a deduction from your payoff according to these rules:

1) Only the lowest investor (or investors in case of a tie) to the BLUE investment will have a deduction taken from their payoff by the Administrator.

2) The size of the deduction will depend on the investment choices of your group members. The deduction will be the difference between the payoff of the lowest investor *and* the payoff of the second lowest investor to the BLUE investment in your group plus $0.30.

3) If there is a tie for the lowest investor, all those who tied will have the deduction taken from their payoff.

4) If all 4 members of your group tie for the lowest investor, then all of you will have $0 taken from your payoffs.

5) If all members of your group allocate the whole of their 20 tokens to the BLUE investment, then no one will have a deduction taken from their payoffs.

Thus, with the Administrator the only way you can avoid having a deduction is to avoid being the lowest investor to the BLUE investment. With the Administrator, the only way everyone in the group can avoid a deduction is if everyone invests all 20 tokens to the BLUE investment.

Earnings:

Example: Suppose that you invest 12 tokens in the RED investment and 8 tokens in the BLUE investment. Suppose that the 3 other members of your group invest 16, 16, and 4 tokens in the BLUE investment respectively. This makes a group total of 44 tokens. Your return from the BLUE investment would be $8.80. The other 3 members of the group would also get a return of $8.80 from the BLUE investment. Your initial payoff from this stage would be: 12*($0.30) + (8+ 16+ 16+ 4)*($0.20) =$12.40

You invested 8 tokens to the BLUE investment, while another player invested only 4 token, so you are **not** the lowest investor to the BLUE investment. Thus, you will **not** have a payoff deduction. Your earnings for Stage 2 of this period will be your initial earnings of $12.40.

Example: Suppose that you invest 12 tokens in the RED investment and 8 tokens in the BLUE investment. Suppose that the 3 other members of your group invest 12, 16, and 8 tokens in the BLUE investment respectively. This makes a group total of 44 tokens. Your return from the BLUE investment would be $8.80. The other 3 members of the group would also get a return of $8.80 from the BLUE investment. Your initial payoff from this stage would be: 12*($0.30) + (12+ 8+ 16+ 8)*($0.20)=$12.40

You invested 8 tokens to the BLUE investment, so you and the other player that invested 8 tokens tied for being the lowest investors to the BLUE investment. Thus, you (and the other player that invested only 8 in the BLUE investment) will have a payoff deduction. The size of the deduction will be $0.30 plus the difference between your initial earnings and the next lowest investor in the BLUE investment. The next lowest investor in your group invested 12 tokens in the BLUE investment and earned $11.20. In this example that would mean your deduction would be $0.3+ ($12.40-$11.20)= $1.5. Your Stage 2 net earnings will be your initial earnings of $12.40 minus your deduction of $1.5, which in total equals $10.9. You will be told that you were the lowest investor when your period earnings are reported to you.

Example: Suppose that you invest 0 tokens in the RED investment and 20 tokens in the BLUE investment. Suppose that the 3 other members of your group invest 20, 20, and 20 tokens in the BLUE investment respectively. This makes a group total of 80 tokens. Your return from the BLUE investment would be $16.00. The other 3 members of the group would also get a return of $16.00 from the BLUE investment.

Everyone invested all their 20 tokens to the BLUE investment, so there is no lowest investor to the BLUE investment. In this specific case even though there is a computer simulated Administrator, no one will have a payoff deduction. Your payoff for Stage 2 of this period will be $16.00.

Your earnings for the last 10 periods are computed by the following formula:

Earnings = ($0.30)*(Your investment to the RED investment) + ($0.20)*(Total group investments to the BLUE investment) – (Payoff Deduction if you are the lowest investor to the BLUE investment)

Your Group

For each decision period you will be in a group of 4 people in the room today. As a result, each period you will be with a new group of 4 participants. The probability that you will ever be in the same group of 4 participants again is extremely remote.

Your Earnings

Once all your decisions in the 20 periods have been made, we will randomly select one of the 20 periods as the period that-counts. We will use the period-that-counts to determine your actual earnings. Note, since all periods are equally likely to be chosen, you should make all your decision in each period as if it will be the period-that-counts.

Things to Remember

- You will be in a group of 4 people
- You will have automatic earnings of $0.40 each period
- You will have 20 tokens to invest each period
- Each token you invest in the RED investment earns you $0.30

- Each token you invest in the BLUE investment earns you and every member of your group $0.20
- The groups will be randomly re-matched every decision period.
- You group will be monitored by a computer-simulated Administrator
  - The Administrator will be responsible for taking a deduction from the earnings of the lowest investor in the BLUE investment.
  - The deduction will equal to (the earnings of the lowest BLUE investor) – (the earnings of the second lowest BLUE investor) + $0.30.
  - If several people are tied for the lowest investor, all will receive a deduction from their earnings.
  - If all people in the group invest all 20 tokens in the BLUE investment, then no one will receive a deduction.
- Please feel free to use the calculator, and scratch paper provided to help you with your calculations.

If you have any questions about the instructions please raise your hand and someone will come and speak with you privately about your question

Thank you. Please wait to be told when you can begin making decisions for the next 10 periods.