Group Size Effect and Over-Punishment in the Case of Third Party Enforcement of Social Norms

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Abstract: One of the important topics in public choice is how people's free-riding behavior could differ by group size in collective action dilemmas. This paper experimentally studies how the strength of third party punishment in a prisoner's dilemma could differ by the number of third parties in a group. Our data indicate that as the number of third party punishers increases in a group, the average punishment intensity per third party punisher decreases. However, the decrease rate is very mild and therefore the size of total punishment in a group substantially increases with an increase in group size. As a result, third party punishment becomes a sufficient deterrent against a player selecting defection in the prisoner's dilemma when the number of third party punishers is sufficiently large. Nevertheless, when there are too many third party punishers in a group, a defector's expected payoff is far lower than that of a cooperator due to strong aggregate punishment, while some cooperators are even hurt through punishment. Therefore, the group incurs a huge efficiency loss. Such over-punishment results from third party punishers' conditional punishment behaviors: their punishment intensity is positively correlated with their beliefs on the peers' punitive actions. Some possible ways to coordinate punishment among peers even when group size is very large, thus enabling the efficiency loss to be mitigated, are also discussed in the paper.

Keywords: experiment, cooperation, third party punishment, dilemma, group size effect

JEL codes: C92, D72, D78, H41

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1. Introduction

Initiated by the influential work by Olson (1965) – *Logic of Collective Action*, substantial efforts have been devoted by scholars in the field of public choice as well as on experiments for the study of the so-called group size paradox. Among others, Pecorino (2015) classifies Olson's group size paradox into two versions: strong and weak.[1] The strong version is a claim that, with the assumption of benefit rivalry, the aggregate level of voluntary provision of public goods may be smaller the larger the size of a group. This claim does not hold theoretically if a pure public good is considered. By contrast, the weak version is a claim that holds theoretically for the case of pure public goods in addition to impure public goods. It states that the gap between the socially optimal level and equilibrium level of public goods provision widens as group size increases.

An extensive volume of experimental research has tested the validity of such group size effects using a number of setups, for example in prisoner's dilemmas (e.g., Hamburger *et al.*, 1975; Fox and Guyer, 1977), linear voluntary contribution mechanisms (e.g., Isaac *et al.*, 1984; Isaac and Walker, 1988; Isaac *et al.*, 1994; Nosenzo *et al.*, 2015) and non-linear voluntary contribution mechanisms (e.g., Marwell and Ames, 1979; Guttman, 1986). It indicates that the level of total voluntary contribution amounts or the number of cooperators increases in a dilemma as group size increases because an increase in group size does not affect, or at most only mildly decreases, individual cooperation behaviors (it may even enhance individual cooperation behaviors under some conditions). This paper contributes to this strand of the literature by providing new evidence on the small impact of group size on individual sanctioning behaviors for the case of third parties' altruistic punishment activities in a prisoner's dilemma and discusses what kind of impact the group size paradox may have on a society.

Third party enforcement or punishment is referred to as punishment imposed on a norm violator by those who are *not* directly involved in the relevant transaction. Community's third

[1] There are a number of other review papers for Olson's work, including Congleton (2015) and Sandler (2015).

party enforcement mechanism is recognized as important as an *informal contract enforcement institution*, along with many other mechanisms such as reputation mechanisms and information transmission network.[2] The informal contract enforcement is not built on the codification by the government, but rather based on factors such as norms and beliefs. The literature discusses that such informal enforcement, together with formal institutions (e.g., legal), facilitates people's exchanges, even anonymous ones, although its relative importance depends on the contexts (e.g., Greif, 1997; Dixit, 2004). Even in an economy with well-developed legal systems, informal enforcement could enhance the efficiency of formal institutions and lead to economic development, for example by promoting pro-social behaviors of both citizens and bureaucrats.[3] In addition, people may even choose to overcome conflicts and opportunism using informal enforcement mechanisms, such as community punishment via gossiping, without resorting to the coercive legal authority (e.g., Ellickson [1991] for the cattle-trespass case in Shasta County, California).[4] In an economy with weak formal institutions, informal enforcement may be the key for successful cooperation to happen. For instance, Mathew and Boyd (2011) found that in warfare in Turkana societies, which lacked formal political institutions, individuals who demonstrated cowardice and deserted from combat were not only subject to verbal punishment by age-mates, women, and seniors, but were also punished by a sufficient number of third parties (the violator's age group) when the community collectively decided to impose corporal punishment through consensus. Warriors who raid another Turkana territorial section could also

[2] The theoretical literature explains that even without any institutions or coordination devices, a community's decentralized punishment enables community members to sustain cooperation in their infinitely repeated interactions with stranger matching if they are sufficiently patient (e.g., Kandori, 1992; Ellison, 1994).

[3] Without well-developed informal institutions, a country may not be able to achieve economic development even if strong formal institutions are successfully established, because governments may select an inefficient or sub-optimal system that benefits the state (e.g., Williamson, 2009). The importance of informal institutions can also be seen with the evidence that high levels of social norms, such as citizens' trust and respect for others, are positive predictors for a region's per capita output (e.g., Tabellini, 2010).

[4] In common pool resource problems, self-organized regimes by those involved frequently outperform formal regimes operated by the government (e.g., Ostrom, 2000). An empirical study that includes both measures of formal and informal institutions indicates that a high quality of informal institution, rather than formal legal systems, may be the key channel that leads to more secure property rights (e.g., Williamson and Kerekes, 2011). One reason for the higher efficiency of private ordering compared to the formal legal system in cases of disputes is the high costs of using the latter, including the time required for the formal authority to enforce a judgement, the courts' limited ability to obtain verifiable information, and a possible low precision of the judgement (e.g., Dixit, 2004).

be subject to third party sanctions, which positively affected warriors' large-scale cooperation behaviors.[5,6] Another example is that third party punishment by ordinary individuals, combined with ad hoc courts and the Althing (an assembly which publicly designates rules), helped support societies' stability and prosperity in medieval Iceland despite the lack of a coercive authority (e.g., Hadfield and Weingast, 2013). Third party enforcement also disciplines behaviors of individuals and firms in business communities (e.g., Nicholas and Maitland, 2007). For instance, in countries with no or only weak formal institutions in the past (e.g., Vietnam in the 1990s), agents created information sharing systems (including blacklisting), by which those who were untrustworthy or opportunistic were informally punished by a number of potential business partners, for instance through ostracism (e.g., McMillan and Woodruff, 1999a, b).[7,8] Such third party punishment can be motivated not only by possible future material benefits but also by purely non-material incentives (e.g., inequity aversion [e.g., Fehr and Schmidt, 1999], (dis)esteem [e.g., McAdams, 1997], guilt [e.g., Cooter, 1996], anger towards violators [e.g., Nelissen and Zeelenberg, 2009]).

With the methodological advancement in laboratory experiments over the last twenty years, scholars have extensively studied possible drivers of third party punishment using controlled experiments. Among others, one established piece of evidence is that even though third parties do *not* receive any material gains immediately or later, some people do take such costly actions towards those who violate norms (whether distributive or cooperation norms). Possible mechanisms behind the third party enforcement of cooperation norms can be examined by using a prisoner's dilemma game setup with a third party punisher (e.g., Fehr and

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[5] Third parties have been shown to inflict punishment on a norm violator regardless of the group affiliation, even if it is costly. However, they inflict stronger punishment on a norm violator if the victim of the norm violation belongs to the same social group as the punisher than otherwise (e.g., Goette *et al.*, 2006).

[6] Third party punishment has been recognized as important to enforce cooperation norms, especially in a large-scale society (e.g., Henrich *et al.*, 2006; Marlowe *et al.*, 2010).

[7] In medieval Europe, private judges called "law merchants" combined with ostracism taken by a number of third party merchants deterred merchants' opportunistic behaviors. See Milgrom *et al.* (1990) and Greif (1993).

[8] Information now spreads more easily among people with the aid of digital media. People frequently encounter misdeeds on the internet, and the moral norm violators can be severely attacked through gossiping, shaming and verbal punishment, online as well as offline, by numerous disinterested third party observers. This behavior could benefit our societies as it may let people realize that some acts are socially unacceptable (e.g., Crockett, 2017).

Fischbacher, 2004). With such a framework, past research has conducted experiments where there are only one, or at most two, third party punishers in a group, and it has been shown that third parties more frequently and more strongly inflict punishment on a defector who exploited a cooperator than on any other type of player, even if the interaction is one-shot and they never directly interact with the punished during the experiment (e.g., Fehr and Fischbacher, 2004; Kurzban *et al.*, 2007; Lergetporer *et al.*, 2014; Kamei, 2017b).[9,10] This suggests that interdependent preferences (e.g., inequity aversion), besides potential future material gains to be obtained within the community, indeed drive third party punishment. However, the past work leaves two important questions unanswered. First, what happens to the levels of individual and aggregate punishment if the number of independent third parties grows in an interaction unit? Second, why do some societies, such as Turkana in the above example, or some societies before the emergence of states (e.g., medieval Iceland), have some rules to determine the size of aggregate punishment towards norm violators? The answer to this question could be related to the group size paradox explained earlier. If the punishment strength per third party does not decrease or decreases only mildly as the number of independent third party punishers grows, third party punishment could be a greater deterrent against players' opportunistic behaviors in a dilemma when there are a sufficiently large number of third party players. However, having too many uncoordinated third parties could be harmful to a society because a norm violator may receive very strong punishment in aggregate from uncoordinated third parties far beyond the threshold level that makes selecting defection not materially beneficial. It is true that social welfare can improve if the community achieves high cooperation norms through punishment. However, such heavy aggregate punishment means that (a) punishers' welfare decreases due to unnecessarily high punitive costs and also that (b) the society may incur a loss from the strong

[9] Third party punishment is shown to be weaker than second party punishment [i.e., a direct punitive action that an agent takes toward her interaction partner].
[10] See also Carpenter and Matthews (2012).

punishment imposed on the norm violators.[11] Or worse, we may even have perverse punishment, such as punishment of cooperators, in a very large group.

In almost all societies around the world, we in fact observe informal enforcement of rules with strong punishment, and also "misdirected" punishment, by a group of individuals, sometimes in the form of mob or vigilante justice, regardless of the quality of formal institutions.[12] However, despite such common observations and the empirical literature on the group size paradox, to our knowledge, the issue of possible third parties' over-punishment has not been central to the theoretical discussions of punishment in relation to group size. Besides, there is little consensus regarding whether third parties free ride on others' punitive acts. For example, the theoretical work on law and public choice proposes that third parties' enforcement systems could have legal attributes. For instance, Hadfield and Weingast (2012, 2013), in re-defining law, explain that the classification of a behavior as wrongful as well as the enforcement of punishment can be made through "decentralized collective punishment," which they define as "independent and simultaneous decisions made by individual actors (nonofficial) to punish a wrongdoer," without requiring formal legal institutions such as a police force. Nevertheless, they argue that a device for coordination would be required for third parties to initiate punishment because (a) there would be no incentives for them to engage in punishment as it is a costly act and (b) each punisher has an idiosyncratic reasoning.[13,14] By contrast, some of the literature that considers non-material motives (e.g., Coorter, 1996; McAdams, 1997) instead suggests that the free-riding problem can be easily resolved if there are a sufficient number of third parties

[11] What exactly is optimal regarding the size of punishment is debatable. While punishment should be a deterrent against norm violations, there is a view that a loss incurred by the punished is a form of economic cost. For example, Becker (1968) discusses that in the case of crime, the economic costs of punishment include not only costs on punishers' sides, but also foregone wages imprisoned offenders could otherwise earn in societies.
[12] Mob justice is observed in almost any country. However it more frequently occurs in some countries, for example, countries in Africa and India. For instance, in Kenya more than 500 people were killed by furious crowds for their wrongdoing in 2011 (Krinninger, 2016).
[13] Ancient Athens (e.g., Lanni, 2009; Carugati *et al.*, 2017) and medieval Iceland (e.g., Hadfield and Weingast, 2013) are discussed as examples. We note that, as explained in footnote 2, theoretically third parties' punishment could emerge as an equilibrium behavior without any institutions if interactions in a given community infinitely or indefinitely continue and people are sufficiently patient.
[14] Masten and Prüfer (2014) discuss that courts and community enforcement are complementary in the sense that community enforcement works best for low value transactions while courts function for high value transactions.

because then the cost each person must share for the punishment becomes small enough. This paper fills the gap between the empirical literature on the group size paradox and the theoretical literature by studying whether third parties' free-riding in fact happens, to what extent if so, and what kind of coordination mechanism may be required considering their behavioral pattern.

In our experiment, there are two players who play a prisoner's dilemma game (PD players, hereafter) in each group along with third parties. In this paper, the phrase "third parties" is used interchangeably with "third party players" and "third party punishers." We vary the number of (independent) third parties in each group: one, two, four and ten. Each third party player can reduce the payoffs of the PD players based on their interaction outcomes, but the punishment acts are costly.

The experiment shows that first, consistent with past research, third parties are more likely to impose strong punishment on a norm violator (a defector who exploited a cooperator) than on a player in any other scenario. Second, punishment intensity per individual third party decreases as the number of third parties increases in a group. However, the decrease rate is only mild, and therefore, third party punishment is in aggregate strong enough to prevent a PD player from defecting when there are at least four third parties. However, if a group has too many third parties (ten in a group), the group suffers from a large efficiency loss due to (a) over-punishment of norm violators and (b) perverse punishment of cooperators. This implies that some institutions that *limit, not encourage,* third parties' punishment behaviors are desirable.

Using an additional experiment, we discuss that the small impact of group size on the punishment intensity per third party player results from third parties' conditional punishment behaviors. The conditional punishment hypothesis assumes that third parties are concerned about inequality with other third parties. Our data show that (i) third party players' punishment targeted at a PD player is positively correlated with their beliefs regarding other third party players' punishment behaviors, and that (ii) they believe that others strongly punish defectors.

This paper further discusses people's ability to democratically mitigate the coordination failure. As an illustration, we show that people can not only eliminate some peers' perverse punishment of cooperators, but can also alleviate over-punishment of norm violators once we allow third parties to democratically regulate their punishment activities through voting. This explains why some societies (e.g., Turkana) have rules to collectively decide the level of punishment to norm violators. This also suggests that, in reality, having a large group size may not be harmful if there are mechanisms for third parties to coordinate their punishment activities.

The rest of the paper proceeds as follows: Section 2 provides the experimental design. Section 3 summarizes the related experiments on group size effects. Section 4 reports the results. Section 5 provides results on third parties' conditional punishment behaviors, and Section 6 explains how the rule-making by third parties could help them coordinate punishment in the case where the group size is large. Section 7 concludes.

2. The Experimental Design

The experimental design is based on a prisoner's dilemma game with third party punishment (Fehr and Fischbacher, 2004). We use a within-subjects design. One advantage of using a within-subjects design is that we can control for individual characteristics thoroughly when identifying group size effects because we compare the behaviors of the same subjects between different group sizes. There are four treatment conditions. Each subject makes third party punishment decisions under all of the four treatment conditions in sequence. The order of the four conditions is randomly determined for each experimental session.[15]

The four treatment conditions have the same structure, except for the number of third party punishers in a group, which is one, two, four or ten (Section 2.1).

2.1. The Structure of Each Treatment Condition

At the onset of each treatment, each player is informed of group size N (3, 4, 6 or 12). Each treatment consists of two stages. We use a strategy method to collect as many observations as possible. In the first stage, each player is asked to assume that (i) the player is endowed with 25 points and is matched with another player in their group and (ii) the number of third party

[15] Each treatment condition was called "period" in the experiment (see Appendix B.1).

punishers is $N - 2$. They are then asked to decide whether or not to send 10 points to the counterpart. The amount sent is tripled and becomes the payoff for the counterpart. The strictly dominant strategy for a player is to keep 10 points since the sender's payoff would be reduced if she sends it. However, the social optimum is achieved when both players send 10 points to each other. Thus, this is a prisoner's dilemma game (Fig. 1). As in Fehr and Fischbacher (2004), PD players do not have a direct punishment opportunity in order to study the pure role of third party punishment in enforcing cooperation norms.

The prisoner's dilemma describes the tension between cooperation and defection using a simple format. Examples include a person's relationship with a neighbor where one has to decide whether to fulfill or not fulfill her responsibility (e.g., the cattle-trespass case in Shasta County [Ellickson, 1991]), a business relationship with her partner where one has to decide whether to keep or break an industry norm (e.g., the secrecy norm in the diamond market [Bernstein, 1992]), and a person's relationship with another member where one has to decide whether to comply with or break a society's norm or non-binding ordinance (e.g., the community's norm regarding livestock raids in another community in Turkana [Mathew and Boyd, 2011]). It also describes the nature of international politics, such as the tension between two countries regarding military competition (e.g., expand or shrink a military budget), trade conflict (e.g., protest or open a market), and voluntary cooperation in the case of crisis (e.g., support or not support a neighboring country in the event of a massive natural disaster).[16] There are usually third parties that are not directly involved in the relevant prisoner's dilemma interaction in these examples.

In the second stage, each player is asked to assume that (i) they are endowed with 40 points and (ii) they are assigned the role of third party punisher. They are then asked to independently and privately decide how many punishment points they wish to impose on each of

[16] The advantage of using a prisoner's dilemma game is its simplicity without losing the important nature of people's tension between two parties. Theoretical studies on third party enforcement of norms often use prisoner's dilemma game setups (e.g., Milgrom *et al.*, 1990; Kandori, 1992; Ellison, 1994). Nevertheless, we acknowledge that some people's interactions can be better described as a two-person public goods game (a near-continuous version of the prisoner's dilemma game).

the two PD players.[17] Specifically, they are asked to choose punishment actions under the following four scenarios, on the condition that they are aware of each PD player's action choices without any noise:[18]

Scenario (a): how many punishment points the player would like to impose on a player who sent 10 points while the matched player also sent 10 points;

Scenario (b): how many punishment points the player would like to impose on a player who did not send 10 points while the matched player sent 10 points;

Scenario (c): how many punishment points the player would like to impose on a player who sent 10 points while the matched player did not send 10 points;

Scenario (d): how many punishment points the player would like to impose on a player who did not send 10 points while the matched player also did not send 10 points.

As in Fehr and Fischbacher (2004), the punishment points to a target must be an integer between 0 and 20. For each punishment point a third party player assigns to a PD player, one point will be deducted from the third party player and three points will be deducted from the target. When the payoff of a PD player is negative, it is set to zero.

Note that as the number of third parties in a group increases, the per-person cost of imposing a given punishment level falls. The costs per third party to impose one punishment point on a PD player are 1, 1/2, 1/4, and 1/10 when the numbers of third parties are one, two, four and ten, respectively. Thus, if income effects are present, third parties' free-riding problem could theoretically be more easily resolved for a larger group size. Nevertheless, a coordination issue could occur as third parties do not know the strength of the punishment that their peers inflict.

[17] Kamei (2017b) studied how the behaviors of two-person pairs who jointly make single punishment decisions through communication differ from those of independent third party individuals. The study showed that there are no differences in the pattern and strength of punishment between the pairs and individuals. Kamei (2017b) also studied whether raising the visibility of punishment actions among independent third parties may enhance their punishment strength, finding an affirmative result.

[18] This strategy method was also used in Kamei (2017b). Using a dictator game with third party punishment, Jordan *et al.* (2016) showed that the strength of third party punishment is not influenced by manipulating the use of the strategy method, compared with letting third parties decide what to punish after learning dictators' action choices.

As there are four treatment conditions, all subjects make sending decisions as a PD player and punishment decisions as a third party punisher four times in the format of the strategy method.

2.2. The Experiment

Subjects are asked to make decisions four times, each with a different group size, in sequence, without being provided any feedback regarding previous treatment conditions. All decisions are incentive-compatible. Once all subjects go through the four treatment conditions, the computer will randomly select one treatment condition for payment calculation. The conversion rate is: 6 points = 1 pound sterling. Subjects will then be randomly assigned to a group of a given size as well as randomly the role of either a PD player or a third party player. If a subject is assigned the role of PD player, the player's choice already made assuming the role of PD player will be used in the interaction. If a subject is assigned the role of third party punisher, the player's choice under one of the four scenarios (scenarios (a), (b), (c) and (d)) will be used to punish each PD player in the group, dependent on the actual sending decisions of the PD players.

We note that third parties in the experiment do not receive any material gains through punishment, although they incur costs for imposing punishment. In most real-world situations described in Section 1, however, third parties are members of a given community and can indirectly benefit from their punitive actions. Thus, we can interpret the punishment intensity we measure in this study as a conservative estimate; therefore, this setup will suffice our aim to study the role of third party punishment in the evolution of cooperation, as in past research (e.g., Fehr and Fischbacher, 2004; Kamei, 2017b).

We also note that all individual-level data are treated as independent because we employ the strategy method and subjects are not given any information feedback on their decisions until the end. This would help secure a high statistical power to study group size effects.[19]

2.3. Experimental Procedure

[19] Using a between-subjects design is not practical because we aim to compare PD players' and third parties' behaviors among four different group sizes, and the largest group size is 12.

All experimental sessions were conducted at the Centre for Experimental Economics Laboratory at the University of York in the United Kingdom in May and June 2017. There were three sufficiently high partitions (one in front and two on the sides) between each desk. A total of 144 students there participated in the experiment (Table 1). Invitation messages were sent to all eligible subjects in the database in *hroot* (Bock *et al.*, 2015); subsequently subjects voluntarily registered for and participated in the experiment. The experiment was programmed with the z-Tree software (Fischbacher, 2007). The experiment (including subject payment) lasted around 50 minutes on average. The average payment was 8.44 pounds sterling. With the same experimental procedure, two additional experiments were conducted from August through October 2017 (see Sections 5 and 6). In total, 96 students at the University of York participated in the additional sessions (Table 1).[20] All the instructions were neutrally framed. Words with positive or negative connotations (e.g., "punish;" "cooperate") were avoided (see Appendix B for the instructions).

3. Related Literature on Group Size Effects

A large volume of experimental literature in dilemma situations has documented that people's free-riding behaviors may depend on group size. However, the impact of group size depends on the formats of the games. First, there is a classic body of work on *N*-person prisoner's dilemma games. It indicates that as the group size increases the percentage of subjects selecting cooperative actions tends to decrease but the total number of cooperators increases (see, e.g., Hamburger *et al.* [1975], Fox and Guyer [1977]).[21]

Initiated by Isaac and Walker (1988), scholars have also studied group size effects using voluntary contribution mechanisms (also known as public goods games). Past research has found that the aggregate level of contributions increases as group size increases, similar to the finding

[20] The number of subjects per session was 24, except for two sessions in the original treatment and two sessions in the Voting treatment (it was 12 for these four sessions due to a low show-up rate).
[21] Group size effects on the percentage of subjects selecting cooperative actions appear to depend on the payoff matrix. Some studies found that group size did not affect subjects' selection of cooperative actions (e.g., Franzen, 1995; Komorita *et al.*, 1980). See also Bonacich *et al.* (1976), who showed that the sign of group size effects may depend on payoff matrices.

in the *N*-person prisoner's dilemmas. Results on the level of individual contributions, however, differ depending on which experimental parameters are used: the size of the Marginal Per Capita Return (MPCR) and the type of voluntary contribution mechanism, among others. On the one hand, in linear voluntary contribution mechanisms (VCMs) with low levels of MPCRs, the level of individual contributions does not decrease, or may even increase, as group size increases (e.g., Isaac *et al.*, 1984; Isaac and Walker, 1988; Isaac *et al.*, 1994; Nosenzo *et al.*, 2015).[22,23] However, on the other hand, when the MPCR is high in linear VCMs, the level of individual contributions decreases, or at most stays at similar levels, as group size increases (see again, e.g., Isaac and Walker, 1988; Isaac *et al.*, 1994; Nosenzo *et al.*, 2015). The latter finding is somewhat similar to the results in *N*-person prisoner's dilemmas. Our paper studies the impact of group size on third party punishment. Notice that the material return for third parties from punishment acts is zero in our case. Thus, the behaviors of third party punishers may be closer to what is seen with low MPCRs: the level of individual punishment may not decrease as group size increases.

The impact of group size has also been studied using non-linear VCMs. Past experimental research found phenomena that are similar to what we see with linear VCMs or *N*-person prisoner's dilemmas: the level of individual contributions decreases only to a small degree, and thus the size of aggregate contribution amount increases, as group size increases (e.g., Marwell and Ames, 1979; Guttman, 1986). Field studies provide similar results. For instance, Goetze *et al.* (1993), using data on voluntary contributions to public broadcasting, show that per household contribution amount declines but the aggregate contribution amount increases as the number of households that receive television signals increases.

Compared with studies using prisoner's dilemma games or VCMs, to our knowledge, there are a relatively small number of studies into the effect of group size on punishment. The impact of group size on direct punishment has been studied by Carpenter (2007), who found that

[22] Lipford (1995) provides field evidence that per member contribution amount to a church does not decline as the membership increases.
[23] See Zelmer (2003) for a meta analysis, which finds that, on average, group size is a positive predictor for the mean contribution in a group.

individual expenditure on second party punishment decreases as group size increases. Regarding third party punishment, the closest studies to ours are Lewisch *et al.* (2011) and Kamei (2017b). Lewisch *et al.* (2011) studied the impact of group size in the case where third parties can punish a dictator who plays a dictator game. They found that the average strength of individual punishment to dictators decreases but the strength of aggregate punishment increases as the number of third parties in a group increases from one to two. Kamei (2017b), using prisoner's dilemma games as second party interactions, found a similar phenomenon in a specific setup where each third party punisher's action is made known to the other punisher in the group (see the I-P-P and 2-I-P-S treatments). These two studies compared punishment strength between one and two third party punishers only. In contrast, the present paper studies group size effects by systematically changing the number of third parties and also by exploring the driving forces behind the group size effects observed in the laboratory.

4. Result

This section is devoted to the analysis of the experimental data. We will first report the behavior of PD players (Section 4.1). We will then study how the group size affected third parties' punitive actions (Sections 4.2 and 4.3).

4.1. Sending Decisions of PD Players

PD players' decisions to send are affected by the number of third party punishers per group. As shown in Fig. 2, the percentage of PD players who chose to send 10 points monotonically increases as the number of third party punishers increases in a group. The percentage is 47.9% when the group size is three, whereas it is 70.8% when the group size is 12.

In order to study the statistical significance of the group size effect, we conducted a regression analysis with the dependent variable being a dummy that equals 1 if a subject sends 10 points to the partner, and 0 otherwise. The independent variables include three group size dummies (the reference group is subjects' sending decisions when the group size is three). As shown in Table 3, the percentages of subjects that send 10 points are significantly larger when the group size is six or 12, compared with when the group size is three or four (see column (1)).[24]

Result 1: *The higher the number of third party punishers there are in a group, the greater likelihood that PD players will send 10 points to their partners.*

4.2. Third Party Punishment and Group Size

We now move on to the behaviors of third parties. Table 2 reports the frequency of punishment as well as the average punishment points per third party player, by scenario and by group size. We will first compare third parties' punishment behaviors between scenarios and will then study how their punishment behaviors in a given scenario are affected by group size.

4.2.1. Comparison between different scenarios

Three clear phenomena were found. First, third party punishment is widespread, in agreement with past research (e.g., Fehr and Fischbacher, 2004; Kamei, 2017b). In particular, third party punishment is more frequently imposed when third parties encounter an unfair economic transaction (i.e., scenario (b)) than in any other situation (see Table 2(I)). The frequency of third party punishment in scenario (b) is greater than 50%. The difference in the frequency between scenario (b) and any other scenario is significant (Appendix Table A.2). This result holds regardless of group size. Second, the same holds also when we use punishment strength for comparisons, for each group size. The average punishment points that third parties impose are significantly stronger in scenario (b) than in any other scenario (Table 2(II), Table A.2). Third, not only the frequency of punishment but also the punishment intensity in scenario (d) is significantly stronger than in scenario (a) [Table 2, Table A.2]. This holds for each group size. This is also consistent with past studies (e.g., Fehr and Fischbacher, 2004; Kamei, 2017b).

Result 2: *(i) Regardless of group size, third parties impose punishment significantly more frequently in scenario (b) than in other scenarios. (ii) The punishment intensity in scenario (b) is*

[24] We also conducted a regression while having a group size variable (= 3, 4, 6, 12) instead of the treatment dummies as an independent variable. This shows that the group size variable is a significantly positive predictor for PD players' decisions to send.

also significantly stronger than in other scenarios. (iii) Not only the frequency of third party punishment, but also the punishment intensity, is stronger in scenario (d) than in scenario (a), for each group size.

Result 2 implies that the behavioral findings in the past research, including Fehr and Fischbacher (2004), extend to different group sizes.

4.2.2. Comparison between different group sizes

How do the third parties' punishment behaviors differ by group size? We found that punishment patterns are similar between different group sizes (Result 2), but there is an interesting pattern for scenario (b). Table 2 shows that while the frequencies of punishment in scenario (b) do not change by group size, the punishment strength per third party seems to decrease, although only to a small degree, as the number of third parties in a group increases. We take a regression approach to investigate whether the decrease in the punishment strength is significant (see column (2) in Table 3). The dependent variable is the punishment points that third party punisher *i* imposes on a defector in scenario (b). Group size dummies are included as independent variables. The estimation indicates that per third party player punishment strength in scenario (b) is significantly weaker for group sizes of 4 and 12 than for a group size of 3. It also shows that the strength is significantly weaker for a group size of 12 than for a group size of 6.[25,26] However, the decrease rate is small, and each third party on average imposes sizable punishment even with a large group size. We also explored whether such a group size effect is present in third parties' punishment acts in scenarios (a), (c) and (d). However, we did not find significant correlations between punishment strength and group sizes in those three scenarios (Appendix Table A.4).

[25] Although third parties played the game under different group sizes in a random order (see Section 2), there was a chance that their behaviors were affected by the orders of group sizes realized. A close look at the data indicates that third parties' punishment behaviors were not affected by such possible order effects. As shown in Appendix Table A.3, we performed regressions while controlling for the ordering of realized group sizes. The estimation reveals almost the same results as Table 3.

[26] See again Table 2. We also conducted a regression with a group size variable (= 3, 4, 6, 12), instead of group size dummies, being an independent variable. The estimation shows that per third party player punishment strength in scenario (b) decreases significantly as the group size increases.

Result 3: *(i) The third party punishers' punishment strength in scenario (b) significantly decreases as the number of the punishers increases in a group, but the decrease rate is very small. (ii) Such a group size effect is not observed in scenarios (a), (c) and (d).*

Punishment activities in scenario (b) play a key role in limiting norm violations. Because of Result 3(i), the total punishment points received by a PD player in scenario (b) [i.e., average punishment points in Table 2(II), multiplied by $N - 2$ (the number of third parties)] is significantly increasing with N (see Appendix Table A.5). Such strong positive correlations can also be seen with punishment in scenario (d). These suggest that third party punishment is more effective in limiting the opportunistic behavior of PD players the more third party punishers there are in a group.

Result 4: *The larger number of third party punishers there are in a group, the more strongly norm violators are punished.*

The fact that punishment intensity per third party declines only mildly, and thus the level of aggregate punishment increases, as the group size grows implies that past findings on group size effects from *N*-person prisoner's dilemmas and voluntary contribution games, overviewed in Section 3, hold also for the case of third party punishment.[27] This result, nevertheless, has both positive and negative implications for a community, as will be explained in Section 4.3.

4.3. Incentive Changes with Third Party Punishment

[27] As an anonymous referee pointed out, the use of the strategy method where everyone selects to cooperate or defect in addition to third party punishment decisions (see Section 2) before the actual role is assigned may potentially have increased the punishment strength because third parties may have realized the virtue of mutual cooperation through the cooperation decisions they made, which could be in effect if they were assigned the role of PD player in the experiment. However, while we cannot say that as in Fehr and Fischbacher (2004) our third party players are fully disinterested third parties, they are still less affected in the first-stage prisoner's dilemma decisions than most of third parties in the real-world situations where they are members of the community, considering that our third parties do not interact with others as PD players, nor are they informed of possible results of the games. (For example, in the cattle-trespass case in Shasta County [Ellickson, 1991], all ranchers decide whether or not to build fence and they also learn what their neighbors or others decide.) If the third parties were directly involved in the prisoner's dilemma other than the relevant dilemma interaction, as is the case with the real-world examples, we can imagine that the punishment level could be even higher. Our results could therefore still be treated as a conservative estimate.

How effective is third party punishment to stop a PD player from selecting defection? To explore this question, we first examine how the incentives of the PD player change because of punishment. Panel (A) of Fig. 3 shows the payoff matrix for each group size when the average total reductions that PD players received are considered.[28] This reveals a clear impact of third party punishment. When the group size is three, defection (not sending 10 points) is the strictly dominant strategy for a PD player, and the unique Nash Equilibrium (NE) is mutual defection. When the group size is four, defection is no longer the strictly dominant strategy, and the situation a PD player faces is a coordination game, where both mutual cooperation and mutual defection are Nash Equilibria (NEs). When the group size is six or 12, cooperation (sending 10 points) is the strictly dominant strategy for a PD player, and mutual cooperation is the unique NE.

Second, we calculated the expected payoffs when a PD player selects to cooperate as well as when the player selects to defect, as in Kamei (2017b). We can do so by calculating the expected payoff from each action choice using the percentage of cooperators in the samples (Fig. 2) and average payoffs for the four scenarios (panel (A) of Fig. 3). Three clear patterns were found (see panel (B) of Fig. 3). First, the expected payoff from selecting defection monotonically decreases as the number of third party punishers in a group increases. When the number of third party punishers is four or ten, a PD player would receive a higher expected payoff when she selects to send 10 points compared to when she does not do so.[29] Second, however, we observe *over-punishment* when the group size is 12 since third parties' inclinations to punish are not that sensitive to the number of third parties present in a group (Result 3(i)). In this treatment condition, a defector would not even obtain a positive payoff. This means that the third parties had unnecessarily high costs for punishment. This implies that we may need some institutions

[28] Average reductions due to punishment points received, calculated based on Table 2, were subtracted from the stage 1 payoff in each scenario.

[29] In Kamei (2017b), third party punishment was a sufficient deterrent even when there were only two independent third party punishers per group, in a setup where each punisher's punitive actions were made known to the other punisher in the group. This suggests that the results in the present experiment could be at the lower end of people's punishment intensity considering that punitive actions were not at all revealed to peer punishers in the present paper.

that help third parties coordinate punitive acts in order for these to inflict punishment efficiently. Third, due to some third parties' punishment of cooperators, even cooperators would be hurt severely in expectation if there are a large number of third party punishers (see also Appendix Table A.5). The expected payoff from selecting cooperation when there are ten third parties is 13.42 points, which is around half the expected payoff from selecting cooperation when the number of third parties in a group is one (26.60 points) [see again panel (B) of Fig. 3].

Result 5: *The relative advantage for a PD player to select defection compared with cooperation decreases as the number of third party punishers in a group increases. The expected payoff is lower when she selects defection than when she selects cooperation if the group size is six or 12. When the group size is 12, however, the total punishment is so large that a defector does not obtain a positive expected payoff, and even a cooperator can be hurt by perverse punishment.*

5. Causes of Over-punishment with Large Group Size

We found that third party punishers tend to free ride on others' punitive actions as the number of third party punishers in a group increases (Result 3(i)). However, the free-riding behaviors are very weak; accordingly, third party punishment as a whole becomes a sufficient deterrent if there are a sufficiently large number of third party punishers in a group (Result 5). Due to this, our data showed two issues of third party punishment. First, when the number of third party punishers is too large, cooperators could be hurt severely by some punishers' perverse punishment. Second, norm violators could be heavily punished in a very large group, making their payoffs far below zero (Fig. 3).

In our view, there are two potential reasons for the third parties' low level of free-riding behavior:

(i) Third parties believe that other third parties spend large amounts on punishing PD players (e.g., Fischbacher *et al.*, 2001; Fischbacher and Gächter, 2010; Kamei, 2014, 2017a).

(ii) Third parties enjoy the act of punishment itself (e.g., Casari and Luini, 2009; Fudenberg and Parag, 2010).

There is past experimental evidence that supports both explanations. First, people are known to be conditionally cooperative upon others' cooperation behaviors (e.g., Fischbacher and Gächter, 2010). In the context of punishment, in their second party interactions agents impose direct punishment on norm violators positively proportional to other punishers' punishment acts, even if such punitive actions are privately costly (Kamei, 2014, 2017a). This is because the punishers are concerned about income inequality with other punishers in their groups, rather than inequality with the norm violators.[30] If the "conditional punishment" hypothesis is applicable for third party punishment, third parties may inflict in aggregate unnecessarily strong punishment on norm violators if they believe that others will carry large costs for punishment. Second, subjects may not be satisfied even if their peers inflict punishment (explanation (ii)). For instance, Casari and Luini (2009) compared punishment decisions when subjects simultaneously decide the strength of punishment as in Fehr and Gächter (2000), with when subjects are randomly given a turn to punish while seeing how much punishment the target has received before their turn. The latter sequential procedure makes it easier for subjects to coordinate on punishment. Casari and Luini (2009) found that frequencies of punishment and total punishment received by free riders are similar between the simultaneous and sequential procedures. If the "enjoy" hypothesis (explanation (ii)) is more appropriate in our context, third parties would on average impose strong punishment to satisfy their desire to punish, regardless of group size and their belief on the peers' punishment acts.

In order to study which explanation is more appropriate, we conducted an additional treatment in which subjects played a one-shot third party punishment game with a group size of 12, and third parties were asked to answer their beliefs regarding their peers' average punishment behaviors in addition to deciding on their own punishment intensity. We call this the "Belief Elicitation" experiment (Table 1). As in the original experiment, the strategy method was used to

[30] See also Kamei and Putterman (2018) for experimental evidence of conditional punishment in the case of costly reporting of defectors by cooperators in a prisoner's dilemma.

elicit subjects' punishment behaviors and their beliefs.[31] The belief elicitation task was incentivized. If a subject was assigned the role of a third party punisher, she was paid based on either her actual punishment behavior realized or the accuracy of the belief elicitation task (one of the two was randomly selected for payment by the computer). The other design pieces were the same as the original experiment: with the same strategy method, all subjects made sending decisions as a PD player and punishment decisions as a third party punisher, with a group size of 12 (see Appendix B.2 for the instructions).

The additional data first show that the pattern of third party punishment is similar to that in the original experiment. The average punishment points per third party were 0.625, 5.083, 0.521, and 2.250, in scenarios (a), (b), (c) and (d), respectively.[32] The high punishment intensity in scenario (b) seen in the Belief Elicitation experiment is consistent with the over-punishment result reported in Section 4.3. A PD player's expected payoff from selecting defection, calculated as in panel (B) of Fig. 3, is much smaller than 0, –87.19 (see panel (B) of Fig. 5).[33] Once third party punishment is taken into account, the unique NE is mutual cooperation as in the original experiment with a group size of 12 (see panel (A1) of Fig. 5).

Third parties' punishment of cooperators was also observed in the additional experiment. Although as mentioned above, the average punishment per third party was relatively small in scenarios (a) and (c), a PD player will receive a negative payoff in expectation due to a large number of third parties if scenario (c) occurs – the player cooperates but his counterpart defects (see panel (A1) of Fig. 5). The PD players' expected payoff from selecting cooperation is

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[31] Unlike the original experiment, we did not let subjects play the games with four different group sizes because we wanted to avoid making the additional experiment too complex for subjects and also because the additional experiment aims to study the issue of over-punishment with a large group size by eliciting beliefs.

[32] Punishment intensity was, however, stronger in the additional experiment than in the original experiment with a group size of 12. It could mean that third parties' inclinations to punish are not at all sensitive to the number of other third parties in a group. However, this perhaps occurred by chance: more pro-social subjects might have participated in the Belief Elicitation experiment. This is confirmed by observing the percentage of PD players who sent 10 points. This percentage was 81.3%, which is higher than the percentage in the original experiment with a group size of 12 (70.8%). We note that Results 1, 3 and 4 were obtained by controlling for individual characteristics thanks to the within-subjects design.

[33] As in the original experiment, we did not take money from subjects and their payoffs were set to zero in the cases where their payoffs were negative.

calculated as 21.21 points, still about 20% lower than the expected payoff from selecting cooperation when there is a single third party punisher (26.60 points) [see panel (B) of Fig. 3 and panel (B) of Fig. 5].

We will now study third parties' punishment behaviors in relation to their beliefs on the others' punishment acts (Fig. 4). Two clear patterns were found. First, third parties' punishment intensity targeted at a norm violator is significantly positively correlated with their beliefs regarding other third parties' punishment intensity (see the graphs for scenarios (b) and (d)). Second, interestingly, third parties' punishment acts towards a cooperator are likewise significantly positively correlated with their beliefs on others' such perverse punishment behaviors, although the majority of third party players did not engage in such punishment (see the graphs for scenarios (a) and (c)).[34] These findings resonate with the idea that third parties impose punishment based on their beliefs on other third party punishers' behaviors and that they are concerned about income inequality amongst them.

Result 6: *Third parties' punishment intensity in each scenario is positively correlated with their beliefs on other punishers' punishment behaviors.*

Result 6 suggests that third party punishers' low level of free-riding behavior seen in the original experiment may have been driven by subjects' conditional punishment behaviors. This implies that the over-punishment problem could be mitigated if some coordination mechanisms on third party punishment were present. Nevertheless, we acknowledge that we cannot fully rule out the possibility that the "enjoy" hypothesis may partly account for the positive correlations between the third parties' own punishment and their beliefs. If third parties gain utility from punishment acts themselves, they may believe that their peers would also enjoy punishment (e.g., social projection).

6. Coordinated Punishment and Discussions

[34] Similar conditional punishment targeted at a cooperator was likewise observed in the case of second party punishment (e.g., Kamei 2014, 2017a).

One possible way to mitigate the third parties' over-punishment phenomenon is to allow them to construct rules that regulate their punishment activities. People's ability to democratically construct rules that govern punishment activities has been documented, whether it is in the form of self-governance or centralized regulations (e.g., Ostrom, 1990; Ertan *et al.*, 2009; Putterman *et al.*, 2011; Kamei *et al.*, 2015). If over-punishment of norm violators happened due to mis-coordination among third parties, it could be attenuated if we let third parties collectively implement rules on punishment. In addition, considering the fact that a minority of third parties were engaged in perverse punishment of cooperators, the majority may outperform the minority's preferences if an appropriate democratic process is available. In this sense, having some formal enforcement based on democracy may be beneficial. Nevertheless, it is unclear how people implement rules for punishing norm violators. Past studies, including Ertan *et al.* (2009), Putterman *et al.* (2011) and Kamei *et al.* (2015), let subjects collectively select rules for their on-going interactions in setups where rules can materially benefit the constituents. For instance, in Putterman *et al.* (2011), most groups collectively selected sanctioning rules that make contributing full amounts to the group account the strictly dominant strategy in a linear VCM (see also Kamei *et al.* [2015]). In the setups where rules are too weak to change the equilibrium for material payoffs, however, it is known that a non-negligible fraction of people vote against the rules. For instance, in Kamei (2016), 53% of subjects voted against implementing non-deterrent sanctions for free-riding in a linear VCM (see also Tyran and Feld [2006]). In our case, third parties' punishment activities can help PD players who select cooperation, but not the third parties themselves. Third party players would be materially better off if they prohibit punishment by voting because punishment is costly.

We conducted an additional experiment where third parties could implement a binding rule, which we call the "Voting" experiment (Table 1). As in the Belief Elicitation experiment, group size was 12, and subjects played the game in a one-shot environment. At the onset of the Voting experiment, subjects were randomly assigned to a group of 12; subsequently, all subjects made sending decisions (Fig. 1), assuming that they were assigned the role of PD player. Their decisions were used only when they were assigned the role of PD player. Once all subjects had made the decisions, the computer randomly assigned the role of PD player to two persons and the role of third party player to ten persons in each group. Next, third party players democratically decided the levels of punishment with the strategy method. The same strategy method as in the other treatments was used. Specifically, third parties voted on the levels of punishment each third party player should impose under the four scenarios. If third parties collectively decided that each person should spend c punishment points in a scenario, then a total of $10 \times c$ punishment points would be imposed on the PD player when that scenario happened. The median of the votes was selected in each scenario as an agreement among the third parties. When the median was not an integer, either the fifth or sixth value (in descending order) was randomly selected by the computer. In this reduction stage, there were no decisions for PD players to make. The beliefs were not elicited from third parties in this Voting experiment to simplify the design. Subjects were informed of the PD players' sending decisions in their groups at the end of the experiment (see Appendix B.3 for the instructions).

We note that constructing an effective rule under the median voting rule is not an easy task. This is because if subjects were to vote similarly to what they chose as their independent punishment points in the original experiment, the group might not reach a sufficiently deterrent rule. In the original experiment with a group size of 12, the median values of third parties' punishment points were 0, 1, 0 and 0 in scenarios (a), (b), (c) and (d), respectively. If this occurs as a group's vote outcome, a defector would collectively receive 10 (=1×10) punishment points if scenario (b) happens and would not receive any punishment if scenario (d) happens. The payoff matrix after deducting the total punishment amounts would become a coordination game where both mutual cooperation and mutual defection are NEs. The reason why a defector would receive such a low level of punishment in this simulation is that 43.7% and 59.0% of third parties do not inflict any punishment in scenarios (b) and (d), respectively, in the original experiment with a group size of 12 (see panel (I) of Table 2). This suggests that to build a deterrent rule, third parties would need to propose punishment levels that are different from the ones they would choose if they were independent. Nevertheless, third parties may attempt to build a deterrent, but not too strong, rule, considering that ten third parties in a group are assured that they incur the same cost for punishment and therefore they would obtain the same payoff.

A total of 48 students participated in the Voting experiment. The percentage of those who sent 10 points was 64.6%. There were four independent observations for third party players' collective choices (i.e., four groups) in this additional experiment. Among others, two interesting patterns were found. First, no cooperators received punishment in all groups, whether their matched partners were cooperators or defectors (panel (C) of Fig. 5), because the majority voted against punishment of cooperators. As a result, the expected payoff when a PD player selected cooperation was at a very high level, namely 34.38 points (see panel (B) of Fig. 5). This suggests that democratic decision-making is indeed a powerful tool to limit the perverse behaviors of a minority of subjects. Second, over-punishment of a norm violator was not seen in three out of four groups (groups 1 to 3 in panel (C)).[35] Overall, a defector received a much lower payoff in expectation compared with a cooperator. However, the negative size of the expected payoff from selecting defection is small, –5.00 points (panel (B)), while the unique NE is mutual cooperation (panel (A2)).[36] The result that the collective decision-making procedure well mitigates the over-punishment problem can explain the real world observations why some societies with weak or no formal institutions, such as Turkana, have a collective decision-making procedure to determine a level of punishment targeted at a norm violator if a severe sanction is considered.

Result 7: *Third parties do not punish cooperators when they democratically decide on the level of punishment that each third party punisher inflicts. The strength of punishment targeted at norm violators is also lower when it is decided democratically, but it is a sufficient deterrent.*

[35] We note that over-punishment of norm violators was observed in group 4 even under the median voting rule. This may mean that the strong punishment targeted at a norm violator is more difficult to be resolved, compared with punishment of cooperators.

[36] Each third party player's voting decision can be treated as independent because this was their very first decision as a third party player before interacting with their peers. The median voting rule was used in the experiment. Thus, in calculating the payoff matrix in panel (A2) and the expected payoffs in panel (B) of Fig. 5, we used the median values of all third parties' voting preferences, assuming that the distribution of 40 third party players' votes is approximately the distribution of people's preferences in the sample.

In our experiment, the strength of collective punishment was determined by the subjects' median opinion. There are other voting rules, such as consensus and super-majority rule. How much the extent to which people can resolve the over-punishment of norm violators and punishment of cooperators differs by the voting rule would be an exciting area for further research.

We note that there are other forms of collective decision-making procedures without formally determining the punishment level unlike in our study. For example, another potential rule could be to allow subjects to impose punishment in a decentralized manner only when a certain number of persons agree on it (e.g., Casari and Luini, 2009; Ertan *et al.*, 2009). For instance, in one treatment of Casari and Luini (2009), a player was punished only when at least two members requested it in a linear VCM with a group size of five. In Ertan *et al.* (2009), a player was allowed to inflict punishment in a decentralized manner if the majority of members voted for such punishment in a linear VCM with a group size of four. With these agreement procedures, informal sanctioning activities were disciplined and high contributions were achieved in both Casari and Luini (2009), and Ertan *et al.* (2009). This kind of procedure could also work for third party punishment.

An alternative to constructing binding rules is to have *unbinding* rules, backed by peer monitoring of third party punishment acts and decentralized punishment of punishers (e.g., Ostrom, 1990), instead of using coercive schemes. A large body of the literature on "order without law" discussed in Section 1 also suggests that this could work under some conditions.

Related to this, allowing people to be engaged in higher-order punishment without having any rule-making may also discipline third parties' behaviors. Punishment of cooperators or the failure to punish a norm violator could be punished by their peers if second-order punishment is allowed (e.g., Denant-Boemont *et al.*, 2007; Henrich and Boyd, 2001). Or perhaps, only having a threat of higher-order punishment or making punishment acts visible to others could be sufficient enough to make punishment better targeted and more effective (e.g., Kamei and Putterman, 2015; Kamei, 2017b).

Lastly, needless to say, letting third party punishers communicate with each other could also help resolve the over-punishment problem (e.g., Ostrom *et al.* [1992] and Bochet *et al.* [2006] for the case of direct punishment).

7. Conclusion

How people's free-riding behaviors may differ by group size is one of the central questions in public choice research, initiated by Olson (1965). This paper examined how people's third party punishment behaviors could differ by the number of third parties in a group. Decentralized third party enforcement is recognized as an important factor in regulating our societies, whether they have well-developed formal institutions or not. Our experiment found that per third party player punishment strength decreases at most only mildly as the number of third party players increases in a group. The third parties' low level of free-riding behavior benefits prisoner's dilemma interactions when the number of third parties is relatively large because aggregate punishment becomes a sufficient deterrent against PD players selecting defection. However, when the number of third parties was ten in a group, we observed over-punishment problems: not only were defectors too heavily punished, but cooperators were also hurt severely by perverse punishment. This suggests that some device in coordinating punishment is desirable for a very large group because of the over-punishment phenomenon, rather than the third parties' free-riding possibility. Although the results are clear, there are many areas where further research is needed to extend our findings. For example, it would be a useful robustness check to study the same research question with a different punishment technology (e.g., with cost ratio of 1:2). It would also be useful to examine the same question when direct punishment is also available in the prisoner's dilemma interactions. Considering that second party punishment is a substitute for third party punishment, third parties' inclinations to punish may diminish, while their free-riding behavior may also increase, in that condition as group size grows.

This paper further showed that the third parties' low level of free-riding behavior may be caused by their conditional punishment behaviors. Moreover, using an additional experiment, we showed that people are able to mitigate the over-punishment problem once we allow third parties to democratically construct a rule to regulate their punishment activities, and thus having a large group could be beneficial if we have appropriate coordination mechanisms in a society. Nevertheless, what happens if there are many more third parties, say 50, 100 or even more, in a group? We cannot answer this question using only our data. It may be difficult for those involved to regulate their punishment activities by rules, for example for reasons such as a more challenging process to implement a rule that is acceptable to everyone. In addition, sharing information of norm violations among all third parties in an entire community may no longer be cost-free, unlike in our experimental setup (e.g., Milgrom *et al.*, 1990; Dixit, 2004). If these are the cases, some form of hierarchical structure or dissolution of a group into small sub-groups, for example as discussed in Olson (1965), may be needed for coordinated decentralized punishment to be successful. On the other hand, considering past studies on private ordering (e.g., Mathew and Boyd, 2011; Hadfield and Weingast, 2013), third parties may be able to regulate their activities democratically by setting a binding rule as in our study, or even merely by implementing an unbinding rule regardless of group size if a complementary legal institution such as courts is available. Studying this question in a controlled environment would be an interesting area for future research.

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Table 1: *Summary of Treatments*

	Experiment condition[#1]	Subjects' decisions	Belief elicitation	Voting	Total number of subjects
Original Experiment	Four treatment conditions (group size = 3, 4, 6, 12)[#2]	All subjects make decisions as a PD player and a third party punisher.	No	No	144
Additional Experiment 1 ("Belief Elicitation")	group size = 12	All subjects make decisions as a PD player and a third party punisher.	Yes	No	48
Additional Experiment 2 ("Voting")	group size = 12	All subjects make decisions as a PD player. Subjects who are randomly assigned the role of a third party player make punishment decisions.	No	Yes	48
Total					240

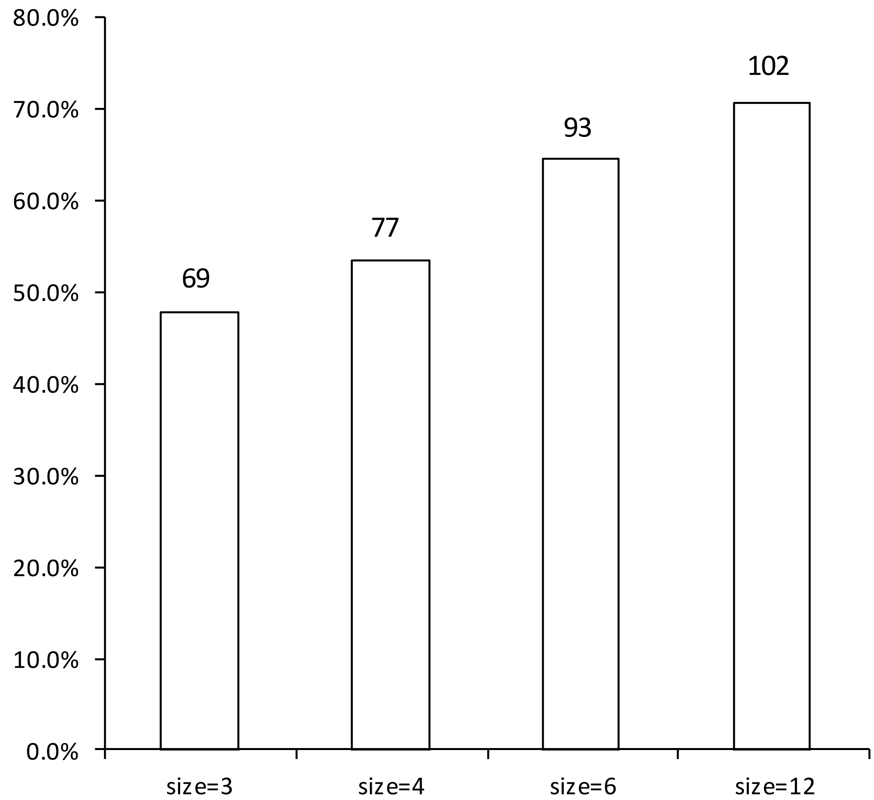
Notes: [#1] The number of third party players is $N - 2$, where N is group size. [#2] A within-subjects design was used.

Fig. 1: *Payoff Matrix*

		Player 1	
		Send (Cooperate)	Not Send (Defect)
Player 2	Send (Cooperate)	45, 45	15, 55
	Not Send (Defect)	55, 15	25, 25

Note: This payoff matrix is from Fehr and Fischbacher (2004).

Fig. 2: *The Percentage of PD Players Who Sent 10 Points by Group Size*



Notes: The number of third party players per group is $N - 2$, where N is group size. Each bar indicates the percentage of PD players who chose to send 10 points among all subjects. The numbers shown on top of each bar are the numbers of PD players who chose to send 10 points to their partners out of the 144 subjects.

Table 2: *Third Party Punishment by Group Size, and by Scenario*

(I) The Percentage of Subjects Who Imposed Positive Punishment Points

Target of punishment: / Group size:	A cooperator who interacted with a cooperator [Scenario (a)]	A defector who interacted with a cooperator [Scenario (b)]	A cooperator who interacted with a defector [Scenario (c)]	A defector who interacted with a defector [Scenario (d)]
3	24.3%	55.6%	16.7%	41.0%
4	22.2%	55.6%	20.8%	40.3%
6	23.6%	61.1%	18.8%	44.4%
12	18.1%	56.3%	16.7%	41.0%

(II) The Average Punishment Points Per Third Party Player

Target of punishment: / Group size:	A cooperator who interacted with a cooperator [Scenario (a)]	A defector who interacted with a cooperator [Scenario (b)]	A cooperator who interacted with a defector [Scenario (c)]	A defector who interacted with a defector [Scenario (d)]
3	1.042	4.104	0.819	1.854
4	1.014	3.076	1.118	1.792
6	0.813	3.563	0.944	1.951
12	0.757	2.722	0.771	1.806

Note: For each punishment point a third party player assigned to a PD player, one point was deducted from the third party player and three points were deducted from the PD player.

Table 3: *The Impact of Group Size on the Sending Behavior of PD players, and on the Punishment Behavior of Third Parties in Scenario (b)*

Dependent variable: / Independent variables:	A dummy which equals 1(0) if a PD player sent (did not send) 10 points to the partner (1)	Punishment points that a third party assigned to a defector who interacted with a cooperator [Scenario (b)] (2)
(i) Group size 4 dummy {= 1 if group size is four; = 0 otherwise}	.139 (.095)	-1.028*** (.361)
(ii) Group size 6 dummy {= 1 if group size is six; = 0 otherwise}	.426*** (.102)	-.542 (.416)
(iii) Group size 12 dummy {= 1 if group size is 12; = 0 otherwise}	.601*** (.121)	-1.382*** (.384)
Constant	-.052 (.105)	4.104*** (.456)
# of observations	576	576
Chi-squared (F)	28.28	5.45
Prob > Chi-squared (F)	.0000***	.0014***
Two-sided *p*-value for Chi-squared test (F test)		
H0: (i) = (ii)	.0029***	.1963
H0: (i) = (iii)	.0001***	.2153
H0: (ii) = (iii)	.0817*	.0071***

Notes: Probit regressions with robust standard errors clustered by subject ID in column (1). Linear regressions with robust standard errors clustered by subject ID in column (2). The numbers in parenthesis are robust standard errors. The reference groups in column (1) and column (2) are subjects' sending and punishment decisions, respectively, when the group size is three. See Appendix Table A.3 for a robustness check when possible order effects are controlled for.

*, **, and *** indicate significance at the .10 level, at the .05 level and at the .01 level, respectively.

Fig. 3: *Payoff Matrix after Punishment, and PD Players' Expected Payoff*

	Send	Not Send
Send	41.9, 41.9	12.5, 42.7
Not Send	42.7, 12.5	19.4, 19.4

(A1) Group size of 3

	Send	Not Send
Send	38.9, 38.9	8.3, 36.5
Not Send	36.5, 8.3	14.3, 14.3

(A2) Group size of 4

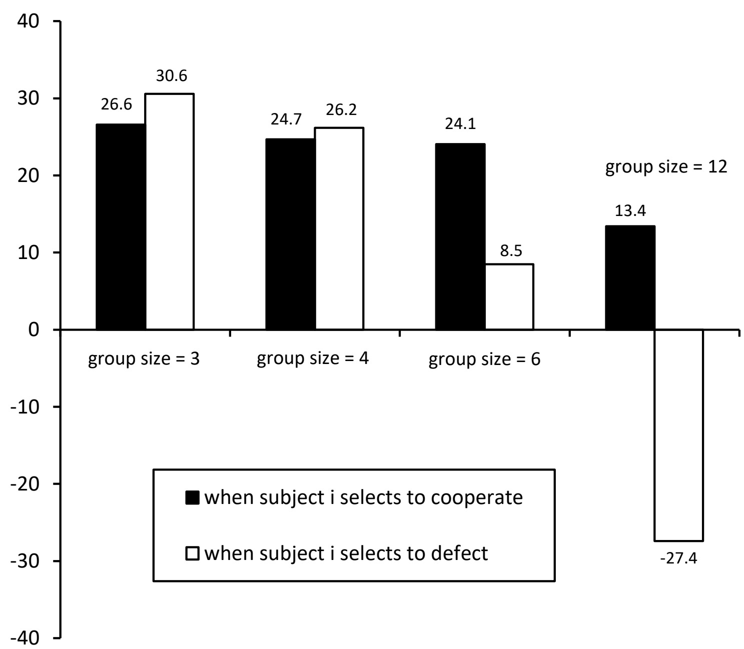
	Send	Not Send
Send	35.3, 35.3	3.7, 12.3
Not Send	12.3, 3.7	1.6, 1.6

(A3) Group size of 6

	Send	Not Send
Send	22.3, 22.3	-8.1, -26.7
Not Send	-26.7, -8.1	-29.2, -29.2

(A4) Group size of 12

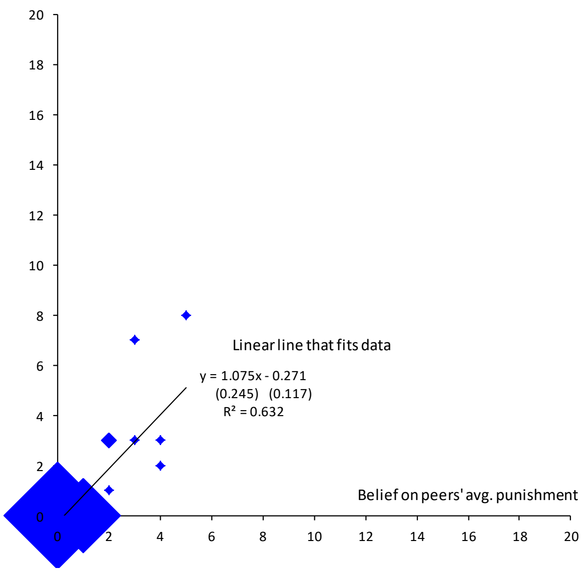
(A) Payoff matrix after the average total punishment PD players received is subtracted



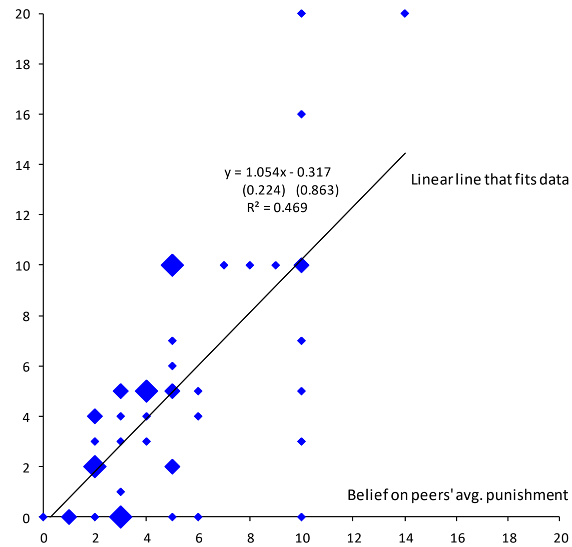
(B) PD players' expected payoff

Notes: The shaded cells in panel (A) are Nash Equilibria. The unit of vertical axis in panel (B) is points. In the case where a PD player received a negative payoff in the experiment, the player's payoff was set to zero (we did not take money from the subject).

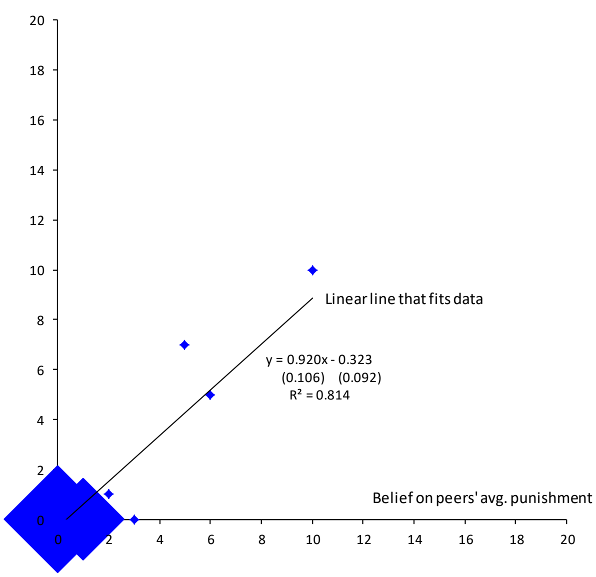
Fig. 4: *Subjects' Own Punishment Behaviors and Beliefs on Other Third Parties' Punishment*



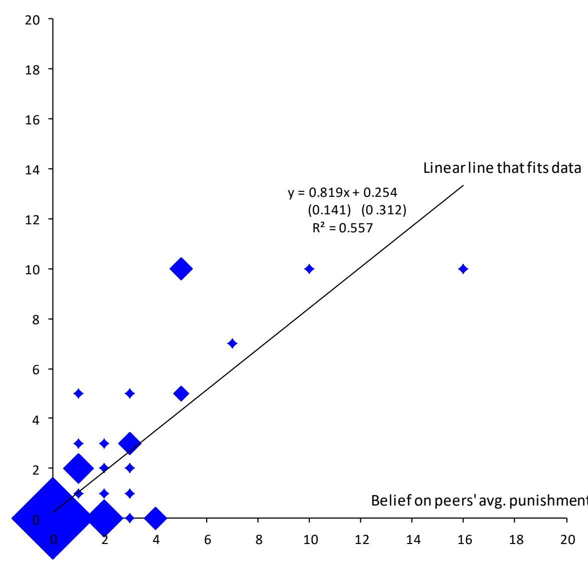
Scenario (a) [punishment to a cooperator who interacted with a cooperator]



Scenario (b) [punishment to a defector who interacted with a cooperator]



Scenario (c) [punishment to a cooperator who interacted with a defector]



Scenario (d) [punishment to a defector who interacted with a defector]

Notes: The horizontal axis (x-axis) is subjects' beliefs on other punishers' average punishment points. The vertical axis (y-axis) is subjects' own punishment points. The size of each point indicates its frequency. The numbers in parenthesis in the linear equations (OLS) in figures are robust standard errors. The slope in each line is significantly positive ($p < .000$). Two-sided F tests do not reject the null that the slope is equal to 1 with $p = .7598$, $p = .8111$, $p = .4541$, and $p = .2062$, in scenarios (a), (b), (c) and (d), respectively.

Fig. 5: *Incentive Changes with Punishment in the Two Additional Treatments*

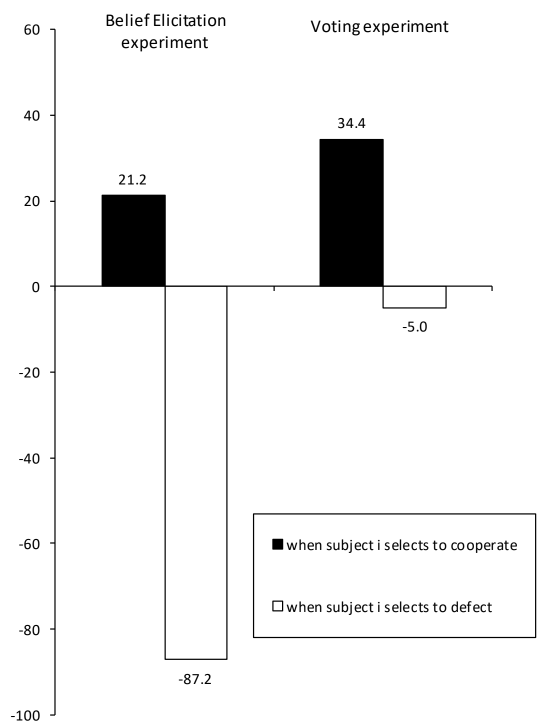
	Send	Not Send
Send	26.3, 26.3	-0.6, -97.5
Not Send	-97.5, -0.6	-42.5, -42.5

(A1) Belief Elicitation Experiment

	Send	Not Send
Send	45.0, 45.0	15.0, -5.0
Not Send	-5.0, 15.0	-5.0, -5.0

(A2) Voting Experiment

(A) Payoff matrix after the average total punishment PD players received is subtracted



(B) PD players' expected payoff

	scenario a	scenario b	scenario c	scenario d
group 1	0	2	0	0
group 2	0	1	0	0
group 3	0	2	0	2
group 4	0	5	0	3
Median of all third parties	0.00	2.00	0.00	1.00

(C) Vote outcomes for each player B's level of punishment in the Voting experiment[#1]

Notes: The shaded cells in panel (A) are Nash Equilibria. [#1] The median values were integers, except the following two cases. First, the median vote for scenario (d) in group 1 was 0.5. The computer randomly selected 0 as each player B's level of reduction points. Second, the median vote for scenario (d) in group 3 was 1.5. The computer randomly selected 2 as each player B's level of reduction points.

Research Highlights:

- Punishment intensity per third party decreases only mildly as the number of third party punishers increases in a group where a prisoner's dilemma interaction takes place.
- Having a sufficiently large number of third parties is helpful in preventing players from selecting defection because of third party punishment.
- Having too many third party players is harmful because aggregate punishment becomes too strong and even cooperators might be punished severely.
- Third parties' punishment intensity is positively correlated with their beliefs on peers' punishment behaviors.
- Third parties prohibit punishment of cooperators and limit over-punishment targeted at norm violators when they are given a chance to democratically decide on the levels of punishment through voting.

Appendix A: Additional Tables

Table A.1: *The Difference in PD Players' Sending Rate by Treatment (supplementing Fig. 2 and Table 3 in the paper)*

[Fisher's exact tests:]

The numbers below indicate two-sided *p*-values for Fisher's exact tests to compare PD players' sending rates between the treatments:

	Group size = 3	Group size = 4	Group size = 6	Group size = 12
Group size = 3	---	.409	.006***	.000***
Group size = 4	---	---	.072*	.002***
Group size = 6	---	---	---	.157
Group size = 12	---	---	---	---

Note: *, **, and *** indicate significance at the .10 level, at the .05 level and at the .01 level, respectively.

Table A.2: *Comparison of the Strength of Third Party Punishment between Different Scenarios (supplementing Table 2 of the paper)*

[For panel (I) of Table 2:]

Dependent variable: A dummy which equals 1 if third party punisher *i* imposed positive punishment points on a PD player, and 0 otherwise

Independent variables: / Treatment:	Group size =3	Group size =4	Group size =6	Group size =12
	(1)	(2)	(3)	(4)
(i) Scenario (a) dummy	.24***	.22***	.24***	.18***
	(.036)	(.035)	(.036)	(.032)
(ii) Scenario (b) dummy	.56***	.56***	.61***	.56***
	(.042)	(.042)	(.041)	(.042)
(iii) Scenario (c) dummy	.17***	.21***	.19***	.17***
	(.031)	(.034)	(.033)	(.031)
(iv) Scenario (d) dummy	.41***	.40***	.44***	.41***
	(.041)	(.041)	(.042)	(.041)
# of observations	576	576	576	576
F	45.91	48.06	57.38	46.56
Prob > F	.0000***	.0000***	.0000***	.0000***
Two-sided *p*-value for F test				
H_0: (i) = (ii)	.0000***	.0000***	.0000***	.0000***
H_0: (i) = (iii)	.0113**	.6721	.1461	.6399
H_0: (i) = (iv)	.0001***	.0000***	.0000***	.0000***
H_0: (ii) = (iii)	.0000***	.0000***	.0000***	.0000***
H_0: (ii) = (iv)	.0000***	.0000***	.0000***	.0000***
H_0: (iii) = (iv)	.0000***	.0001***	.0000***	.0000***

Notes: Linear regressions (linear probability model) without constant terms, and with robust standard errors clustered by subject ID. The numbers in parenthesis are standard errors.

*, **, and *** indicate significance at the .10 level, at the .05 level and at the .01 level, respectively.

[For panel (II) of Table 2:]

Dependent variable: Punishment points given from third party punisher *i* to a PD player

Treatment: / Independent variables:	Group size =3 (1)	Group size =4 (2)	Group size =6 (3)	Group size =12 (4)
(i) Scenario (a) dummy	1.04***	1.01***	.81***	.76***
	(.23)	(.24)	(.19)	(.24)
(ii) Scenario (b) dummy	4.10***	3.08***	3.56***	2.72***
	(.46)	(.36)	(.40)	(.34)
(iii) Scenario (c) dummy	.82***	1.12***	.94***	.77***
	(.24)	(.26)	(.27)	(.22)
(iv) Scenario (d) dummy	1.85***	1.79***	1.95***	1.81***
	(.29)	(.31)	(.32)	(.34)
# of observations	576	576	576	576
F	22.94	21.72	21.07	17.01
Prob > F	.0000***	.0000***	.0000***	.0000***
Two-sided *p*-value for F test				
H_0: (i) = (ii)	.0000***	.0000***	.0000***	.0000***
H_0: (i) = (iii)	.3467	.6568	.5897	.9390
H_0: (i) = (iv)	.0178**	.0335**	.0015***	.0018***
H_0: (ii) = (iii)	.0000***	.0000***	.0000***	.0000***
H_0: (ii) = (iv)	.0000***	.0000***	.0000***	.0001***
H_0: (iii) = (iv)	.0014***	.0629*	.0031***	.0004***

Notes: Linear regressions without constant terms, and with robust standard errors clustered by subject ID. The numbers in parenthesis are standard errors.

*, **, and *** indicate significance at the .10 level, at the .05 level and at the .01 level, respectively.

Table A.3: *Possible Order Effects (supplementing Table 3 in the paper)*

In the experiment, in order to rule out potential order effects, subjects played the game for four different group sizes in a random order. Subjects' decisions might be affected by the realized orders of group sizes, nevertheless. If this is the case, results shown in Table 3 of the paper might have been affected by such potential order effects. A close look at the data shows that our results reported in Table 3 are not due to potential order effects.

To study possible order effects, we compared the percentages in which PD players chose to send 10 points (cooperate) between two group sizes while controlling for realized orders of the two group sizes. We also compared third party players' decisions to inflict punishment between two group sizes controlling for realized orders of the two group sizes. These comparisons were conducted for any possible two group sizes (e.g., 3 versus 12). As summarized in the following tables, we have qualitatively the same results even when we control for potential order effects.

(A) PD players' selection of sending 10 points (cooperating)

We studied group size effects on PD players while having an Order dummy as an independent variable to control for possible order effects. Results shown below are almost the same as Table 3 of the paper.

Dependent variable: A dummy which equals 1(0) if a PD player sent (did not send) 10 points to the partner

Independent variables: \ Comparison:	Group size 3 versus 4 (1)	Group size 3 versus 6 (2)	Group size 3 versus 12 (3)	Group size 4 versus 6 (4)	Group size 4 versus 12 (5)	Group size 6 versus 12 (6)
(i) Group size 4 dummy {= 1 if group size is four; = 0 otherwise}	.139 (.095)	---	---	---	---	---
(ii) Group size 6 dummy {= 1 if group size is six; = 0 otherwise}	---	.428*** (.103)	---	.288*** (.096)	---	---
(iii) Group size 12 dummy {= 1 if group size is 12; = 0 otherwise}	---	---	.601*** (.121)	---	.462*** (.120)	.175* (.100)
Order dummy {= 1 if the smaller group size was realized earlier; = 0 otherwise.}[#1]	-.070 (.215)	-.173 (.208)	-.065 (.194)	.156 (.192)	.021 (.179)	-.119 (.231)

Constant	.0002 (.192)	.077 (.184)	-.004 (.173)	.022 (.132)	.076 (.143)	.464** (.208)
Data used in the regression	Decisions when size = 3 or 4	Decisions when size = 3 or 6	Decisions when size = 3 or 12	Decisions when size = 4 or 6	Decisions when size = 4 or 12	Decisions when size = 6 or 12
Reference group	Group size of 3	Group size of 3	Group size of 3	Group size of 4	Group size of 4	Group size of 6
# of observations	288	288	288	288	288	288
Chi-squared	2.25	18.20	24.81	9.60	14.83	3.32
Prob > Chi-squared	.3246	.0001	.0000	.0082	.0006	.1905

Notes: Probit regressions with robust standard errors clustered by subject ID. The numbers in parenthesis are robust standard errors. The reference group in each regression is subjects' punishment decisions in the smaller group.

[#1] The Order dummy in column (1) equals 1 if a subject made a decision in the smaller group (size = 3) before the larger group (size = 4), and 0 otherwise. The Order dummy in column (2) equals 1 if a subject made a decision in the smaller group (size = 3) before the larger group (size = 6), and 0 otherwise. The Order dummy in column (3) equals 1 if a subject made a decision in the smaller group (size = 3) before the larger group (size = 12), and 0 otherwise. The Order dummy in column (4) equals 1 if a subject made a decision in the smaller group (size = 4) before the larger group (size = 6), and 0 otherwise. The Order dummy in column (5) equals 1 if a subject made a decision in the smaller group (size = 4) before the larger group (size = 12), and 0 otherwise. The Order dummy in column (6) equals 1 if a subject made a decision in the smaller group (size = 6) before the larger group (size = 12), and 0 otherwise.

*, **, and *** indicate significance at the .10 level, at the .05 level and at the .01 level, respectively.

RESULT: *Results on PD players' sending decisions reported in Table 3 in the paper are robust when controlling for order effects. The results little change when controlling for realized orders of the group sizes in regressions: PD players are significantly more likely to send 10 points when the group size is six or 12, compared with when the group size is three or four.*

(B) Third party players' decisions to punish in scenario (b)

As in Part (A) of Table A.3, we studied group size effects on third party players' punishment decisions while having an Order dummy as an independent variable to control for possible order effects. Results shown below are almost the same as Table 3 of the paper.

Dependent variable: Punishment points that a third party player assigned to a defector who interacted with a cooperator [Scenario (b)]

Independent variables: / Comparison:	Group size 3 versus 4 (1)	Group size 3 versus 6 (2)	Group size 3 versus 12 (3)	Group size 4 versus 6 (4)	Group size 4 versus 12 (5)	Group size 6 versus 12 (6)
(i) Group size 4 dummy {= 1 if group size is four; = 0 otherwise}	-1.028*** (.361)	---	---	---	---	---
(ii) Group size 6 dummy {= 1 if group size is six; = 0 otherwise}	---	-.542 (.417)	---	.486 (.375)	---	---
(iii) Group size 12 dummy {= 1 if group size is 12; = 0 otherwise}	---	---	-1.382*** (.385)	---	-.354 (.284)	-.840*** (.308)
Order dummy {= 1 if the smaller group size was realized earlier; = 0 otherwise.}[#1]	-.843 (.811)	.056 (.783)	-.394 (.773)	-.276 (.637)	.938 (.635)	1.116* (.619)
Constant	4.736*** (.726)	4.063*** (.686)	4.399*** (.685)	3.191*** (.488)	2.608*** (.450)	2.726*** (.472)
Data used in the regression	Decisions when size = 3 or 4	Decisions when size = 3 or 6	Decisions when size = 3 or 12	Decisions when size = 4 or 6	Decisions when size = 4 or 12	Decisions when size = 6 or 12
Reference group	Group size of 3	Group size of 3	Group size of 3	Group size of 4	Group size of 4	Group size of 6
# of observations	288	288	288	288	288	288
F	4.85	.85	7.01	.4134	2.03	4.62
Prob > F	.0092	.4314	.0012	.0038	.1350	.0114

Notes: Linear regressions with robust standard errors clustered by subject ID. The numbers in parenthesis are robust standard errors. The reference group in each regression is subjects' punishment decisions in the smaller group.

[#1] The Order dummy in column (1) equals 1 if a subject made a decision in the smaller group (size = 3) before the larger group (size = 4), and 0 otherwise. The Order dummy in column (2) equals 1 if a subject made a decision in the smaller group (size = 3) before the larger group (size = 6), and 0 otherwise. The Order dummy in column (3) equals 1 if a subject made a decision in the smaller group (size = 3) before the larger group (size = 12), and 0 otherwise. The

Order dummy in column (4) equals 1 if a subject made a decision in the smaller group (size = 4) before the larger group (size = 6), and 0 otherwise. The Order dummy in column (5) equals 1 if a subject made a decision in the smaller group (size = 4) before the larger group (size = 12), and 0 otherwise. The Order dummy in column (6) equals 1 if a subject made a decision in the smaller group (size = 6) before the larger group (size = 12), and 0 otherwise.
*, **, and *** indicate significance at the .10 level, at the .05 level and at the .01 level, respectively.

RESULT: *Results on third party players' punishment decisions reported in Table 3 in the paper are robust. They little change when controlling for realized orders of the group sizes. Specifically, third parties' punishment points in scenario (b) are significantly smaller with a group size of four than with a group size of three (see column (1) in the table above). Also, third parties' punishment points in scenario (b) are significantly smaller with a group size of 12 than with a group size of three (see column (3) in the table above). Lastly, third parties' punishment points in scenario (b) are significantly smaller with a group size of 12 than with a group size of six (see column (6) in the table above).*

Table A.4: *The Impact of Group Size on the Punishment Behavior of Third Parties in Scenarios (a), (c) and (d) [supplementing Tables 2 and 3 in the paper]*

Dependent variable: / Independent variables:	Punishment points that a third party assigned to a cooperator who was matched with a cooperator [Scenario (a)] (1)	Punishment points that a third party assigned to a cooperator who was matched with a defector [Scenario (c)] (2)	Punishment points that a third party assigned to a defector who was matched with a defector [Scenario (d)] (3)
(i) Group size 4 dummy {= 1 if group size is four; = 0 otherwise}	-.028 (.21)	.30* (.18)	-.063 (.26)
(ii) Group size 6 dummy {= 1 if group size is six; = 0 otherwise}	-.23 (.15)	.13 (.18)	.097 (.30)
(iii) Group size 12 dummy {= 1 if group size is 12; = 0 otherwise}	-.28 (.26)	-.049 (.23)	-.049 (.28)
Constant	1.04*** (.23)	.82*** (.24)	1.85*** (.29)
# of observations	576	576	576
F	1.25	1.16	.13
Prob > F	.2924	.3256	.9439
Two-sided *p*-value for F test			
H_0: (i) = (ii)	.2554	.2914	.5920
H_0: (i) = (iii)	.3049	.1604	.9556
H_0: (ii) = (iii)	.8174	.4759	.5773

Notes: Linear regressions with robust standard errors clustered by subject ID. The numbers in parenthesis are robust standard errors. The reference group is subjects' punishment decisions when the group size is three.

*, **, and *** indicate significance at the .10 level, at the .05 level and at the .01 level, respectively.

Remark: We also conducted a regression with a group size variable (= 3, 4, 6, 12), instead of having three group size dummies, being an independent variable. The estimation shows that the group size variable does not have a significant coefficient in each scenario (scenarios (a), (c) and (d)).

Table A.5: *The Impact of Group Size on the Total Punishment Points Received by a PD Player*

Because subjects' third party punishment decisions were elicited by using the strategy method, we studied the relationships between total punishment strength and group size with the following three steps:

Step 1: We calculated the average punishment points imposed by third party individuals in each scenario, by group size and session.

Step 2: We then, for each session data, calculated the average total punishment points received by PD players under each scenario by: $N - 2 \times$ the average strength for a given group size (calculated in Step 1). Here, N is a given group size [$N - 2$ is the number of third party punishers per group].

Step 3: We performed linear regressions using session-level data created in Step 2.

As shown in the table below, the total punishment points received by a defector are strongly positively correlated with the group sizes both in scenarios (b) and (d). We also find that a cooperator is more strongly punished in groups with a larger size (see columns (1) and (3)).

Dependent variable: / Independent variables:	Total punishment points received by a PD player in Scenario (a) (1)	Total punishment points received by a PD player in Scenario (b) (2)	Total punishment points received by a PD player in Scenario (c) (3)	Total punishment points received by a PD player in Scenario (d) (4)
(i) Group size 4 dummy {= 1 if group size is four; = 0 otherwise}	.92** (.30)	2.38** (.93)	1.33** (.40)	1.89** (.63)
(ii) Group size 6 dummy {= 1 if group size is six; = 0 otherwise}	2.06*** (.53)	9.70*** (1.97)	2.72 (1.59)	5.86*** (.90)
(iii) Group size 12 dummy {= 1 if group size is 12; = 0 otherwise}	5.85* (2.51)	23.5*** (4.01)	6.29** (2.06)	16.2*** (3.95)
Constant	.94** (.27)	3.99*** (.51)	.73 (.42)	1.92*** (.34)
# of observations	28	28	28	28
F	8.40	14.30	4.19	21.23
Prob > F	.0144**	.0038***	.0640*	.0014***
Two-sided *p*-value for F test				
H_0: (i) = (ii)	.1114	.0176**	.3313	.0139**
H_0: (i) = (iii)	.0989*	.0011***	.0317**	.0088***
H_0: (ii) = (iii)	.1359	.0098***	.1266	.0258**

Notes: Linear regressions with robust standard errors clustered by session ID. The numbers in parenthesis are robust standard errors. The reference group is session-average total punishment points when the group size is three.

*, **, and *** indicate significance at the .10 level, at the .05 level and at the .01 level, respectively.