Pro-Social Risk-Taking and Intergroup Conflict

A Volunteer's Dilemma Experiment

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November 2022

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Abstract

Pro-social risk-taking involves the willingness to commit resources to initiatives and opportunities with a social benefit, as well as a risk of costly failure. These situations often occur in an environment in which groups compete for resources. In these contexts of intergroup conflict, often individuals make personal sacrifices on a voluntary basis, involving considerable risks of failure. We study the context of pro-social risk-taking and intergroup conflict by extending the volunteer's dilemma along both of these dimensions. We introduce a novel group competition treatment to identify the effect of intergroup competition without providing with an additional collective prize like the majority of past laboratory experiments. We find evidence that intergroup competition significantly increases the volunteering rate of providing a public good, and mitigates the negative impact of risk on intragroup cooperation. Regarding individual heterogeneity, we explore and discuss the impact of risk aversion and gender, and its implication for parochial altruism.

Keywords: volunteer's dilemma, altruism, intergroup conflict, lab experiment, risk-taking

1. Introduction

The provision of public goods involves a social dilemma in which individuals would be better off cooperating but are tempted to freeride on other's contributions. Cooperation among unrelated individuals is a universal and fundamental trait of human life, but its evolution remains puzzling to explain. In game theory, the prisoner's dilemma and the public good game are the most typical examples of social dilemmas. In these games, defection is a dominant strategy, which leads to a Pareto-inefficient equilibrium, so the maintenance of cooperation often relies on reciprocation, punishment and reputation effects (Axelrod and Hamilton 1981; Fehr and Gächter 2000; Suzuki and Akiyama 2005). The volunteer's dilemma, by contrast, is a social dilemma game that does not require repeated interaction or other-regarding preferences to bring about cooperation. In this game, the public good is produced if and only if (at least) one volunteer makes a costly investment, so cooperation becomes a dominant strategy if other players do not volunteer. Freeriders and cooperators coexist in a stable equilibrium (Diekmann 1985). Therefore, the problem in the volunteer's dilemma is not how cooperation is sustained, but who is willing to volunteer and how situational factors influence the willingness to volunteer (Krueger, Ullrich, and Chen 2016; Healy and Pate 2018; Fischer et al. 2011).

The volunteer's dilemma reflects important dynamics from social and economic life, and applies to any setting where the responsibility is not contractible or is diffused among multiple agents. For example, which family members will volunteer to perform housework such as taking out the garbage, which bystanders will decide to help a victim of emergency, which soldiers risk their lives to advance or defend on the front line, which colleagues will accept task requests with low promotability (Babcock et al. 2017), and which software engineers may contribute code to an open-source project (Johnson 2002)? Examples extend into the non-human context, where groups of vertebrates rely on alarm calls as defense against approaching predators (Archetti 2009a; Searcy and Nowicki 2006). Another prominent application involves altruistic punishment requiring volunteers to make personal sacrifice to punish norm violators (Przepiorka and Diekmann 2013). For instance, whistle-blowers risk their own career by going public about unethical activities or wrongdoings, and they could stay silent and wait for others to blow a whistle.

In a volunteer's dilemma game (VDG), individuals face the decision to either make a personal sacrifice for the benefit of the group, or to freeride on others' sacrifice. Each group member – including the individual making the sacrifice – is better off when there is at least one volunteer, compared to when there is no volunteer. As in other social dilemmas, such as the prisoner's dilemma, an individual has to choose between defecting (favoring herself), and cooperating (benefiting the group or another person). Unlike in many other social dilemma games, however, there exists no dominant pure-strategy equilibrium in a VDG, and the socially optimal outcome is attained when exactly one individual decides to cooperate. Since the pure-strategy Nash equilibria in a VDG are asymmetric and require coordination, research usually focuses on symmetric mixed-strategy Nash equilibria. In a VDG, the probability of volunteering in the symmetric mixed-strategy Nash equilibrium is a decreasing function of group size, representing the bystander effect or the diffusion of responsibility (Hillenbrand and Winter 2018; Darley and Latane 1968).

VDGs have been extended and investigated focusing on loss aversion (Holt 2007), cost-sharing (Weesie and Franzen 1998), decision of timing (Otsubo and Rapoport 2008; Weesie 1993), asymmetric costs or preferences (Diekmann 1984; Weesie 1993; Healy and Pate 2018; Healy and Pate 2009), relatedness (Archetti 2009b), social norm enforcement (Przepiorka and Diekmann 2013), and social projection (Krueger, Ullrich, and Chen 2016). VDGs have gained attention across a range of disciplines. In evolutionary biology, for instance, the volunteer's dilemma appears to better describe most social dilemmas underlying the evolution of cooperation than other dilemma games (Archetti 2009a). Archetti and Scheuring (2011) further demonstrate that the volunteer's dilemma and the *N*-person prisoners' dilemma are the two opposite extremes of a general public goods game, and all intermediate cases can have a mixed equilibrium like a VDG, where cooperators and defectors can coexist in the absence of iterations, relatedness, or external enforcement. Therefore, the volunteer's dilemma is an ideal example to examine the antecedents of pro-social behavior. Laboratory VDG experiments often observe a large degree of heterogeneity across players in their volunteering (Otsubo and Rapoport 2008; Goeree, Holt, and Smith 2017). Goeree, Holt, and Smith (2017) establish a heterogeneous equilibrium model with a distribution of "warm glow" propensity, providing a better reflection of the empirical data. Their results imply that some individuals may derive more utility from volunteering than others.

In the present study, we offer a three-fold contribution to the VDG literature. The first and second contribution are that we expand the standard VDG towards two dimensions: risk-taking and intergroup competition. The third contribution is that we develop a new experimental protocol with sequential moves, which provides the opportunity to set up corresponding treatments that are identical to the subgame of the second stage (the decision node for the group of the second movers). Before we introduce the details of our experimental set-up and the findings, we first position our study in the broader literature. After presenting our theory, protocol and evidence, we conclude with a discussion, in which we reflect on our main findings that (a) intergroup competition significantly increases the volunteering rate of providing a public good, and (b) mitigates the negative impact of risk on intragroup cooperation.

2. BACKGROUND

Our *first contribution* is that we explore pro-social risk-taking behavior in a VDG context, which involves the act of engaging in a risky decision to volunteer to provide a public good. Indeed, in real-life settings, pro-social behavior often involves a certain degree of risk-taking. For instance, helping a victim in case of an emergency could turn out to be unsuccessful, or wrongdoing could be covered up even if a whistle-blower risks her career and reputation.[1] To the best of our knowledge, prior research investigating the interaction of risk attitudes and other-regarding concerns is scarce.[2] Our study contributes towards filling this gap in the literature in the context of the volunteer's dilemma.

Our *second contribution* involves intergroup competition, which may have a positive effect on volunteering in the absence of leadership and communication. Intergroup conflict often involves individuals who voluntarily cooperate to make a personal sacrifice to provide collective benefits (Hugh-Jones and Zultan 2013; Olson 1965). Darwin (1871) argues that intergroup conflict creates an environment in which natural selection favors groups ready "to give aid to each other, and to sacrifice themselves for the common good." Theoretical models show that the evolution of altruism can be explained by multi-level selection via intergroup competition under specific conditions (Bowles 2006; Choi and Bowles 2007); yet whether multi-level selection actually led to the human evolution of altruism is still contested. If ingroup altruism originally responded to

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[1] In a non-human context, Searcy and Nowicki (2006) find that 13% (14 of 107) of squirrels observed to give a terrestrial alarm against an approaching predator were chased or stalked by the predator, compared to only 5% (8 of 168) of those that did not alarm. This nicely illustrates how the existence of risky pro-social behavior extends beyond the human or primate context.

[2] Brennan et al. (2008) investigate attitudes towards risk borne by others in a strategic and non-strategic environment. They find no relationship between risk attitudes and other-regarding concerns.

the adaptive challenges of forming a cohesive coalition to compete for resources with other groups of people, though, then intergroup competition could have been the trigger for such an innate psychological trait to develop. In the process, this would engender a sense of obligation to serve the interest of the ingroup (Brewer 1979).

We design a novel treatment where groups compete for the public good in a sequential move: The second-moving group can make decisions to volunteer or not, contingent on the volunteering outcome of the first-moving group. Sequential moves provide the opportunity to set up corresponding treatments that are identical to the subgame of the second stage (the decision node for the group of the second movers). Hence, we can investigate the effect of intergroup competition without having to operate with multiple payoff matrices resulting from intergroup competition. In so doing, we can identify the exact effect of intergroup competition in engendering group identity and stimulating cooperative behavior. We find that intergroup competition can increase the tendency to cooperate in a VDG and can sustain cooperation when pro-social behavior involves risk-taking. This is our second contribution to the literature.

This type of sequential intergroup competition is not only analytically convenient, but also reflects real-world phenomena. When bidding for hosting major events such as the Olympic Games and reputational annual conferences, the decision to submit interest and bid is observable, and can hence influence potential competitors' choices. For instance, seeing the setup of the Boston Olympic Exploratory Committee, like-minded citizens and officials in Los Angeles were pushed to wage a campaign as well (Whiteside 2013). Furthermore, pro-social norms are often built by pioneers who set an example for others to follow, competing for public recognition. For instance, competition of charities for giving behavior may heat up to a zero-sum game (Schmitz 2021): Fierce competition among a multitude of charities may result in over-volunteering in fundraising.

One charity comes up with new fundraising opportunities or new social projects, and others follow to compete against the first mover.

Prior evidence from related lab experiments suggested a positive effect of intergroup competition on intragroup cooperation. Bornstein, Erev, and Rosen (1990) were among the first to run a lab experiment with the opportunity to win a reward for outperforming the rival group. Employing the give-or-take-some game, which is a multi-person prisoner's dilemma in which the dominant strategy results in mutual defection, they find that the competition element improves intragroup cooperation. Since then, laboratory studies employing intergroup competition for winning a group reward observed an increase in intragroup cooperation in the prisoners' dilemma game (Erev, Bornstein, and Galili 1993; Bornstein and Ben-Yossef 1994; Gunnthorsdottir and Rapoport 2006; Halevy, Bornstein, and Sagiv 2008), the coordination game (Bornstein, Gneezy, and Nagel 2002), and the public goods game (Rapoport and Bornstein 1989; Sääksvuori, Mappes, and Puurtinen 2011; Tan and Bolle 2007; Puurtinen and Mappes 2008; Cárdenas and Mantilla 2015).

Three possible mechanisms may explain the role of intergroup competition. *Firstly*, the majority of studies devise an intergroup competition treatment with an additional collective prize for the winning group, transforming the payoff structure by making the individual payoff interdependent on other members to win a collective prize (Tan and Bolle 2007). Such interdependence increases individual self-efficiency (the perceived collective benefits from cooperation), and thus the willingness to cooperate (Bornstein and Ben-Yossef 1994). Therefore, intergroup competition helps to alleviate the conflict of interests between individuals and the group. *Secondly*, winning the competition against the outgroup could constitute a focal point that facilitates coordination, making team members give more attention to the ingroup's welfare

(Bornstein and Ben-Yossef 1994; Bornstein, Gneezy, and Nagel 2002). Hence, competition may enhance group identification by creating a common fate among ingroup members (Bornstein and Ben-Yossef 1994; Tan and Bolle 2007). *Thirdly*, even without monetary incentives, the mere group comparison can induce cooperation among strangers in the public goods game. Tan and Bolle (2007) observe that contributions decrease in response to wins and increase after losses, suggesting that the increase in cooperation could be due to benchmarking. Similarly, Jordan et al. (2017) find that a threshold effect, not motivational change, increases cooperation in the public goods game with intergroup competition: A prize competition creates a need for the group to win a public good prize by contributing more than a threshold that is set out by another group.

In the present study, we devise an intergroup competition treatment that can avoid any transformation of payoff structure (i.e., no need for an additional prize) when we make a comparison with the standard VDG, identifying the exact motivation effect of intergroup competition on cooperation. Also, we can exclude the possibility of benchmarking, since competition for the public good is not based on the number of contributions (only one volunteer is sufficient), and because we do not provide players with information about the number of volunteers in the own group or the rival group. As a result, we are able to identify the exact motivational change due to intergroup competition and rule out all other possible explanations, shedding light on the evolutionary interplay of intergroup conflict and altruism. Our treatment design implies a *third contribution* to the literature.

3. The Model

The control treatment (*CT*) is a standard volunteer's dilemma where players decide whether or not to incur a personal cost to provide a public good (Diekmann 1985). We vary treatments across two dimensions to examine the effect of risk-taking (RK treatment) and intergroup competition (*GC* treatment). The first dimension introduces the risky production of public goods: There is a 50% chance of failing to produce a public good. The second dimension involves an intergroup competition treatment, where two groups compete for a public good sequentially: A group with one or more volunteers wins a public good against another group with no volunteer. There is a 50% chance of winning in case of a tie, when both groups have at least one volunteer. Sequential moves result in three potential subgames: the first mover group *GC-Lead* decides in the first stage, and the following group plays *GC-CT* and *GC-RK*, with a payoff structure identical to *CT* and *RK*, respectively. An overview of the resulting treatments is provided in Table 1.

[Insert Table 1 about here]

3.1 The Control Treatment (*CT*): The baseline

Each player decides whether or not to make a personal sacrifice C and to volunteer to produce a public good. Everyone receives a high payoff value of V if at least one player volunteers, and a lower payoff L otherwise. As $V - C > L$, all players choosing not to volunteer cannot be a Nash equilibrium. There are many asymmetric pure strategy equilibria in which one group member volunteers while the others do not. In such an equilibrium, the volunteer forms the belief that the public good would not be produced if she did not volunteer. Since the asymmetric equilibrium in pure strategies requires coordination, most research on one-shot VDGs focuses on the set of symmetric Nash equilibria in mixed strategies, in which each player volunteers with a certain probability.

In a symmetric Nash equilibrium, each player must be indifferent between volunteering and freeriding, and therefore be willing to randomize. Otherwise, players would simply play their preferred action. Let p be the probability of volunteering. A decision to volunteer guarantees a payoff of $V - C$. A decision not to volunteer results in a payoff of V if at least one other player volunteers or L otherwise. The probability of at least one other player volunteering is $1 - (1 - p)^{N-1}$. Accordingly, if all players randomize, we must have

$$V - C = V[1 - (1 - p)^{N-1}] + L(1 - p)^{N-1}, \tag{1}$$

where the left-hand side is the sure payoff of volunteering and the right-hand side is the expected payoff of not volunteering.

Solving Equation (1) for p, the symmetric Nash equilibrium probability of volunteering in the CT treatment under the assumption $V - L > 0$ is:

$$p^{CT} = 1 - \left(\frac{C}{V - L}\right)^{\frac{1}{N-1}}, \tag{2}$$

which is increasing in the added value of the public good $V - L$, and decreasing in both the cost of volunteering C and the number of people N (the bystander effect). All this is true under risk neutrality. If players are risk averse, the collective risk of no volunteering (with probability $(1 - p)^{N-1}$) would encourage them to volunteer more in order to secure a sure payoff $V - C$. Hence, the volunteering rate in a VDG increases with the degree of risk aversion (see Appendix A.1).

3.2 Risk Treatment (*RK*): Risky volunteering

The *RK* treatment is similar to the *CT* treatment, except that now there is only a 50% chance of producing a public good with value V, if at least one player volunteers. This means that volunteers take a risk that their contribution may not pay off. A decision to volunteer yields the expected payoff $\frac{V+L}{2} - C$. Let p be the probability of volunteering. A decision not to volunteer results in the expected payoff $\frac{V+L}{2}$ if at least one other player volunteers or L otherwise. We further plausibly assume $\frac{V+L}{2} - C > L$ so that not volunteering cannot be a Nash Equilibrium. For each player to be willing to randomize, we must have

$$\frac{V+L}{2} - C = \left(\frac{V+L}{2}\right)[1-(1-p)^{N-1}] + L(1-p)^{N-1}. \quad (3)$$

Solving Equation (3), the symmetric Nash equilibrium probability of volunteering in the *RK* treatment is:

$$p^{RK} = 1 - \left(\frac{2C}{V-L}\right)^{\frac{1}{N-1}}. \quad (4)$$

The risk of failing to produce the public good reduces the expected benefits of volunteering. Hence, the equilibrium probability to volunteer is lower than the one in the *CT* treatment ($p^{CT} > p^{RK}$). Further comparative statics under risk neutrality are equivalent to the analysis of the *CT* treatment (i.e., with a positive marginal effect from the value of public good ($V - L$), a negative marginal effect from cost of volunteering (C), et cetera).

Note that the *RK* treatment involves two types of risk: the risk of no volunteering and the risk of unsuccessful volunteering. The risk of no volunteering encourages risk-averse players to volunteer more than risk-neutral players in order to avoid the outcome of collective inaction – a type of risk that also manifests in the *CT* treatment. The risk of unsuccessful volunteering, by contrast, only appears in the *RK* treatment, inducing risk-averse individuals to not volunteer and secure their endowment (*L*). Accordingly, in the *RK* treatment, individuals trade off these two risks when making risky decisions, creating an inverted-U shaped relationship between risk aversion and risky volunteering (see Appendix A.2 for a theoretical discussion and A.3 for a numerical simulation). Unlike in the *CT* treatment, where risk-averse players tend to volunteer more, highly risk-averse individuals would rather lose the chance to produce a public good than take the risk of unsuccessful volunteering in the *RK* treatment, exhibiting a lower volunteering rate than with risk-neutral players.

3.3 Intergroup Competition Treatment (*GC*)

In the *GC* treatment, two groups (Team *A* and Team *B*) play volunteer's dilemma games within each group and compete for a winner-takes-all prize of value *V* to each member of the winning group. For each group, the probability of winning depends on whether or not at least one member decides to volunteer. One group can win the prize for sure if the group has at least one volunteer, while the other group does not. If both groups have at least one volunteer, then the winning chance is 50 percent. Unlike other intergroup competition experiments, we make the competition sequential. Members of Team *A* move first in stage 1, deciding whether to volunteer or not. In stage 2, members of Team *B* can decide to volunteer or not, contingent on the observed outcome of stage 1. Sequential moves provide the opportunity to design corresponding treatments that are identical to the subgame of the second stage (the decision node for Team *B*). If no first mover volunteers, then the subgame of the second movers (*GC-CT*) is identical to the *CT* treatment: The probability of winning the prize is 1.

The equilibrium probability to volunteer for Team *B* is the same as the one in the *CT* treatment ($p_B^{GC-CT} = p^{CT}$) if nobody in Team *A* volunteers, and the same as the one in the *RK* treatment ($p_B^{GC-RK} = p^{RK}$) if at least one member in Team *A* volunteers. Therefore, the set-up maintains the intragroup structure of a social dilemma while keeping payoff structures identical between the two subgames of the *GC* treatment (*GC-CT* or *GC-RK*) and the corresponding single group treatments (*CT* or *RK* treatment): The associated counterpart treatments face the exactly identical game structure for Team *B's* contingent responses. This allows us to identify the exact motivational effect of intergroup competition on self-sacrificial behavior whilst keeping the general payoff structure intact. In prior studies, by contrast, the intergroup competition treatment introduces a collective consequence that impacts the intragroup payoff structure, which changes the expected benefit of cooperation.

In the sequential team competition, members of Team *A* first decide whether or not to volunteer in stage 1 (*GC-Lead*), and then members of Team *B* make their decisions at stage 2, contingent on the prior action of Team *A*. As said, at the second stage, players in Team *B* either face the same subgame as in the *RK* treatment if at least one member of Team *A* volunteers, or the same subgame as in the *CT* treatment if nobody of Team *A* volunteers. For players in Team *B*, the mixed strategy equilibrium for volunteering in each case is either Equation (4) or Equation (2), respectively. At stage 1, let p_A be the probability of volunteering for the members of Team *A*. On the one hand, the decision for players in Team *A* to volunteer transforms the second-stage subgame into an equivalent of the *RK* treatment. The equilibrium probability of no volunteer in Team *B* is $q_B \equiv (1 - p_B^{GC-RK})^N = (1 - p^{RK})^N$, and this event yields a payoff of $V - C$ for volunteering members of Team *A*. The possibility that at least one player in Team *B* volunteers results in an expected payoff of $\frac{V+L}{2} - C$ under the tiebreak rule of 50% chance of winning. In all, the expected payoff of volunteering in the first stage therefore is:

$$(V - C)q_B + \left(\frac{V+L}{2} - C\right)(1 - q_B). \tag{5}$$

On the other hand, the decision not to volunteer results in a payoff of L if no other member of Team A volunteers, and the probability of such an event is $q_A \equiv (1 - p_A)^{N-1}$ under symmetric equilibria. If another member of Team A volunteers, the second-stage subgame becomes equivalent to the RK treatment, and the expected payoff is Equation (5) without cost incurred. Therefore, the expected payoff of not volunteering in the first stage is:

$$Lq_A + \left[Vq_B + \left(\frac{V+L}{2}\right)(1 - q_B)\right](1 - q_A). \tag{6}$$

For each person in Team A to be willing to randomize, we must have Equation (5) equal to Equation (6), which gives the Nash equilibrium probability of volunteering in the first stage by solving for p^A:

$$p_A^{GC} = 1 - \left[\left(\frac{2C}{V-L}\right)\left(\frac{1}{1+q_B}\right)\right]^{\frac{1}{N-1}}, \tag{7}$$

with $q_B \equiv (1 - p^{RK})^N$, which is the equilibrium probability of no volunteer in Team B in the risk treatment. Note that p_A^{GC} is decreasing in p^{RK}, implying that the (belief on the) followers' likelihood to volunteer has a negative effect on leaders' volunteering rate.

4. Procedures

We conducted the experiment in the CentERlab at Tilburg University in the Netherlands,[3] inviting 126 participants between September 2018 and November 2018. Of these, 53.4% are female. They are 22.6 (s.d. = 3.20) years old, on average. Of the recruited participants, 54.8% are undergraduate students, and 45.2% are graduate students – all participating voluntarily on a fee basis. By far the majority of the recruited students were from the social sciences and humanities: business and management (42.1%), economics (27.8%), psychology (15.1%), other social sciences (3.2%), and applied sciences (5.7%).

Participants were divided into seven sessions, and were given written instructions for the experiment. The number of participants per session ranges from 12 to 24, but always with a multiplier of 3. All participants first completed in the Holt-Laury risk task to measure their risk aversion (Holt and Laury 2002), and then participated in the *CT* treatment in ten consecutive decision periods.[4] Afterward, 48 participants of three sessions played the *RK* treatment in ten consecutive decision periods, and the other 78 participants of four sessions played the *GC* treatment in ten consecutive decision periods. To make sure that they understood the game structure, all participants had to correctly answer a few test questions before making their decisions.

[3] The experimental procedures were examined and approved by CentERlab, and abide by the ethical rules for employing human subjects in research. The experiments were conducted following the procedures established by Tilburg University's CentERlab. Our study went through an open peer review meeting that is mandatory for all scholars wishing to use the CentERlab facilities. All experiments were conducted with the informed consent of healthy adults who were free to withdraw from participation at any time. Only individuals who voluntarily entered Tilburg University's experiment recruiting database were invited, and informed consent was indicated by electronic acceptance of an invitation to attend an experimental session.

[4] Before the experiment, all participants were asked to participate in a ten-minute on-line survey regarding personal information and attributes.

Participants were randomly assigned to a group of three ($N = 3$). The *GC* treatment employs stranger matching with fixed roles: The role assignment into Team *A* (leaders) or Team *B* (followers) is fixed throughout the entire treatment. Also, we employ the strategy method for Team *B* in order to collect more observations at two decision nodes (whether someone in Team *A* invests or not), as the strategy method usually produces results consistent with the direct response method in games involving voluntary cooperation (Fischbacher, Gächter, and Quercia 2012). Across all treatments, the benefit to every member of the group when the public good was attained is €12 ($V = 12$), and the personal cost of volunteering is €2 ($C = 2$) for each volunteer. When the public good was not attained, each person in the group earned €4 ($L = 4$). There was no feedback to participants on the number of volunteers. Participants were only informed after each round about the binary outcome of public good production (whether one or more people in the own group invested), the outcome of the lottery in the *RK* treatment, and the outcome of the team competition in the *GC* treatment.

We designed and ran the experiment using *z-Tree* (Fischbacher 2007). Participants received their earnings for one randomly drawn game from the 20 decision rounds, plus the earnings from the Holt-Laury risk task. The experiment lasted approximately 50 minutes (including instructions), and participants earned about €12, on average, and were paid in cash at the conclusion of the experiment. Below, we first report descriptive statistics of individual risk attitudes and the average volunteering rate per treatment. Then, we utilize individual decision data to examine treatment effects, and heterogeneous treatment effects of risk aversion and gender by estimating a mixed-effects linear regression model.

5. Results

5.1 Descriptive Statistics

Table 2 displays the results from the Holt-Laury risk task from 128 participants. The mean of the Holt-Laury risk task is 4.72 and the majority (71.42%) of people are risk averse. Table 3 shows the average rate of volunteering by sessions, treatment average, and the Nash equilibrium across treatments. We have 128 participates playing the *CT* treatment, 48 participants the *RK* treatment, and 39 participants in both the *GC-CT* and *GC-RK* treatment, and another 39 participants in *GC-Lead* treatment.

[Insert Tables 2 and 3 about here]

In Figure 1, bars show the treatment averages of volunteering, and whiskers indicate the 95% confidence intervals (at the level of individuals). The observed average volunteering rate is 46.3% when no risk and intergroup competition are involved (*CT* treatment), slightly lower than what the Nash equilibrium predicts. When producing public goods is risky (*RK* treatment), the volunteering rate drops to 32.7%, as predicted by the Nash equilibrium. Intergroup competition increases the volunteering rate by around 10% above the Nash equilibrium probability, particularly when volunteering involves risk-taking. Figure 2 shows that intergroup competition shifts the cumulative distribution function of the *CT* and *RK* treatments to the right, particularly increasing the median of safe volunteering and the upper quartile of risky volunteering.

In addition, the no-volunteering rates (the frequency of no volunteer in the own group) in the *CT* and *RK* treatments are close to the Nash equilibrium prediction, at 14.3% and 31.9%, respectively.[5] Intergroup competition increases individuals' volunteering rate and thereby reduces the no-volunteering rate to 6.9% and 21.5% in *GC-CT* and *GC-RK* treatment, respectively. Finally, the volunteering rate in *GC-Lead* is 35.1% – close to the Nash equilibrium prediction[6] – resulting in a no-volunteering rate of 26.2%.

[Insert Figures 1 and 2 about here]

5.2 Regression Analysis

Strictly speaking, we only have 7 (*CT* treatment), 3 (*RK* treatment), and 4 (*GC* treatment) independent observations per treatment, since all participants in one session were connected. We therefore employ a mixed-effects (ME) linear model with repeated measures for our analysis of treatment effects. The 2×2 treatment effects are modeled as binary fixed effects, and sessions and participants within each session are modeled as random effects. The observations in the *GC-Lead* treatment are dropped from the regression analyses for treatment effects since the *GC-Lead* treatment cannot be neatly compared to other treatments in terms of payoff matrix. We will discuss the treatment effect of the *GC-Lead* treatment towards the end of this subsection. Table 4 reports regression estimates aimed to test the effect of intergroup competition and risky production on volunteering. Because there could be substantial variation in volunteering across sessions resulting

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[5] The probability of nobody volunteering in a group is $(1-p)^N$.

[6] We use Equation (7) to determine the subgame perfect equilibrium probability of volunteering in the *GC-Lead* treatment. Let each member of the follower group volunteer at the subgame perfect volunteering rate of $p^{RK} \approx 0.293$. With $q_B = (1-p^{RK})^N \approx 0.354$, the equilibrium probability of volunteering in the *GC-Lead* treatment derives at $p_A^{GC} \approx 0.392$. Alternatively, if participants in the leading group correctly predict the actual p^{RK} to be 43.1% (i.e., $q_B \approx 0.225$ in Equation (7)), they should volunteer with a probability of 35.0% instead. Our experimental data is remarkably close to these two predicted probabilities.

from the random stranger matching within each session, we generalized the error structure to include heteroskedastic variances across individuals and sessions.

[Insert Table 4 about here]

The dependent variable in Model 1 is the average volunteering rate across ten rounds for each observation. In Models 2, 3, and 4, the dependent variable is the binary volunteering decision (1 = to invest/volunteer) in each round.[7] Models 2, 3, and 4 control for experience (the number of rounds played), and previous win (whether the group has won or successfully produced a public good in the previous round). Model 4' excludes data from Session 7 as a robustness check, as this session witnesses a substantially higher volunteering rate in the *GC-CT* treatment.[8] All models control for gender,[9] risk aversion (the number of safe choices chosen in the Holt-Laury risk task, centered at three choices, or risk-neutral individuals), and Models 3 and 4 allow for heterogeneous effects of risk aversion across treatments.

On the one hand, group competition increases the volunteering rate or likelihood by 13-15% from the baseline volunteering rate of 47-51%. On the other hand, risky production decreases the volunteering rate or likelihood by 13-19%, consistent with the theoretical prediction that risk reduces the expected benefit from volunteering. Intergroup competition can mitigate the negative impact of risk and maintain the volunteering rate: The estimated coefficient difference between

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[7] We find no significant time trend for the volunteering decision across treatments. The Spearman's rank correlation test reports: $\rho=-0.042$, $p = 0.140$ in the *CT* treatment; $\rho=-0.005$, $p = 0.906$ in the *RK* treatment; $\rho=-0.036$, $p = 0.476$ in the *GC-CT* treatment; and $\rho=-0.018$, $p = 0.723$ in the *GC-RK* treatment.

[8] The difference between Session 7 and other sessions in the *GC-CT* treatment is mainly driven by men: Men in Session 7 volunteer as much as women do in the *GC-CT* treatment (73% versus 78%), while men in other sessions volunteer significantly less than women do (30% versus 70%). Demographically, the majority of men in Session 7 are Economics students (62%, compared to 30% in other sessions), most of them are Dutch (75%, compared to 32% in other sessions), and all of them are Caucasian (100%, compared to 60% in other sessions).

[9] One participant marked a third gender and was dropped from the regression analysis.

RK and *GC-RK* is significant (from mildly to strongly across models; test statistics are shown in the last row of Table 4). In short, the tendency to volunteer increases in response to intergroup competition, even if there is no payoff transformation or monetary incentive. Regarding other controls, females are more likely to volunteer than males, though the evidence is mild (p = 0.087 in Model 1 and p = 0.098 in Model 2). We do not find any evidence that volunteering decisions respond to experience or previous success of producing a public good.

Regarding risk aversion, expected utility theory predicts a positive relationship between risk aversion and volunteering in the *CT* and *GC-CT* treatments, and an inverted U-shaped relationship in the *RK* and *GC-RK* treatments. Models 1 and 2 reveal no robust evidence for a relationship between risk aversion and volunteering, unless volunteering involves only risky production (Model 3). By including a squared term for each risk aversion variables, an inverted-U shape relationship is found in Model 4 between risk aversion and volunteering in the *GC-CT* treatment (joint significance $\chi^2(2)$ = 7.25, p = 0.026), and the positive effect peaks at highly risk-averse individuals (the number of safe choices = 5.91). In the *RK* treatment, the relationship remains significantly positive. Model 4' demonstrates that excluding the observations from Session 7 by way of robustness check does not fundamentally change our results, albeit reducing the treatment effect of *GC-CT* from 13.2% to 10.5%.

Figure 3 plots the probability of volunteering predicted using Model 4 across different levels of risk aversion. Figure 4 then employs piecewise regression using Model 4 to plot the probability of volunteering. As such, we partition risk aversion into two intervals, taking risk neutrality (four safe choices) as breakpoint. The above findings are inconsistent with expected utility theory: Risk aversion does not have a clear relationship with volunteering in the *CT* treatment; risk-averse individuals are more likely to volunteer than risk-neutral and risk-seeking ones in the *RK* treatment, opposite to the prediction of expected utility theory. Also, on the one hand, the negative impact of volunteering risk is mainly driven by risk-seekers who are less likely to volunteer in the *RK* treatment than in the *CT* treatment. On the other hand, the positive effect of intergroup competition in the *GC-CT* treatment is driven mainly by risk-averse individuals, and in the *GC-RK* treatment by risk-seekers.

[Insert Figures 3 and 4 about here]

Subsequently, examining differences in volunteering between male and female participants per treatment, we do find significant patterns. In Table 5, we take a closer look at the gender effect across the respective treatments. Model 5 uses the treatment average as observations, and Models 6 and 7 utilize observations per period. In addition, Model 7' excludes observations from Session 7 as a robustness check. Again, excluding observations from Session 7 does not fundamentally change the regression results (Model 7'); only some of coefficients become less significant. Figure 5 shows the predicted probability of volunteering using Model 7 for males and females across treatments.[10] On average, males volunteer more than females in the *GC-RK* treatment, while females volunteer more in the other three treatments. On the one hand, in response to intergroup competition, females increase no-risk volunteering by 20.19% ($z = 4.88$, $p = 0.000$, Model 7), but not risky volunteering ($\tilde{\chi}^2(1) = 0.69$, $p = 0.406$, Model 7). On the other hand, in response to intergroup competition, males increase risky volunteering significantly by 30.42% ($\tilde{\chi}^2(1) = 23.76$, $p = 0.000$, Model 7) and increase no-risk volunteering mildly by 9.24% ($\tilde{\chi}^2(1) = 3.16$, $p = 0.076$, Model 7). Males over-volunteer under the risk of failure when facing intergroup competition:

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[10] Since gender differences between treatments may come from gender differences in risk attitudes, we also ran a combined model of Models 4 and 7, which includes heterogeneous treatment effects across both genders and risk attitudes. The resulted figure of predicated probability of volunteering for males and females is very similar to Figure 5.

Males' volunteering tendency in the *GC-RK* treatment is even significantly higher than in the *CT* treatment ($\chi^2(1) = 8.72$, $p = 0.003$, Model 7).[11] As a result, a group with more females has significantly more volunteers in the *RK* and *GC-CT* treatments, but not in *GC-RK* one (see Figure 6). On the contrary, the number of volunteers significantly decreases with the number of males in the own group in the *RK* treatment, but not in the *GC-RK* treatment.

[Insert Table 5 and Figures 5 and 6 about here]

Finally, we estimate a mixed-effects (ME) model using within-subject per period observations of *GC-Lead* participants (see Table A.1 in the Appendix). Like in Model 4, we control for gender, experience, previous win, and heterogenous effects of risk aversion across treatments. We find that the *GC-Lead* treatment reduces the volunteering rate by 7.5% ($p = 0.079$, Model A4), and that the treatment effect is driven by men: Men reduce the rate of volunteering in the *GC-Lead* treatment significantly by 15.0% ($\chi^2(1) = 20.10$, $p = 0.000$), with such treatment effect being absent for women ($p = 0.247$). Moreover, risk aversion has a negative effect on volunteering in the *GC-Lead* treatment: One more safe choice in the Holt-Laury risk task reduces the volunteering rate by 4.1% ($p = 0.036$). Figure 7 plots the predicted probability of volunteering across different levels of risk aversion for *GC-Lead* participants: Risk-seekers volunteer in the *GC-Lead* treatment as much as in the *CT* treatment, yet risk-averse individuals are significantly less likely to volunteer in the *GC-Lead* treatment.

6. Discussion and Conclusion

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[11] The statistic becomes weakly significant ($\chi^2(1) = 2.98$, $p = 0.084$, Model 7') when dropping the observations from Session 7

We extend the classic volunteer's dilemma game to examine the role of risk-taking and intergroup competition, and develop novel treatments to investigate pro-social risk-taking and competitive behavior. We find that individuals respond to intergroup competition even if there is no payoff structure transformation or additional monetary incentive. Intergroup competition can increase the tendency to volunteer and sustain cooperation when volunteering involves the risk of failure. Previous experiments link monetary incentives to competition, and such payoff interdependence creates a threshold effect that motivates individuals to contribute to public goods and win a prize (Jordan et al. 2017). Our *GC* and *RK* treatments avoid additional monetary incentives: No additional group bonus or prize is provided, so the treatments for comparison have identical payoff structures. This allows us to identify the exact motivational effect resulting from intergroup competition. Our design further avoids any benchmarking effects from the rival group's performance in the volunteer's dilemma, because a single volunteer is sufficient for public good production, and because players do not have information on the number of volunteers.

Our experiment shows that intergroup competition can act as a payoff-irrelevant focal point that increases the salience of group identity. Intergroup rivalry may enhance the salience of a collective social identity, motivating individuals to allocate greater weight to the joint welfare over individual gains alone (Tan and Bolle 2007; Brewer and Kramer 1986). However, intergroup competition engenders an important behavioral trait – parochial altruism – that spurs individuals to make personal sacrifices for ingroup welfare, and to be hostile towards competing outgroups (Schelling 1958; Choi and Bowles 2007; Bernhard, Fischbacher, and Fehr 2006). In other words, intergroup competition can stimulate cooperative behavior that comes with ingroup favoritism and outgroup hostility[12] (Balliet, Wu, and De Dreu 2014). Bernhard, Fischbacher, and Fehr (2006) find a puzzling result in a third-party altruistic punishment game in that punishers protect ingroup victims, who suffer from a norm violation more when facing outgroup norm violators than they do when facing ingroup violators. Therefore, human altruism can be parochial and responsive to intergroup conflicts, implying that individuals are more likely to volunteer and benefit ingroup members in the presence of outgroup threats.

We also extend the volunteer's dilemma game to involve pro-social risk-taking. In many real-life settings, volunteers not only expend personal efforts to begin with; these efforts also bear the risk of turning out to be a useless sacrifice. Similar to Brennan et al. (2008), we find no evidence for the association between risk attitudes and other-regarding preferences in the standard volunteer's dilemma game. Our study does reveal that risk-averse individuals tend to volunteer more than risk-neutral and risk-seeking ones, demonstrating that risk attitudes can influence the decision to provide a public good in specific cases. This finding is inconsistent with expected utility theory, which suggests that risk aversion should discourage individuals from performing risky volunteering. Instead, it is risk-seekers who are more discouraged from bearing the risk of unsuccessful volunteering than risk-averse individuals in the experiment. Brewer and Kramer (1986) offer the intuition that risk-averse individuals are more sensitive to collective risk (the risk of no volunteering in our experiment), whereas risk-seekers respond more to the risk associated with self-interested behavior (the risk of unsuccessful sacrifice). The bias towards attending to the collective risk could mitigate the negative effect from the risk of failure, and hence increase the

[12] Normatively speaking, parochial altruism is pro-social from the in-group perspective but anti-social in terms of the society as a whole, so this innate predisposition is a biased form of pro-social behavior (Diesendruck and Benozio 2012), or what Haidt and Graham (2007) refer to as the loyalty foundation.

tendency to take a risk and volunteer for risk-averse individuals. On the contrary, the presence of the risk of failure may only make risk associated with self-interested behavior more salient for risk-seekers. However, no single explanation can account for the entire pattern of the relationship between volunteering and risk attitudes across all treatments. The intergroup contest may make the risk of collective inaction salient, but such effect may interact with competitive contexts (whether the opponent group has a volunteer to compete) and risk factors (weather volunteering involves risk of failure). Future studies could further explore the relationship between risk attitudes, competitive behaviors, and collective action problems.

Gender differences are another prominent aspect of investigating risk attitudes, cooperation and competition in the economics and psychology literatures. Females are found to be more risk averse, more averse to competition, and more context-sensitive in their other-regarding preferences (Gneezy and Rustichini 2004; Croson and Gneezy 2009). Our study shows that males are responsive to intergroup competition when volunteering involves risk of failure (the *GC-RK* treatment), while females respond to intergroup competition only when volunteering guarantees the success of producing public goods (the *GC-CT* treatment). The presence of gender-heterogeneous treatment effects could be attributed to three sources of differences: i.e., gender differences regarding (i) preference for risky investment, (ii) competitiveness, and (iii) attitudes toward outgroup members.

First, males are more likely to see risky situations as a challenge that evokes approach behavior and intervention, while females tend to perceive these as a threat that initiates avoidance behavior (Arch 1993). Intergroup competition therefore could stimulate men's motivation to volunteer in order to cope with risky/challenging situations. *Second*, unlike the *GC-CT* treatment, the *GC-RK* treatment puts two competing groups into a winner-takes-all lottery if someone from the second-mover group decides to volunteer. In a laboratory experiment, Gneezy, Niederle, and Rustichini (2003) find that a more competitive environment such as a winner-takes-all tournament increases the performance of men, but not of women, in solving mazes on a computer. Hence, the intergroup competitiveness in *GC-RK* could stimulate men to volunteer and make a risky investment.

Third, males could be more hostile toward the welfare of outgroup members in the *GC-RK* treatment. Evolutionary psychologists propose the "male warrior hypothesis", arguing that males are more attentive to cues of outgroup threat, and more likely to exhibit ingroup solidarity and outgroup hostility (McDonald, Navarrete, and Van Vugt 2012; Vugt, Cremer, and Janssen 2007; Sugiura et al. 2017). In other words, the parochial altruism triggered by an outgroup threat cue is specific to males (Sugiura et al. 2017). Unlike in the *GC-CT* treatment, in which the payoff of outgroup members (first movers) is already determined and certain, the decision to volunteer in the *GC-RK* treatment has payoff consequences for both ingroup and outgroup members. Such payoff interdependence could be perceived as an outgroup threat, and engender an aggressive response among males to opt for risky volunteering, and to prevent the no-volunteer outcome in which the outgroup wins the public good prize with no roadblocks (i.e., without facing a lottery). Alternatively, females could be more other-regarding toward outgroup members, refraining from increasing their rate of volunteering and competing for resources.

Dekel and Scotchmer (1999) develop an evolutionary model of preference formation to examine to what extent evolution leads to risk-taking and competitive behavior in winner-takes-all environments, and argue that males will evolve to be risk-takers under the pressure of reproduction that resembles a winner-takes-all game. Therefore, men are more likely than women to engage in risky and heroic forms of helping (Eagly and Crowley 1986). Our study provides experimental evidence for this gender-differentiated helping behavior in response to the-winner-takes-all competition. We find that females tend to volunteer more than males in all except the *GC-RK* treatment, and that women tend to increase their rate of volunteering in response to intergroup competition if public good provision is certain and not competitive. Males, by contrast, over-volunteer when public good provision is risky and competitive. This finding can provide a rationale for the phenomenon that females at work volunteer more than males for a task with low promotability (Babcock et al. 2017): A task with high promotability and promotion per se usually entail a zero-sum or the winner-takes-all game that females tend to shy away from, and women tend to volunteer to provide public goods that involve less rivalry. The broader social science literature mainly focuses on masculine actions in intergroup conflict, such as dominant and competitive behavior. Future research can further explore the role of females in intergroup conflict, and investigate gender differences in responsiveness to intergroup conflict.

The volunteer's dilemma is a game of anti-coordination: Players have an incentive to choose opposite strategies, so they are more willing to make personal sacrifices and produce a public good if others are more likely to freeride. In other words, volunteering to provide a public good is a game of strategic substitutes. Cantoni et al. (2019) find consistent evidence from Hong Kong's anti-authoritarian movement in 2014 that protest participation exhibits strategic substitutability, rather than strategic complementarity that many recent models of protest participation assume. Protest involves a threshold of participation to produce a political public good and a risk of government crackdown, which both can be captured by our extended model of the volunteer's dilemma. From our experiment, we observe over-volunteering under intergroup competition. Intergroup conflict may make individuals more alert to the outgroup threat, and regard others' participation as strategic complements that contribute to ingroup cohesion, driving more people into the conflict. Therefore, whether collective actions exhibit strategic substitutability or complementarity can depend on the perceived intensity of ingroup identity or outgroup threat. Future work may investigate strategic considerations of volunteering under intergroup conflicts and failure risk in VDGs to shed more light on political participation.

Finally, over-volunteering is socially inefficient. Intergroup competition stimulates unnecessary volunteering and risk-taking. Abbink et al. (2010) find that intergroup contests with punishment opportunities result in an extremely high level of costly punishment and voluntary contribution in the public goods game. As mentioned above, altruistic punishment in the public goods game can be conceived as a second-order freerider problem, which can be explained by VDGs without assuming punitive preferences (Przepiorka and Diekmann 2013). Outgroup threat, therefore, may trigger a strong motive for ingroup cohesion, and thus may trigger an over-volunteering effect that leads to over-disciplining and wasteful investment. Even though parochial altruism is inefficient in some contexts, the lower fitness of altruists could be compensated with a higher survival rate of more altruistic groups if human ancestors have faced high levels of lethal intergroup conflicts, which resemble a winner-take-all, repeated one-shot game (Bowles 2006; Choi and Bowles 2007). Parochial altruism is a psychological trait designed through evolution that may serve specific survival functions in the ancestral environment, but might cause “human errors” in the current environment. The research paradigm developed in this study is useful to conduct further investigations of cooperation and competition in a risky environment. Future studies can rely on extended models to explore the role that individual heterogeneity plays in the evolution of parochial altruism.

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Appendix

A. Model with Expected Utility

A.1 The Control Treatment (*CT*): The Baseline

Let p be the probability of volunteering. A decision to volunteer guarantees a utility level $u(V-C)$. A decision not to volunteer results in a utility level $u(V)$ if at least one other volunteers or $u(L)$ otherwise. The probability of getting at least one volunteering decision is $1-(1-p)^{N-1}$. Therefore, for each person to be willing to randomize, we must have

$$u(V-C) = u(V)[1-(1-p)^{N-1}] + u(L)(1-p)^{N-1}, \qquad \text{(A.1)}$$

where the left-hand side is the sure utility of volunteering and the right-hand side is the expected utility of not volunteering. Solving (A.1), the symmetric Nash equilibrium probability of volunteering in the *CT* treatment under the assumption $u(V-C) > u(L)$ is:

$$p^{CT} = 1 - \left(\frac{u(V) - u(V-C)}{u(v) - u(L)}\right)^{\frac{1}{N-1}}, \qquad \text{(A.2)}$$

which is increasing in utility gain from the public good $u(V) - u(L)$, and decreasing in disutility from volunteering $u(V) - u(V-C)$ and the number of people N (the bystanders' effect). The ratio $\frac{u(V)-u(V-C)}{u(v)-u(L)}$ is decreasing in the degree of risk aversion, because risk aversion exhibits diminishing marginal utility. Therefore, risk-averse individuals tend to make a small personal sacrifice to avoid the risk of no volunteering, whereas risk-seeking individuals are willing to run the risk of no volunteering to benefit from freeriding.

A.2 Risk Treatment (*RK*): VDG with Risky Production

A decision to volunteer yields the expected utility $\frac{1}{2}[u(V-C)+u(L-C)]$. Let p be the probability of volunteering. A decision not to volunteer results in the expected payoff $\frac{u(V)+u(L)}{2}$ if at least one other volunteers or L otherwise. Note that we need to assume $\frac{u(V-C)+u(L-C)}{2} > u(L)$ so that not volunteering could not become Nash Equilibrium. For each person to be willing to randomize, we must have

$$\frac{u(V-C)+u(L-C)}{2} = \left(\frac{u(V)+u(L)}{2}\right)[1-(1-p)^{N-1}] + u(L)(1-p)^{N-1}. \qquad \text{(A.3)}$$

Solving (A.3), the symmetric Nash equilibrium probability of volunteering in the *RK* treatment is:

$$p^{RK} = 1 - \left(\frac{u(V)-u(V-C)}{u(V)-u(L)} + \frac{u(L)-u(L-C)}{u(V)-u(L)}\right)^{\frac{1}{N-1}}. \qquad \text{(A.4)}$$

Comparing (A.4) to (A.2), the nominator includes a second term $\frac{u(L)-u(L-C)}{u(V)-u(L)}$ in the *RK* treatment, which is a ratio of a disutility from unsuccessful volunteering to utility gain from the public good. This ratio is increasing in the degree of risk aversion, demotivating risk-averse individuals to volunteer because they prefer not risking their endowment for a public good lottery. Therefore, two types of risk have two opposing directional effects, and their total effect on volunteering exhibits an inverted U-shape relationship.

A.3 Numerical Simulation

We use the parameters set in the experiment for numerical simulation to show the relationship between risk attitudes and volunteering: $N = 3$, $V = 12$, $L = 4$, and $C = 2$. We do numerical simulation in Figure A1, assuming an exponential utility function (the left graph) or a power utility function (the right graph). The results show that p^{CT} is increasing monotonically in the degree of risk aversion, whereas p^{RK} shows an inverted U-shaped relationship. In the *RK* treatment, risk aversion, on the one hand, discourages individuals to volunteer for fear of unsuccessful volunteering. Risk-seeking, on the other hand, can sustain the volunteering rate as in the *CT* treatment by increasing the willingness to invest in a public good lottery. p^{RK} converges to p^{CT} from the right-hand side because the second term in the bracket of (A.3) goes to zero as the degree of risk-seeking increases (i.e., $\frac{u(L)-u(L-C)}{u(V)-u(L)} \rightarrow 0$ as $-\frac{u(x)''}{u(x)'} \rightarrow -\infty$).

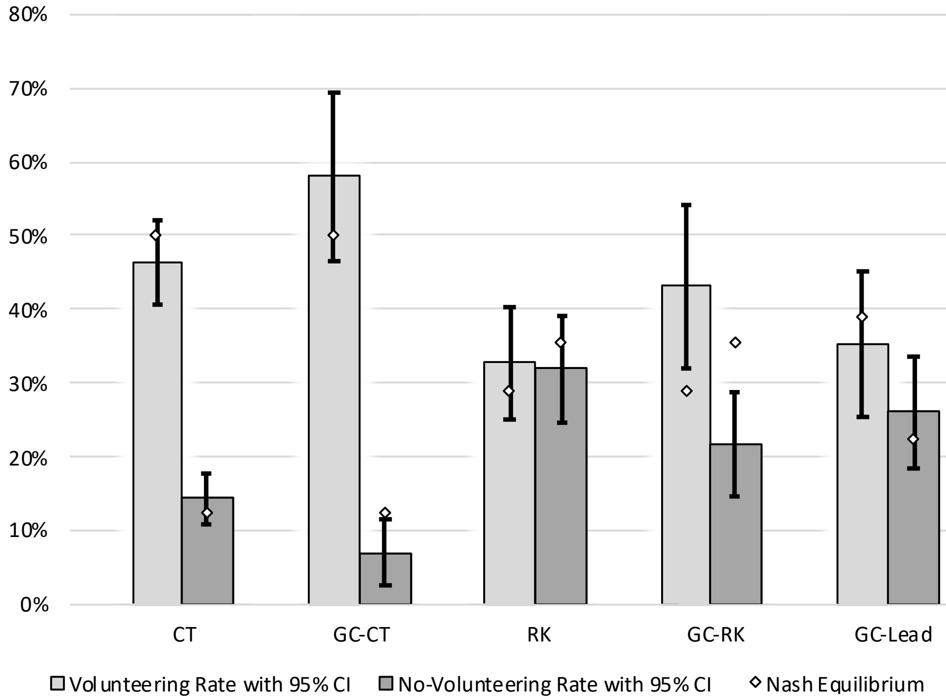

Figure 1: Volunteering and no-volunteering rates across treatment. Confidence intervals are based on observation per individual per treatment for the volunteering rates, and per group per period for the no-volunteering rates.

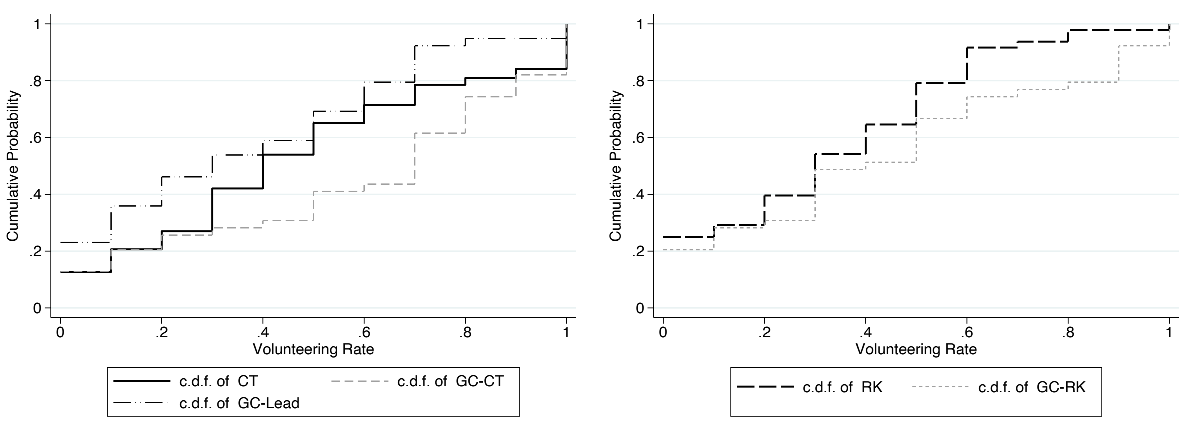

Figure 2: Cumulative distribution of volunteering rate

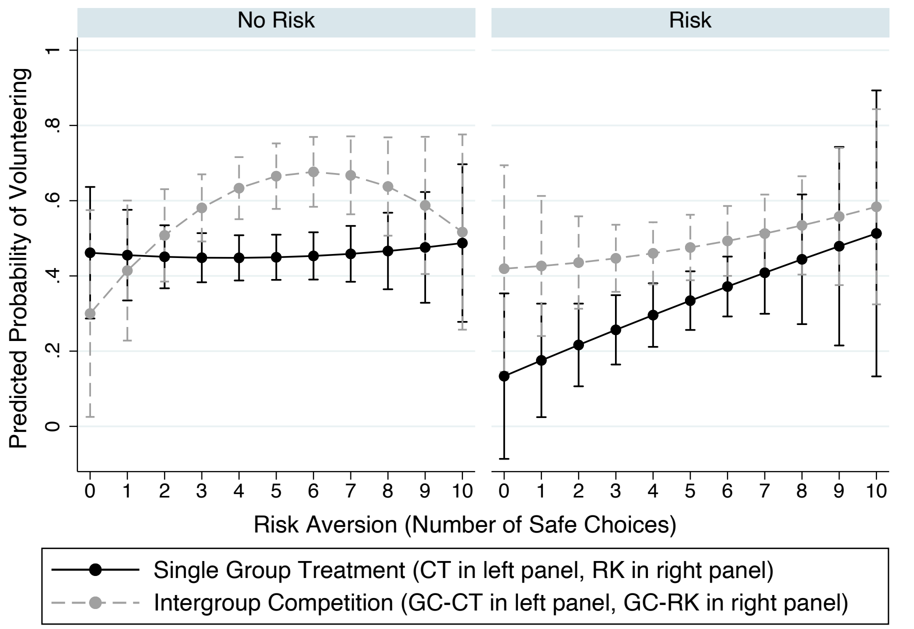

Figure 3: Prediction of Model 4 with 95% confidence intervals

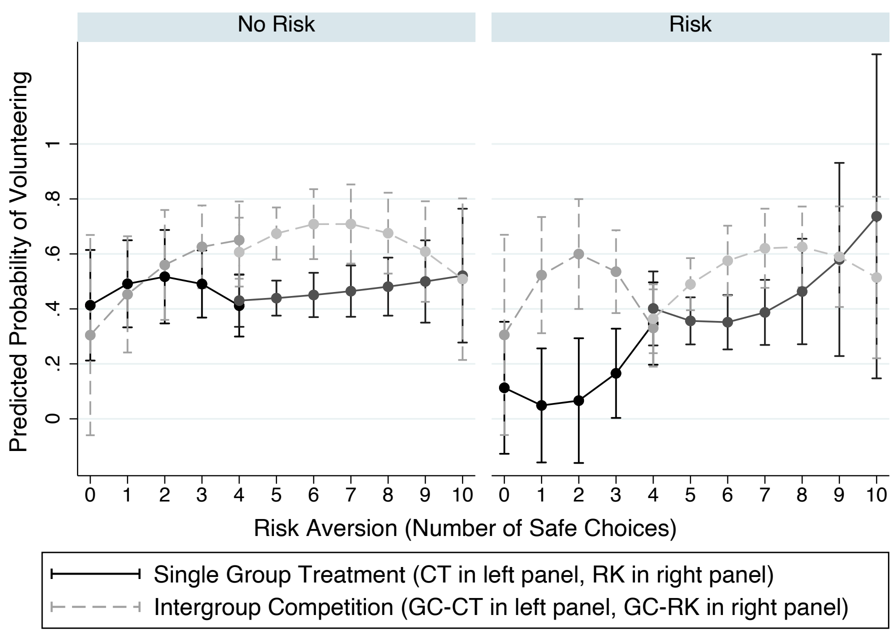

Figure 4: Prediction of Model 4 using piecewise regression (4 of safe choices as a knot) with 95% confidence intervals.

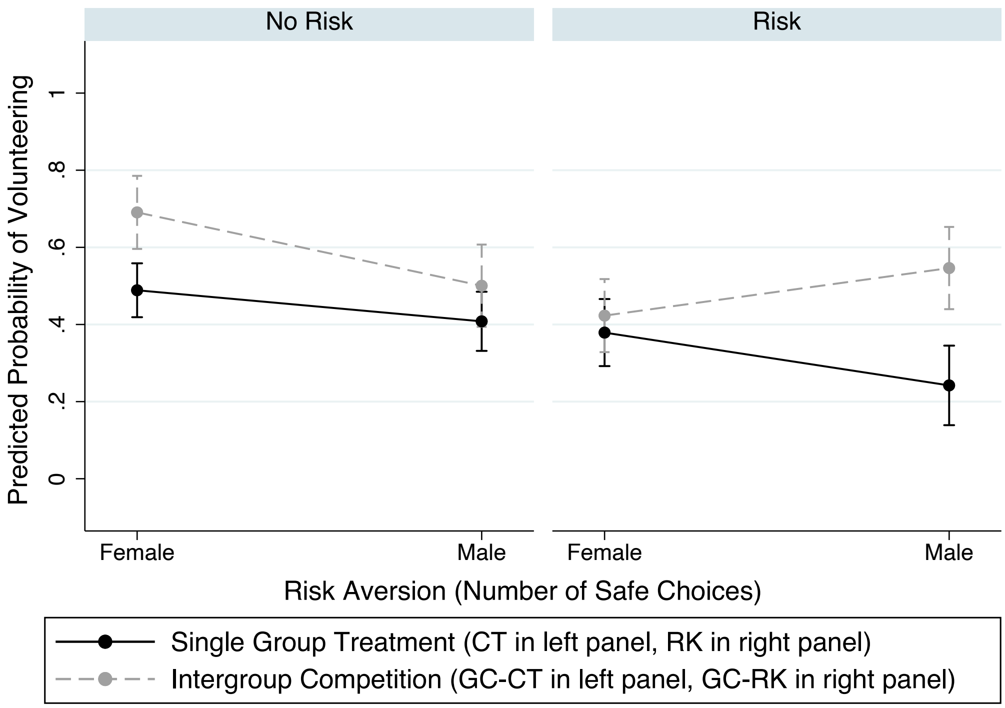

Figure 5: Linear prediction of Model 6 with 95% confidence intervals

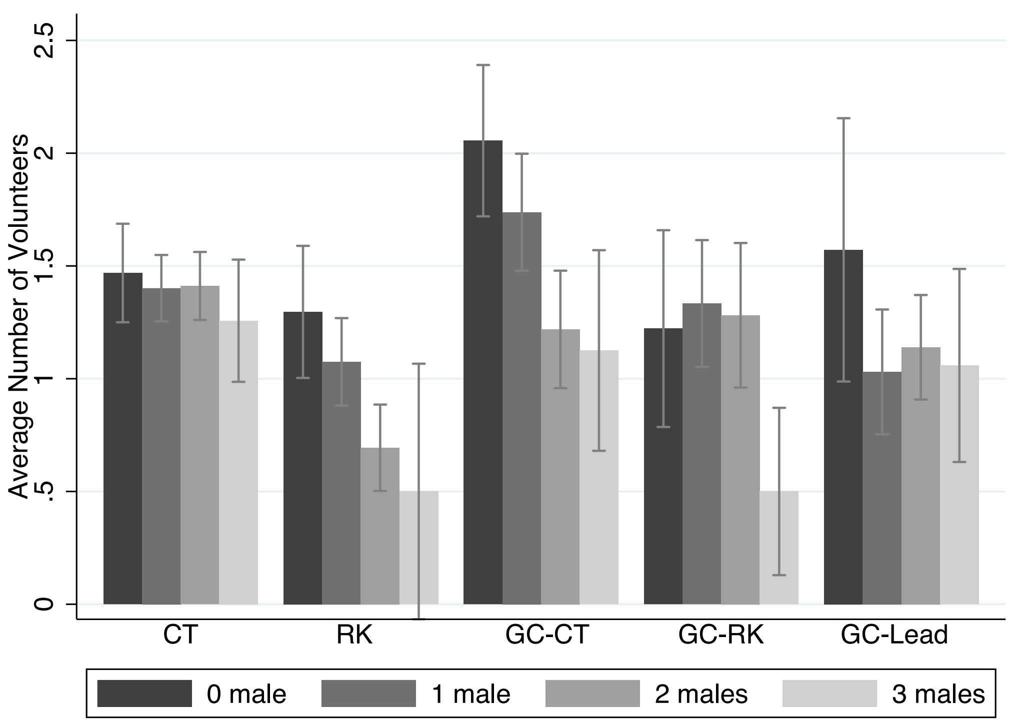

Figure 6: Average number of volunteers across treatments, over the number of males in the own group

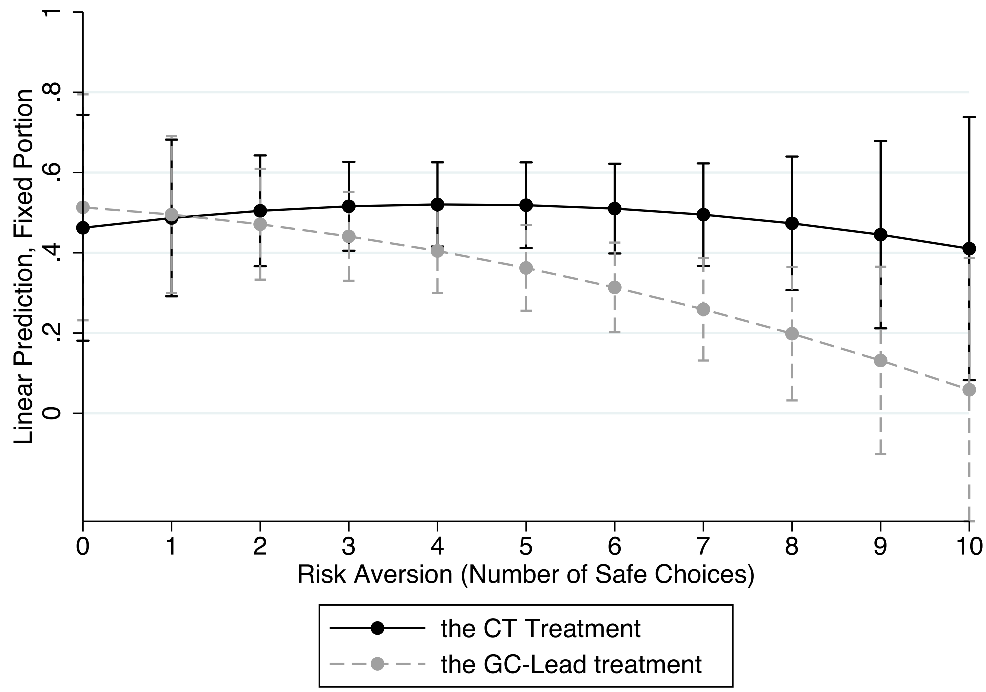

Figure 7: Prediction for participants of the leading groups

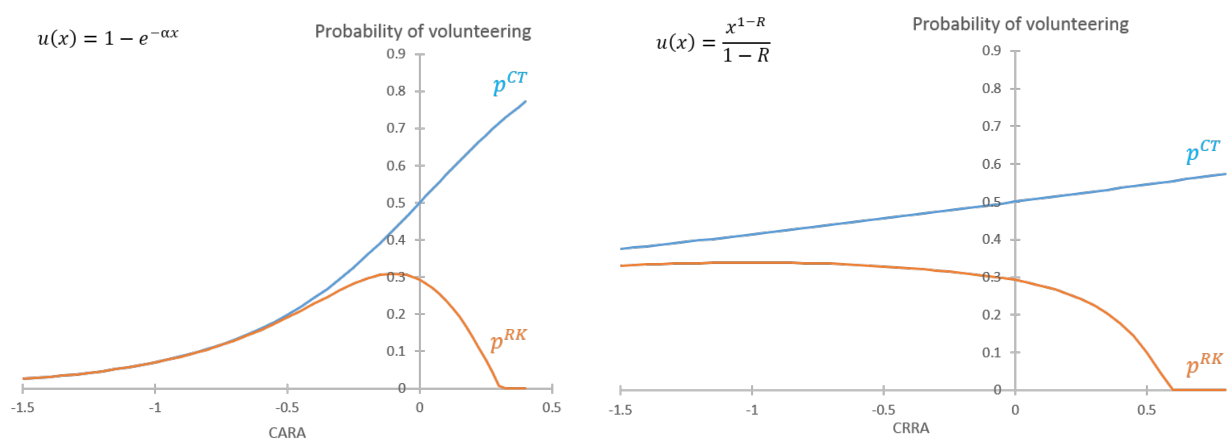

Figure A1: The relationship between risk attitudes and volunteering

Table 1: Overview of treatments

	Single Group Production		Intergroup Competition		
			Second Mover	Second Mover	First Mover
	No Risk	Risk	No Risk	Risk	Risk
Treatment acronym	*CT*	*RK*	*GC-CT*	*GC-RK*	*GC-Lead*

Table 2: Summary of treatment results

# of Safe Choice	Implied CRRA	Implied CARA	Risk Preference	Percentage
0	r<-1.54	r<-0.58	extremely risk-seeking	6.35
1	-1.54<r<-0.70	-0.58<r<-0.27	highly risk-seeking	1.59
2	-0.70<r<-0.15	-0.27<r<-0.16	risk-seeking	3.17
3	-0.15<r<0.29	-0.06<r<0.12	risk neutral	13.49
4	0.29<r<0.70	0.12<r<0.28	risk averse	22.2
5	0.70<r<1.01	0.28<r<0.45	very risk averse	19.84
6	1.01<r<1.54	0.45<r<0.64	highly risk averse	15.87
7	1.54<r<2.06	0.64<r<0.87	extremely risk averse	8.73
8	2.06<r<2.85	0.87<r<1.23	extremely risk averse	3.17
9, 10	2.85<r	r>1.23	extremely risk averse	5.56

Table 3: Rate of volunteering

Treatment	*CT*	*RK*	*GC-CT*	*GC-RK*	*GC-Lead*
	No-Risk, single group	Risk, single group	No-risk, intergroup, second mover	Risk, intergroup, second mover	Risk, intergroup, first mover
Number of Obs.	126	48	39	39	39
Session	1, 2, 3, 4, 5, 6, 7	1, 4, 5	2, 3, 6, 7	2, 3, 6, 7	2, 3, 6, 7
Obs. per Session	21, 18, 24, 12, 15, 18, 18	21, 12, 15	9, 12, 9, 9	9, 12, 9, 9	9, 12, 9, 9
Session average of volunteering	0.49, 0.38, 0.50, 0.58, 0.33, 0.53, 0.44	0.33, 0.33, 0.31	0.5, 0.58, 0.48, 0.76	0.44, 0.38, 0.42, 0.5	0.37, 0.38, 0.37, 0.28
Treatment average of volunteering	0.46 (0.029)	0.33 (0.038)	0.58 (0.056)	0.43 (0.054)	0.35 (0.049)
Nash Equilibrium of volunteering	0.5	0.29	0.5	0.29	0.39
Number of volunteers	1.39 (0.034)	0.98 (0.045)	1.74 (0.031)	1.29 (0.064)	1.05 (0.045)
No-volunteering rate in the own group	0.14 (0.017)	0.32 (0.036)	0.07 (0.022)	0.22 (0.036)	0.26 (0.038)
NE of no-volunteering rate	0.13	0.35	0.13	0.35	0.22

Standard errors in parentheses (the unit of observation is per group per period when computing the standard errors of number of volunteers and no-volunteering outcome).

Table 4: Regression results: Treatment effect

Dependent Variable:	Decision(s) to volunteer				
	(1) Treatment Average	(2) Decision per round	(3) Decision per round	(4) Decision per round	(4') Decision per round (Dropping Session 7)
Treatment (*CT* as the baseline)					
GC-CT	0.132***	0.154***	0.133***	0.132***	0.105**
	(0.051)	(0.032)	(0.039)	(0.039)	(0.044)
RK	−0.136***	−0.132***	−0.197***	−0.192***	-0.197***
	(0.047)	(0.029)	(0.037)	(0.041)	(0.041)
GC-RK	−0.017	0.023	−0.002	−0.002	-0.008
	(0.051)	(0.032)	(0.039)	(0.039)	(0.044)
Risk aversion	0.014	0.011	0.002	−0.001	0.002
	(0.011)	(0.012)	(0.012)	(0.017)	(0.019)
× *GC-CT*			0.012	0.064***	0.042
			(0.014)	(0.025)	(0.026)
× *RK*			0.038***	0.041**	0.041**
			(0.014)	(0.017)	(0.017)
× *GC-RK*			0.014	0.014	0.000
			(0.014)	(0.025)	(0.026)
Risk aversion squared				0.001	0.000
				(0.004)	(0.004)
× *GC-CT*				−0.011**	-0.008*
				(0.004)	(0.005)
× *RK*				−0.001	-0.002
				(0.005)	(0.005)
× *GC-RK*				0.000	0.001
				(0.004)	(0.005)
Gender (male= 1)	−0.082*	−0.083*	−0.080	−0.081	-0.075
	(0.048)	(0.050)	(0.050)	(0.051)	(0.056)
Experience (Round)		−0.002	−0.002	−0.002	-0.001
		(0.003)	(0.003)	(0.003)	(0.004)
Previous win		−0.022	−0.024	−0.024	-0.034
		(0.021)	(0.021)	(0.021)	(0.023)
Constant	0.473***	0.497***	0.513***	0.512***	0.518***
	(0.042)	(0.050)	(0.051)	(0.050)	(0.056)
Observations	251	2259	2259	2259	1935
Obs per subject	1,2,3	9,18,27	9,18,27	9,18,27	9,18,27
Log likelihood	−55.917	−1393.174	−1388.948	−1384.852	-1168.290
Wald statistic	24.392***	57.520***	66.193***	74.652***	53.402***
Test statistic on $\beta^{GC-RK} > \beta^{RK}$	3.504*	14.594***	14.111***	12.050***	10.716***

* $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$. Standard errors in parentheses.

Note: Mixed-effects linear regression models are estimated. Standard errors are clustered at the session and individual level. Risk aversion is centered at 3. Previous win = 1 if the group won or successfully produced a public good in the previous round and = 0 if otherwise.

Table 5: Regression results: Heterogeneous treatment effect across genders

Dependent Variable:	Decision(s) to volunteer			
	(5) Treatment Average	(6) Decision per round	(7) Decision per round	(7') Decision per round (dropping Session 7)
Treatment (*CT* as the baseline)				
GC-CT	0.208***	0.202***	0.202***	0.165***
	(0.066)	(0.041)	(0.041)	(0.047)
RK	−0.127**	−0.110***	−0.110***	-0.113***
	(0.059)	(0.036)	(0.036)	(0.036)
GC-RK	−0.083	−0.066	−0.066	-0.063
	(0.066)	(0.041)	(0.041)	(0.047)
Male	−0.075	−0.082	−0.081	-0.063
	(0.056)	(0.053)	(0.054)	(0.059)
× *GC-CT*	−0.248**	−0.191***	−0.190***	-0.197**
	(0.096)	(0.073)	(0.073)	(0.083)
× *RK*	−0.097	−0.139**	−0.137**	-0.124*
	(0.088)	(0.069)	(0.069)	(0.072)
× *GC-RK*	0.079	0.122*	0.123*	0.092
	(0.096)	(0.072)	(0.073)	(0.083)
Risk aversion	0.014	0.011	0.013	0.016
	(0.011)	(0.011)	(0.017)	(0.018)
Risk aversion squared			−0.001	-0.001
			(0.003)	(0.004)
Experience (Round)		−0.002	−0.002	-0.001
		(0.003)	(0.003)	(0.004)
Previous win		−0.023	−0.022	-0.032
		(0.021)	(0.021)	(0.023)
Constant	0.470***	0.498***	0.498***	0.500***
	(0.044)	(0.051)	(0.051)	(0.056)
Observations	251	2259	2259	1935
Obs per subject	1,2,3	9,18,27	9,18,27	
Log likelihood	−51.904	−1380.438	−1380.422	-1165.965
Wald statistic	33.558***	83.790***	83.822***	58.186***

* $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$. Standard errors in parentheses.

Note: Mixed-effects linear regression models are estimated. Standard errors are clustered at the session and individual level. Risk aversion is centered at 3. Previous win = 1 if the group won or successfully produced a public good in the previous round and = 0 if otherwise.

Table A.1: Regression results for *GC-Lead* participants

Dependent Variable:	Decision(s) to volunteer			
	(A1)	(A2)	(A3)	(A4)
	Treatment Average	Decision per round	Decision per round	Decision per round
Treatment (*CT* as the baseline)				
GC-Lead	-0.15***	-0.139***	-0.074*	-0.075*
	(0.056)	(0.036)	(0.042)	(0.043)
Risk aversion	-0.022	-0.024	-0.004	0.008
	0.018	(0.018)	(0.020)	(0.028)
× *GC-Lead*			-0.040***	-0.041**
			(0.014)	(0.020)
Risk aversion squared				-0.003
				(0.006)
× *GC-Lead*				0.000
				(0.004)
Gender (male= 1)	-0.109	-0.132	-0.132	-0.118
	(0.084)	(0.085)	(0.085)	(0.088)
Experience (Round)		-0.009	-0.009	-0.009
		(0.006)	(0.006)	(0.006)
Previous win		-0.011	-0.015	-0.014
		(0.039)	(0.039)	(0.039)
Constant	0.599***	0.676***	0.646***	0.645***
	(0.077)	(0.090)	(0.090)	(0.090)
Observations	76	684	684	684
Obs per subject	2	18	18	18
Log likelihood	-15.292	-416.011	-411.889	-411.708
Wald statistic	10.020***	23.180***	31.728***	32.126***

* $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$. Standard errors in parentheses.

Note: Mixed-effects linear regression models are estimated. Standard errors are clustered at the session and individual level. Risk aversion is centered at 3. Previous win = 1 if the group won or successfully produced a public good in the previous round and = 0 if otherwise.