Non-exclusive Group Contests: An Experimental Analysis

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Discussion Paper

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Non-exclusive group contests: an experimental analysis *

Jian Song† Daniel Houser‡

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ABSTRACT

We experimentally study a non-exclusive group contest in which contestants actively participate in multiple groups simultaneously. We compare the results of this contest to those of an exclusive group contest in which each contestant belongs to a single group. In contrast to theoretical predictions, we find that the non-exclusive group contest generates less aggregate effort than the equivalent exclusive group contest. We hypothesize that groups in the non-exclusive group contest are less responsive to their rival group's effort than those in the exclusive group contest. Likewise, on the individual level, players in the non-exclusive group contest are more likely to free-ride on their group members' contributions. Our data indicate that non-free-riders in the non-exclusive group contest are more likely, over time, to allocate their effort toward a single group. This finding is consistent with previous findings that players facing a complex strategy space tend to focus on specific winning combinations. Moreover, given that players are affected by their group members' contributions, they tend to exert their effort primarily toward a single group. Taken together, our findings suggest that a non-exclusive group contest may evolve, over time, into an exclusive group contest.

Keywords: Group contest, Non-exclusive, inter-group competition, Free-rider, Effort allocation

JEL classification: C9, D7

PsycINFO classification: 2260, 3020

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1 Introduction

Group contests are prevalent in real life. Examples include competitions between political parties, team contests within firms, and competition among social groups for government funds. Due to their prevalence, group contests have been studied extensively in the theoretical and experimental contexts. The majority of group contest studies assume that each contestant belongs to a single group (we refer to this type as "exclusive group (EG)" contest hereinafter). In practice, however, many group contests permit contestants to belong to multiple groups simultaneously.

Consider the following example provided by Send (2020a): The government plans to use the public budget to renovate several facilities. A wealthy individual living in a rural area wants to upgrade the digital infrastructure to the countryside and construct a public yacht harbor. The wealthy individual can lobby for a subsidy for both projects at the same time. However, due to budget constraints, there is only enough funding for one project. Consequently, the group contest is divided along two dimensions. Along the spatial dimension, the rural group opposes the urban group. Along the class dimension, the wealthier group opposes the poorer group. Each individual is an active member of two groups (spatial/class) at the same time. This conflict is shown in Figure 1 below.

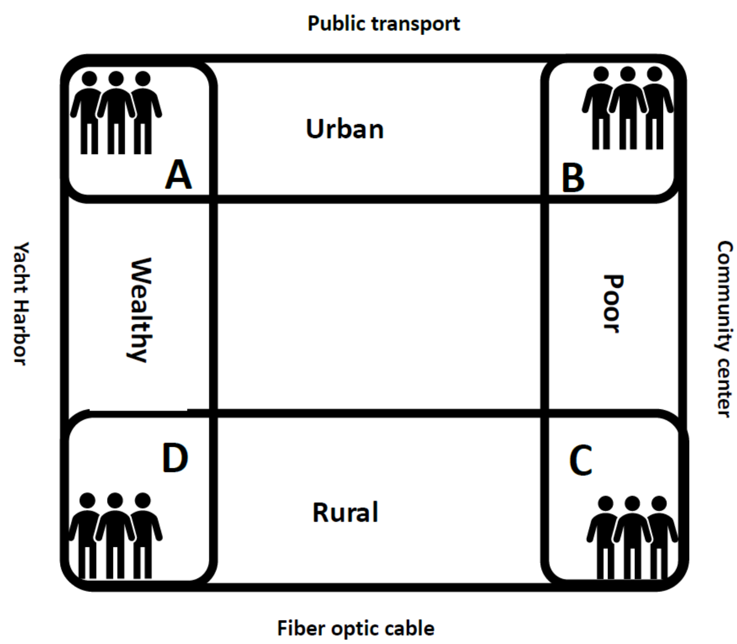


Figure 1: An example of non-exclusive group (NEG) contest

To explore this type of non-exclusive group (NEG, hereafter) contest, Send (2020a) proposed a theoretical model in which groups compete over a single public-good prize. In the model, contestants actively belong to multiple groups simultaneously. In particular, Send's model demonstrates that if groups are equal in size, all contestants are homogenous and value the prize equally. Under the quadratic effort cost and the lottery contest success function assumptions, contestants in

NEG contests exert the same aggregate effort as those in EG contests, and such aggregate effort is uniquely defined. However, it remains poorly understood whether observed behavior in NEG contests is empirically consistent with theoretical predictions. This paper takes up this challenge.

A number of experimental studies have studied group contest games. As noted in Sheremeta (2018), group contests are prevalent in natural environments and share two prominent features: First, group members must reconcile two competing incentives. On the one hand, to win competitions, group members have an incentive to increase their effort provision to outperform their opponents. On the other hand, given that effort is costly and the contest prize has a public good favor for the winning group, group members have an incentive to free-ride on their group members' effort, leading to lower effort provision. The second feature is that, in equilibrium, group members exert positive levels of effort to win the prize; however, when the price is fixed, this is unproductive and socially wasteful[1] (Abbink *et al.* (2010)). As a result, greater effort provision leads to more socially inefficient outcomes. Experimental studies have found that group members exert significantly greater effort than theory would predict (Abbink *et al.* (2010), Abbink *et al.* (2012), Ahn *et al.* (2011), Kugler *et al.* (2010), Sheremeta (2011), Cason *et al.* (2012)). There is also widespread heterogeneity of individual behavior, i.e., significant levels of free-riding (Abbink *et al.* (2010), Sheremeta (2011), Cason *et al.* (2012)).

All experimental studies mentioned above are constrained in the EG contest format. In contrast to EG contests, NEG contests introduce an additional layer of complexity to the strategic characteristics of the interaction. Using Figure 1 as an illustration, if contestants in subgroup D view the contest along the spatial dimension, contestants in subgroup C are their "group members." However, if they view the contest along the class dimension, contestants in subgroup C are their "group opponents." The relatively complex structure in NEG contests makes it more difficult for contestants to clearly identify their "enemy" and "ally"; as a result, the structure could influence behavior in ways that are difficult to predict theoretically.

Psychological studies have demonstrated that assigning an individual multiple memberships simultaneously (referred as "cross-categorization" hereinafter)[2] significantly reduce levels of prejudice and inter-group discrimination (Marcus-Newhall *et al.* (1993), Rust (1996), Bettencourt & Dorr (1998)). Our study considers group contest environments, experimentally to investigate how cross-categorization affects individual competitive behavior and group competition results.

While the theoretical model provides clear predictions about effort provision at the aggregate level, it is silent as to allocation decisions among individuals. Previous studies on multi-dimensional contests suggest that individuals often pursue specific strategies, allocating substantial effort in certain regions, while ignoring other regions (Deck *et al.* (2017)). In this study, we investigate whether this behavioral pattern also emerges in NEG contests. We test whether players gradually

[1] Effort is "unproductive and socially wasteful" due to the fact that it is not used for production, but to allocate a fixed prize. However, in other environments where prizes are not fixed, that may not be true.

[2] For a literature review of cross-categorization, see Brewer (2000).

shift their effort toward one group, causing a NEG contest to become an EG contest.

In this paper, we use laboratory methods to compare behavior between NEG and EG contests. In particular, we investigate how individuals in NEG contests reconcile rival incentives between exerting effort to win the group contest and shrinking to free-ride on group members' effort. Our experiment design is based on Send's (2020a) theoretical model, a version of a lottery contest game in which groups compete for a single public-good prize by exerting costly effort. Our experiment includes two treatments that vary according to the competition dimension: the EG contest, in which players belong to a single group, and the NEG contest, in which players belong to two groups simultaneously.

We find that, in contrast to theoretical predictions, the NEG contest generates lower aggregate effort than the equivalent EG contest. Groups in NEG contests are less responsive to their rival group's effort. In both treatments, players fail to cooperate[3] well with their group members.

On the individual level, players in the NEG contest are more likely to free-ride on their group members' effort. Most non-free-riders in the NEG contest either invest all their effort in a single group or equally split their effort between two groups. As time goes on, players tend to allocate all their effort toward a single group. This tendency toward effort concentration in the NEG contest is consistent with previous findings that players facing the complex contest structure tend to focus on specific winning combinations. Moreover, we find that players are affected by their group members' contributions, they tend to exert their effort toward a certain group. This suggests that an NEG contest may eventually become an EG contest.

This paper proceeds as follows: Section 2 provides a brief literature review. Section 3 describes the model, behavioral hypotheses and experimental design. Section 4 reports the results. Section 5 offers concluding remarks.

2 Literature Review

Group contests have been investigated extensively due to their real-life prevalence. The literature begins with Olson (1965) seminal contribution. Katz *et al.* (1990), Ursprung (1990) and Nti (1998) theoretically investigated group contests over a public good prize. Hausken (2005) and Münster (2007) considered group contests where the prize can be increased through effort provision. For a literature review on theoretical work about group contests, see Konrad (2009) and Kolmar *et al.* (2013).

Examining real effort through observational data is difficult; as a result, laboratory experiments are an effective tool for observing group members' behavior in group contests. Early work includes Rapoport & Bornstein (1989), and Bornstein (1992), who both provided experimental analysis on

[3]We use the method stated in Abbink *et al.* (2010) to measure the extent of group members' cooperation. If group members cooperate well, there should be no difference in effort provision between group members. See Appendix C for detailed analysis.

individuals' behavior in group contests. One interesting question in group contests focuses on the nontrivial trade-offs between the incentive to increase effort provision to win the contest and the incentive to lower effort provision to free-ride on group members' effort. The experimental studies find that players tend to overbid in group contests in relation to the Nash equilibrium prediction. Factors that affect overbidding include: non-monetary utility of winning (Sheremeta (2010)), pro-social orientation (Abbink *et al.* (2012)), and relative payoff maximization (Mago *et al.* (2016)). Another common finding in group contest experiments is that there exists a nonnegligible fraction of free-riders. Factors that impact the fraction of free-riders include: group size (Abbink *et al.* (2010); Ahn *et al.* (2011); Levine & Palfrey (2007)), the profit-sharing rule (Kugler *et al.* (2010); Gunnthorsdottir & Rapoport (2006)), the contest success function (Sheremeta (2011); Brookins *et al.* (2018)), and the heterogeneity of individuals (Sheremeta (2011); Brookins *et al.* (2015); Brookins *et al.* (2018)). To reduce the fraction of free-riders, thereby promoting group members' cooperation, contest designers can punish the free-riders (Abbink *et al.* (2010); Abbink *et al.* (2012)), enable intra-group communications (Bornstein (1992); Cason *et al.* (2012); Brookins *et al.* (2018)), or select group leaders (Eisenkopf (2014)). For a literature review on group contest experiments, see Sheremeta (2018). In contrast to previous literature, our study investigates whether the competition dimension influences overbidding behavior and the fraction of free-riders in group contests.

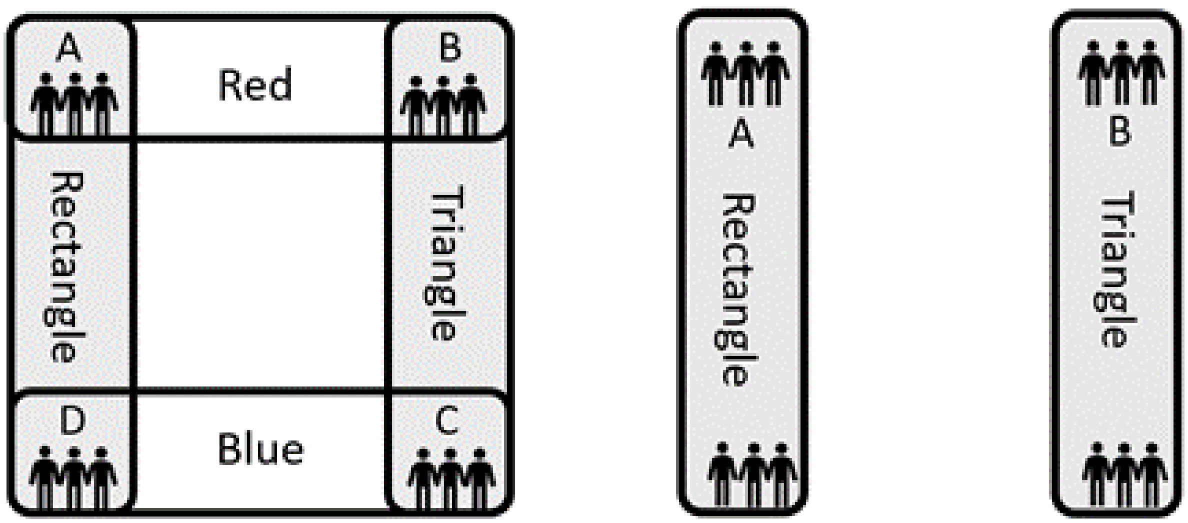
All literature mentioned above focuses on single-dimensional group contests. In practice, however, multi-dimensional contests are common and have been investigated both experimentally and theoretically. Mago & Sheremeta (2017) compared individual behavior in simultaneous and sequential multi-battle contests; Deck *et al.* (2017) experimentally investigated a multi-battle contest with value complementarities among the battles; and Kovenock *et al.* (2019) tested two multi-battle contest models that differed in their contest success functions. However, they all focused on individual contests. Fu *et al.* (2015) and Esteban & Ray (2008) considered effort provision in multi-dimensional group contests, but the competitions among the various dimensions did not occur simultaneously. Send (2020a) analyzed non-exclusive group contests where individuals had to make decisions for their groups at the same time. In another paper related to non-exclusive group contests, Send (2020b) investigated whether group leaders would like to offer non-exclusive membership to a potential new group member. To the best of our knowledge, no experimental work has studied the non-exclusive group contest proposed by Send (2020a). This paper fills this gap.

Our study also relates to the psychological work of cross-categorization. The experimental studies of Marcus-Newhall *et al.* (1993), Rust (1996), Bettencourt & Dorr (1998) demonstrated that in the cross-categorization condition, the degree of inter-group bias reduced significantly. However, Crisp *et al.* (2001) found that there is no significant difference in discrimination between the simple outgroup and partial outgroup categorization. We consider group competition environments and explore how the cross-categorization affects individual competitive behavior, as well as group competition results.

3 Model and Experimental Design

3.1 Model and Behavioral Hypotheses

We investigate NEG contests using the model proposed by Send (2020a). N ($N \geq 4$, and is a multiple of 4) players participate in a two-dimensional group contest, where each player belongs to two groups and must exert effort for the two groups simultaneously. To keep the terminology neutral, we use "red" and "blue" to represent the groups in the first dimension, and "triangle" and "rectangle" to represent the groups in the second dimension. The NEG contest and the EG contest are shown in Figure 2.



(a) NEG contest (b) EG contest

Figure 2: Group contest in (a) NEG contest and (b) EG contest

All players are risk neutral and identical. The effort exerted by different players are perfect substitutes. In the NEG contest, player i ($i = 1, 2, \ldots N$) exerts x_i^c effort for group c, where $c \in \{\text{red, blue}\}$ and x_i^s effort for group s, where $s \in \{\text{triangle, rectangle}\}$. The total effort exerted for player i is therefore denoted as $x_i = x_i^c + x_i^s$, and the total effort exerted for all players is $X = \sum_{i=1}^{N} x_i$. On the group level, the total effort exerted for group c is $X^c = \sum_{i \in c} x_i^c$ and for group s is $X^s = \sum_{i \in s} x_i^s$. As a result, the total effort exerted for all players can also be written as $X = \sum_{k \in \Gamma} X^k$, where $\Gamma = c \cup s = \{\text{red, blue, triangle, rectangle}\}$.

The groups compete in a contest over a public good prize, V. The contest success function (CSF) takes the form of a lottery contest, in which the probability that group g wins the contest, p^g, is defined as:

Treatment	N	V	X^*
NEG contest	12	100	24.5
EG contest	12	100	24.5

Table 1: Parameters and aggregate equilibrium effort in each treatment

$$p^g = \begin{cases} \frac{X^g}{X}, & \text{for } X \geq 0 \\ \frac{1}{4}, & \text{for } X = 0 \end{cases} \quad (1)$$

where $g \in \{\text{red, blue, rectangle, triangle}\}$.

The expected utility for player i, who is a member of group $c \in \{\text{red, blue}\}$ and group $s \in \{\text{triangle, rectangle}\}$ simultaneously, is:

$$u_i = \frac{X^c + X^s}{X} V - c(x_i) \quad (2)$$

where $c(.)$ is the cost function. In this study, we assume $c(x_i) = \frac{x_i^2}{2}$, to ensure that the aggregate equilibrium effort is uniquely defined. Players choose effort $\{x_i^c, x_i^s\}$ to exert for their two groups, to maximize their expected utilities.

As shown in Send (2020a), if the groups and players are both symmetric, the unique aggregate equilibrium effort in the NEG contest is:

$$X^* = \sqrt{\frac{NV}{2}} \quad (3)$$

which equals the aggregate effort in the EG contest.[4] The equilibrium provides a clear-cut solution at the aggregate level, but at the individual level, the optimal effort is ambiguous: any combination of effort provision by players that adds up to $\sqrt{\frac{NV}{2}}$ constitutes an equilibrium. The parameters and the equilibrium aggregate effort, X^*, in our experimental treatments, are shown in Table 1.

Although we consider the equilibrium predictions as benchmarks for evaluating aggregate effort, we have good reason to expect systematic deviations from equilibrium play, as almost all laboratory studies of behavior in group contests find significantly greater effort than the Nash equilibrium predicts (Sheremeta (2018)). As a result, our first behavioral hypothesis is:

Hypothesis 1 *The aggregate effort is significantly greater than the theoretical predictions in both the NEG and EG contests*

In the model considered above, when groups and players are both symmetric, the aggregate equilibrium effort in the NEG contest is the same as in the EG contest. However, due to the different ways that players connect with their group members/opponents, we would expect the

[4]For the theoretical prediction of aggregate effort in the EG contest, see Esteban & Ray (2001).

aggregate effort exerted by all players to vary between the NEG and EG contests. More intuitively, in the NEG contest, players in rival groups along one competition dimension can also be group members along another competition dimension.[5] This relatively complex structure makes it difficult for players to clearly identify their "enemy" and "ally";[6] thus, they are less responsive to their opponents' effort. Hereinafter, we define the intensity of inter-group competition as the responsiveness of group effort to the rival group's effort. Similarly, the relatively complex structure in NEG contests also provides players more channels to free-ride on their group members' effort.[7] Consequently, players are more likely to free-ride on their group members' effort in NEG contests. The combination of less intensified inter-group competition and greater free-riding fraction would suggest that the aggregate effort in NEG contests should be lower than in EG contests. The following behavioral hypotheses capture these differences.

Hypothesis 2 *Aggregate effort exerted in the NEG contest is lower than in the EG contest.*

Hypothesis 3 *Inter-group competition in the NEG contest is less intense than in the EG contest.*

Hypothesis 4 *Players are more likely to free-ride on their group members' effort in the NEG contest than in the EG contest.*

Our last hypothesis relates to individual behavior in the NEG contest. While theory predicts the aggregate level of effort as 24.5, it is uninformative regarding individual behavior. In our work, we are particularly interested in how players actually allocate effort between their two groups. Previous studies demonstrate that in multi-battle contests, due to the complex strategy space, players do not behave in accordance with theoretical predictions. Instead, they tend to concentrate their effort on the minimum number of battlefields needed for winning (Mago & Sheremeta (2017); Deck *et al.* (2017); Kovenock *et al.* (2019)). Therefore, we would expect players in non-exclusive group contests to exhibit similar behavioral patterns, i.e., to allocate their effort

[5] Use Figure 1 as an illustration. For subgroup D, if we consider the competition along the major dimension, then players in C are D's group members, while players in A are D's group opponents; however, if we consider the competition over the occupation dimension, then players in C are D's group opponents, while players in A are now D's group members.

[6] Psychological studies have demonstrated that having a group opponent on one competition dimension who is a group member on another competition dimension can decrease the inter-group bias level (Gaertner *et al.* (1993)). Various psychological factors are attributed to whether individuals view their various identities differently. These factors include (but not limited to) personalization, valence of mood, cognitive overload, and category dominance. For a summary of factors related to such cross-categorization effect, see Urban & Miller (1998). There are also some networked studies that have investigated whether individuals view their "enemy" and "ally" connections asymmetrically. König *et al.* (2017) theoretically and empirically studied how a network of military alliances and enmities affects the result of a conflict. They found that each group's fighting effort is increasing in the total fighting effort of its enemies (in the scale of 0.083) and decreasing in the total fighting effort of its allies (in the scale of 0.114). Rong *et al.* (2016) considered how social identity affects truth-telling. They found that sharing the same identity does not promote truth-telling, but holding different identities reduces truthfulness.

[7] Use Figure 1 as an illustration. Players in subgroup D have two ways to win the contest: either Blue or Rectangle wins. Therefore, they can either free-ride on C's effort or free-ride on A's effort.

primarily to just one group. If so, then NEG contests would evolve into EG contests.[8] Our last behavioral hypothesis is as follows.

Hypothesis 5 *In the NEG contests, each player's effort gravitates towards only one group.*

3.2 Experimental Design

To test the hypotheses mentioned above, we propose a laboratory experiment with two different treatments with varying competition dimensions. The first treatment is an EG contest, where two groups compete for a public good prize and each group comprises six players. Each player belongs to a single group. The second treatment is a NEG contest, where four groups compete for the same public good prize and each group comprises six players. Each player belongs to two groups simultaneously. The group compositions are shown in Figure 2.

The experiment proceeds as follows: Before the experiment, players are asked to complete a one-shot prisoner's dilemma game as in Abbink *et al.* (2012),[9] which yields independent evidence on the pro-sociality or selfishness of the players. Players then participate in the group contest. They are provided instructions for the group contest,[10] which is the main part of our experiment. The instructions are also read aloud by the experimenter. After players finish reading the instructions and successfully complete the comprehensive quiz,[11] they proceed to the group contest.

The group contest consists of 20 rounds. Players' roles remain fixed during these 20 rounds. At the beginning of each round, each player receives 1000 points.[12] In our experiment, "effort" is represented by "tokens," and players can use their points to purchase tokens for their group(s). Players can use the "Decision Costs" sheet to find the cost in points associated with the number of tokens they purchased. The cost function is quadratic to ensure that the aggregate equilibrium effort is uniquely defined. Any points not spent on tokens are added to the players' points balance. In each round, players must decide how many tokens they would like to purchase for their group(s) in total. In the NEG contest, players must also decide how to allocate those tokens between their two groups. Once everyone has chosen how many contest tokens to purchase, and how to allocate the tokens between their two groups in the NEG contest, a computer program determines the winning group.[13] The prize for members of the winning group is worth 6000 points (1000 for each group member). The probability of a group winning the prize equals the total number of tokens purchased by that particular group, divided by the sum of tokens purchased by all groups. After the winning group is selected by the computer, each player is informed of the number of tokens

[8] It should be noted that, the NEG contest evolving to the equivalent EG contest over time does not contradict the theory proposed by Send (2020a).

[9] See Appendix A for the instructions.

[10] See Appendix B for the instructions.

[11] See supplementary materials for the quiz.

[12] To avoid decimals, in the experiment, values are multiplied by 10 compared to Table 1.

[13] Specifically, there are two groups in the EG contest and four groups in the NEG contest.

each group received; the competition results (which group won); and their corresponding payoffs in this round. The points that players earned in each round are added together. At the end of the session, players are paid based on their total point earnings from all 20 rounds.[14]

After all players complete the group contest game, they are re-matched into new groups of six players for a single round individual contest. They are given the same endowment of 1000 points and are asked to purchase tokens to win the contest. In contrast to the group contest, the winning prize is now zero points. This part of the experiment measures each player's non-monetary utility of winning, following the approach introduced by Sheremeta (2010).[15] Before players privately receive their final payments, we further propose to elicit their group attachments and risk attitudes, using the methods proposed by Aron *et al.* (1992) and Holt & Laury (2002), and obtain their demographic information through a short questionnaire.

The experiments were programmed in oTree (Chen *et al.* (2016)). We conducted all experiments at George Mason University, from February 2020 to March 2020.[16] 132 undergraduate students participated in our experiments (96 in NEG treatment and 36 in EG treatment). The experiments lasted for about 60 minutes. Players could earn \$31.60 (including the \$10 show-up fees) on average.

4 Results

4.1 Aggregate results

The average levels of aggregate effort, X, between the NEG and EG treatments, are shown in Figure 3. The figure shows a downward trend over time in both treatments (Wald test, $p < 0.001$ in NEG and $p = 0.04$ in EG). However, the aggregate effort exerted by players remains well above the Nash equilibrium prediction (Mann-Whitney test, $p < 0.001$ in both treatments, $m = n = 20$).

To investigate the reasons for overbidding in both treatments, we estimate several random effect models where the dependent variable is the total effort exerted by each player (x_i) and the independent variables are a time trend; player's traits (pro-social orientation, non-monetary utility of winning, risk aversion, gender and sense of isolation); and a treatment dummy. The results are shown in specifications (1) and (2) in Table 2. The estimation of specification (2) indicates a significant positive correlation between effort provision and a player's non-monetary utility of winning, a significant negative correlation between effort provision and a player's sense of isolation, and a (weakly) significant positive correlation between effort provision and a player's pro-social

[14]Our design is similar to Abbink *et al.* (2010), Kugler *et al.* (2010) and Ahn *et al.* (2011), where players were paid based on their total point earnings. We use the same method to ensure our results are comparable with those studies. Moreover, we do not provide previous earnings history to players, making it difficult for them to track their payoff throughout the session.

[15]See supplementary materials for the instructions.

[16]We conducted all sessions in-person before the spring break at GMU, the campus was not close due to COVID-19 at that time.

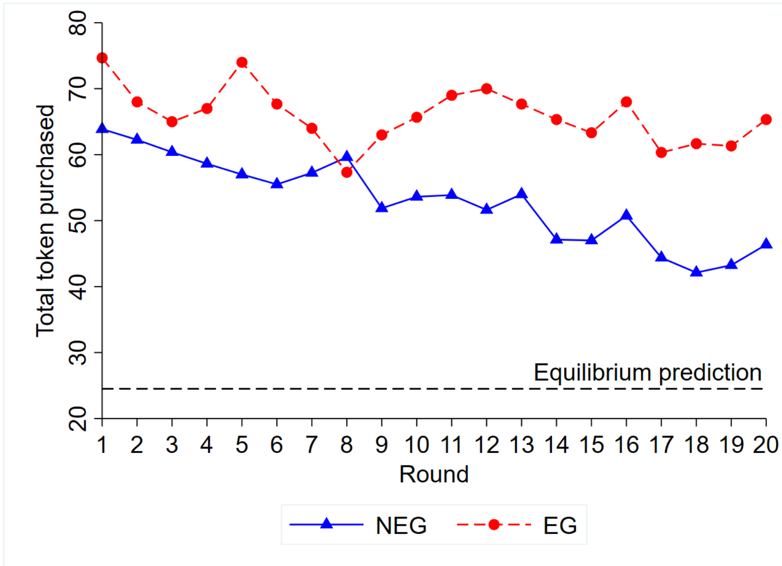


Figure 3: Average aggregate effort

orientation ($p = 0.133$). This is consistent with the previous findings in Sheremeta (2010), and Abbink *et al.* (2012). Our Hypothesis 1 is verified.

Result 1 *There is significant overbidding in both the NEG and EG contests, partially due to players' non-monetary utility of winning and pro-social preferences.*

The estimations of specifications (3) and (4) in Table 2 indicate the treatment difference of effort provision at the aggregate level, where the dependent variable is the total effort exertion, X. The result in specification (4) shows that the aggregate effort in the NEG contest is significantly lower than in the EG contest. Thus, our Hypothesis 2 is verified. As stated in the previous section, one possible reason for lower effort provision in the NEG contest is that the inter-group competition is less intense. Similarly, it may provide players more channels to free-ride on their group members' effort. We will verify these hypotheses in the following sections.

Result 2 *The aggregate effort in NEG contests is significantly lower than in EG contests.*

4.2 Inter-group competition

To explore the distinctions in the inter-group competition in NEG versus EG contests, we calculate the average effort exerted between the rival groups: in the NEG contests, players knew there were two sets of rival groups: 1) Red versus Blue[17]; and 2) Rectangle versus Triangle. In the EG contest,

[17]One concern is that players might attach a "political preference" to the red or blue colors. First, although the average effort in Blue is significantly greater than in Red (t-test, $p = 0.001$), the average effort in Rectangle remains significantly greater than in Triangle (t-test, $p < 0.001$). There is no evidence that the relationship between Red versus Blue is special. Second, from the self-report group attachment survey, nine out of 48 in the Red group and eleven out of 48 in the Blue group reported feeling like they totally belonged to one group. That difference is also not significant.

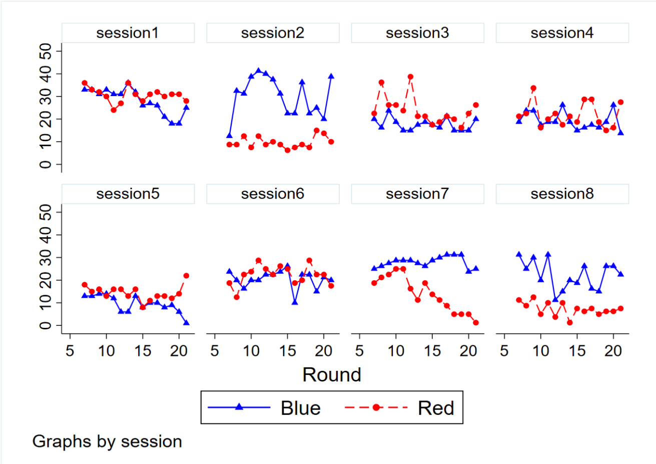
	Individual effort (x_i)		Aggregate effort (X)	
	(1)	(2)	(3)	(4)
NEG	-1.064^{**}	-1.005^{**}	-12.892^{**}	-12.892^{**}
	(0.475)	(0.470)	(5.769)	(5.782)
Round	-0.067^{***}	-0.067^{***}		-0.835^{***}
	(0.012)	(0.012)		(0.156)
Joy of winning		0.003^{***}		
		(0.001)		
Pro-social		0.719		
		(0.479)		
Risk aversion		-0.136		
		(0.115)		
Female		-0.413		
		(0.312)		
Isolation		-2.208^{***}		
		(0.675)		
Constant	6.149^{***}	6.899^{***}	65.917^{***}	74.683^{***}
	(0.372)	(0.830)	(4.838)	(4.699)
Observations	2480	2480	220	220

Table 2: Determinants of effort provision in group contests. Note: Specifications (1) and (2) are individual random effect panel regression models with standard errors clustered at the session level. Isolation equals 1 if players indicate not belonging to any groups in the group attachment survey and 0 otherwise. We have deleted the observations where pro-social orientation was "non-classifiable." Specifications (3) and (4) are the linear regression models on the aggregate level with standard errors clustered at the session level. Clustered standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

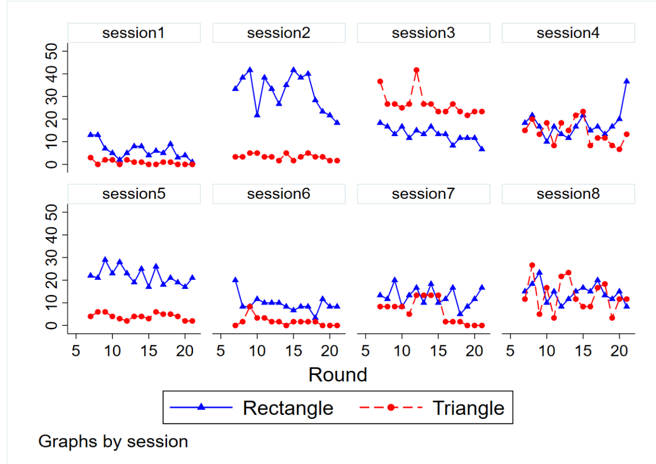
there was only one set of rival groups: Rectangle versus Triangle. The average effort contributed between the rival groups, by session, is shown in Figure 4.[18]

As shown in Figure 4, groups in the NEG contest are less responsive to their rival group's effort than groups in the EG contest. To further verify this finding, Table 3 shows the regression analysis results, where the dependent variable is the effort exerted at the group level and the independent variables are the lagged variables for the effort provision on the group itself and the rival group, as well as a time trend. The results indicate that, in contrast to the EG contest, rival groups' effort in the NEG contest have an insignificant impact on groups' effort provision. Therefore, the inter-group competition in the NEG contest is less intense relative to the EG contest. Our third

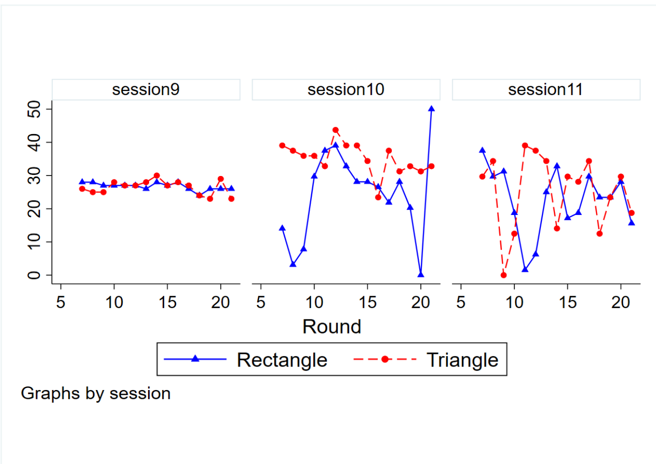
[18] In the NEG contest, there is evidence of the positional order effects, i.e., the effect arising from the ordering of groups on the screen: In our experiment, Red /Blue is ahead of Rectangle/Triangle. The average effort exerted in Red / Blue is significantly greater than the average effort in Rectangle / Triangle (Mann-Whitney test, $p = 0.002$, $m = n = 20$). That is consistent with the findings in Mago & Sheremeta (2017).



(a) NEG contests, Blue v.s. Red



(b) NEG contests, Rectangle v.s. Triangle



(c) EG contests, Rectangle v.s. Triangle

Figure 4: Responsiveness to group opponents' effort in (a)(b) NEG contests and (c) EG contests

hypothesis is verified.

Result 3 *In the NEG contest, groups are less responsive to their rival group's effort; as a result, the inter-group competition in the NEG contest is less intense relative to the EG contest.*

In Appendix C, we also compare the extent of group members' cooperation between NEG and EG contests, adopting the method in Abbink *et al.* (2010). In both treatments, we find extreme differences in effort provision between group members at the beginning of the session. We further find that gaps in effort provision between the top and bottom contributors remained large throughout the session. This demonstrates that players failed to cooperate with their group members in both treatments.

One reason that players failed to cooperate with their group members in both the NEG and EG treatments is that a portion of them did not think they belonged to their group(s). From the survey used to elicit players' group attachments, 12.5% of players in the NEG contest and

	(1) NEG	(2) EG
Own_{t-1}	0.699***	0.222*
	(0.075)	(0.126)
$Rival_{t-1}$	−0.041	0.268**
	(0.082)	(0.110)
Round	−0.244***	−0.034
	(0.027)	(0.164)
Constant	8.021***	15.774***
	(1.756)	(5.516)
Observations	304	57

Table 3: Determinants of effort contributions at group level. Note: random effect panel regression model, allowing the random effect at the group level. Clustered standard errors at the session level, are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

13.8% of players in the EG contest reported feeling that "they do not belong to any of these groups".[19] As a result, a potential avenue for follow-up studies could focus on enhancing players' group attachments to promote group members' cooperation, especially in NEG contests.

4.3 Fraction of free-riders

To verify Hypothesis 4, Figure 5 shows the histogram of effort exerted by players (x_i) in the NEG and EG treatments, respectively. We find strong evidence that the fraction of free-riders in the NEG contest is significantly greater than in the EG contest (Mann-Whitney test, $p < 0.001$). The regression analysis in Table 4 further confirms that, after controlling for individual traits and time trend, players in the NEG contest are still more likely to free-ride on their group members' effort. Moreover, there is a strong time trend on the fraction of free-riders in the NEG contest: As time goes on, players are more likely to free-ride on their group members' effort. One explanation for the greater free-riding fraction in the NEG contest is the complex structure, which provides players more channels to free-ride on others' effort. Our Hypothesis 4 is confirmed.

Result 4 *Players in NEG contests are more likely to free-ride on their group members' effort.*

4.4 Effort allocations in NEG contest

According to theory, non-free-riding players in the NEG contest allocate their effort ambiguously between the two groups. Investigating effort allocation decisions can help us verify whether,

[19] Although the percentage of players who feel "they do not belong to any group" is similar between the two treatments, there are significant treatment differences on remaining parts in the group attachment survey. See Appendix C for detailed analysis.

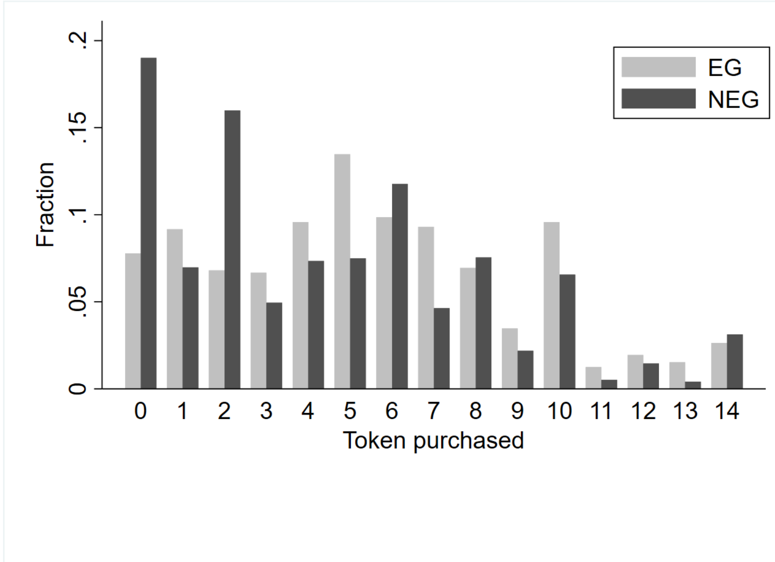


Figure 5: Histogram of the effort exerted by players (x_i)

consistent with previous studies, players focus on certain strategies. Moreover, another question of particular interest is whether players in a group contest cooperate with their group members by allocating their effort within certain groups. If so, an NEG contest would eventually evolve into an EG contest. We define the allocation indicator for player i, a_i, as:

$$a_i = \frac{|x_i^c - x_i^s|}{x_i} \tag{4}$$

where $x_i > 0$, and $c \in \{\text{red, blue}\}$, $s \in \{\text{triangle, rectangle}\}$. Therefore, if $a_i = 1$, that means a player exerts all effort to one group. If $a_i = 0$, that means a player equally splits effort between two groups. The time trend for $a_i = 1$ and $a_i = 0$ in our experiment is shown in Figure 6.

In total, among the 1450 observations of a_i, 533 are cases where $a_i = 1$, and 548 are cases where $a_i = 0$. There is a strong time pattern for a_i:[20] as time goes on, players are more likely to concentrate their effort within one group.[21]

As in Arad & Rubinstein (2012), Mago & Sheremeta (2017), Deck *et al.* (2017) and Kovenock *et al.* (2019), when players engage in relatively complicated strategic situations in contests, it is natural for them to concentrate their effort on the minimum number of groups needed for winning. In NEG contests, players will win if one of their groups wins, as a result, they tend to allocate their effort only within one group. Our behavioral patterns are consistent with the predictions of

[20]We conduct a censored regression where the dependent variable is the value of a_i, and the independent variables include a time trend, players' traits and the amount of effort they exerted. We find that the time trend has significant impact on players' effort allocation decisions ($p < 0.001$).

[21]We also investigate the possible relation between effort concentration and free-riding. We find that if players exhibit different effort allocation decisions than their group members, they seldom react by free-riding, and around 65% of our observations could successfully switch their allocation decisions to match their group members' decisions in the following round. See supplementary materials for detailed analysis.

	(1)	(2)
NEG	0.062**	0.084***
	(0.030)	(0.033)
Round	0.004**	0.004***
	(0.002)	(0.001)
Joy of winning		−0.000
		(0.000)
Risk aversion		0.006
		(0.006)
Pro-social		−0.030
		(0.022)
Female		−0.008
		(0.015)
Isolation		0.253***
		(0.051)
Observations	2480	2480

Table 4: Determinants for free-riders. Note: Individual random effect probit regression with standard errors clustered at the session level. Coefficients are average marginal effects. The dependent variable is a dummy variable indicating whether a player is a free-rider. Isolation equals 1 if players indicate not belonging to any groups in the group attachment survey and 0 otherwise. We have deleted the observations where pro-social orientation is "non-classifiable". Clustered standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

previous studies mentioned above.

Moreover, in addition to behavioral patterns that are similar to individual contests, we also investigate whether the NEG contest becomes an EG contest. To answer this question, we calculate the fraction of effort exerted toward each group. We observe a clear pattern that, as time goes on, all group members tend to concentrate their effort within certain groups. On average, more than 82.87% of their effort concentrate within two groups by the end of the contest game.[22] This suggests that the NEG contest may turn into an EG contest as players gradually concentrate their effort toward certain groups.

To further verify the fact that players tend to concentrate their effort within certain groups, we conduct probit regression analysis, allowing random effect at the individual level. The dependent variable is a dummy indicating whether a player allocates all her/his effort to a group.[23] The inde-

[22]We find that effort concentration cannot be fully explained by order effect. There is clear evidence that players do think carefully and apply strategic considerations in NEG contests. See supplementary materials for detailed analysis.

[23]We provide a robustness check for Table 5, where the dependent variable indicates whether players allocate

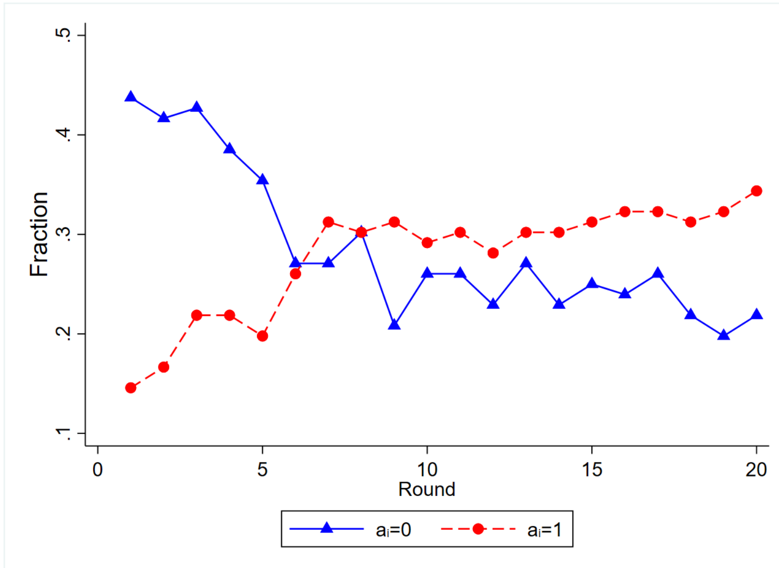


Figure 6: The time trend of a_i in NEG contest

pendent variables include the lagged total effort provision by their group members, a time trend, and individual traits. The results in Table 5 demonstrate that when controlling for individual traits, as group members' contributions increase, players are more likely to allocate all their effort toward that group.

Result 5 *Most non-free-riders in NEG contests either invest all their effort in a single group, or equally split their effort between two groups. As time went on, players were more likely to invest all their effort in a single group. Moreover, affected by their group members, players tend to focus their effort within certain group, gradually turning the NEG contest into an EG contest.*

5 Conclusion

This paper provides the first experimental test of the NEG contest model proposed by Send (2020a). In contrast to EG contests, contestants in NEG contests belong to multiple groups, and must allocate their effort among these groups simultaneously. The theoretical model predicts that the unique aggregate effort in an NEG contest should be the same as in the equivalent EG contest, if we assume: i) contestants are partitioned into two groups along two dimensions each; ii) the effort cost function is quadratic; iii) the contest success function is in the lottery format; iv) groups are equal in size; and v) all contestants are homogenous and attach the same value to the public-good prize.

the majority (more than 75%) of their effort within one group. The results in Table 5 still hold. See supplementary materials for detailed analysis.

	(1)	(2)
Group member$_{t-1}$	0.018***	0.019***
	(0.004)	(0.003)
Round	0.010***	0.010***
	(0.003)	(0.003)
Joy of winning		−0.000**
		(0.000)
Risk aversion		−0.000
		(0.010)
Pro-social		−0.116***
		(0.044)
Female		−0.077**
		(0.037)
Isolation		−0.088
		(0.069)
Observations	2624	2624

Table 5: Probit regression on effort concentration. Note: We allow the random effect at the individual level and the standard errors are clustered at session level. Coefficients are average marginal effects. The dependent variable indicates whether players allocate all their effort in group i. Isolation equals 1 if players indicate not belonging to any groups in the group attachment survey and 0 otherwise. Group member$_{t-1}$ is the total effort provided by group i's other members at immediately previous round. We look at the group's members on both competition dimensions. We have deleted the observations of free-riders and those whose pro-social orientation is "non-classifiable." Clustered standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

To test this theoretical prediction, we conduct a laboratory experiment with two treatments that vary according to competition dimensions. The first treatment is the NEG contest, where each player is an active member of two groups simultaneously. The second treatment is the EG contest, where each player belongs to a single group. We find that both treatments are overbid relative to the equilibrium prediction. More importantly, in contrast to the theoretical prediction, players in the NEG contest contribute significantly less effort than in the equivalent EG contest.

We believe the relatively complex structure of the NEG contest makes it difficult for players to clearly identify "enemies" and "allies", due to the fact that their group members are their rivals along another competition dimension. As a result, the inter-group competition is less intense in the NEG contest. Similarly, the complex structure of the NEG contest also provides players more channels to free-ride on their group members' effort, making them more likely to do so. Combining these two effects, the aggregate effort in the NEG contest is less than in the EG contest.

Most non-free-riding players in the NEG contest either invest all their effort in a single group, or equally split their effort between two groups. The allocation decision demonstrates a strong time pattern: as time goes on, players are more likely to exert their effort toward a single group. Such tendency is consistent with previous studies which have found that, given the complex structure and strategy space, players tend to pursue the strategy that concentrates their effort on the minimum number of groups needed for winning. Moreover, in the NEG contest, players are affected by their group members. As a result, their effort gradually gravitates towards certain groups, suggesting that a NEG contest may eventually become an EG contest.

There are several possible follow-up studies: First, in our study, we found that players in both treatments failed to cooperate well with their group members. The reason may be that a non-negligible proportion of players did not feel they belonged to either of their groups. Several mechanisms have been proven to effectively promote within-group cooperation in EG contests (e.g., communications, information feedback, etc.). Studying whether these mechanisms can also work in NEG contests is a potentially profitable avenue for further investigation. Second, in group contests over a public good prize, greater effort provision means greater "waste" from a social efficiency standpoint. We find that players in the NEG contest still exert significantly greater effort than is socially desirable. A follow-up study could focus on potential mechanisms to reduce effort provision in NEG contests. Finally, we observed that NEG contests seem to evolve into EG contests. Further studies could drill down on this finding, exploring the psychology and economics underlying this effect.

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Appendix A. Instructions on one-shot prisoner's dilemma game

Before we proceed to the experiment, please make your decisions for the following game. This game is **independent** with the remaining parts of the experiment. You will be randomly and anonymously paired with another participant (your opponent) in this game. Each of you simultaneously and privately makes your choice. Your payoffs will be determined by the choices of both as below:

		Your opponent chooses	
		A	B
You choose	A	**$2** (you), $2 (opponent)	**$0** (you), $3 (opponent)
	B	**$3** (you), $0 (opponent)	**$1** (you), $1 (opponent)

In each cell, the amount to the left is the payoff for you and to the right for your opponent.
For example, if you choose A and your opponent chooses A, then you can earn $2, and your opponent also earns $2; if you choose B and you opponent chooses B, then you can earn $1, and your opponent also earns $1.

You need to make your decisions under the following condition:
Condition 1: You will make your decisions without knowing what your opponent choice.

(Circle one): I choose A / B no matter what my opponent chooses.

Your ID number:

When you complete this page, please raise your hand, we will give you the second page of this game.

Page 1/2

Your opponent chooses

		A	B
You choose	A	$2 **$2**	$3 **$0**
	B	$0 **$3**	$1 **$1**

(This is the same payoff matrix as in page 1)

In each cell, the amount to the left is the payoff for you and to the right for your opponent. For example, if you choose A and your opponent chooses A, then you can earn $2, and your opponent also earns $2; if you choose B and you opponent chooses B, then you can earn $1, and your opponent also earns $1.

You need to make your decisions under the following condition:
Condition 2: You will make your decisions separately for the case that your opponent chooses A and for the case that your opponent chooses B.

(Circle one): If my opponent chooses A, then I choose A / B.
(Circle one): If my opponent chooses B, then I choose A / B.

Your ID number:

This is the end of this game.

We will randomly pick one of your decisions matched with your opponent's decision to determine your payments. For example, if we pick your decision under condition 1 (condition 2), then it will be matched with your opponent's decision under condition 2 (condition 1).

Page 2/2

Note: As in Abbink *et al.* (2012), based on players' decisions under condition 2, we classify them as pro-social (always choose A; or choose A if the opponent chooses A, B otherwise), pro-self (always choose B), or non-classifiable (choose A if the opponent chooses B, B otherwise).

Appendix B. Instructions on group-contest game (use the NEG contest as example)

Welcome! You've already earned $10 show-up bonus. You are about to take part in an experiment in the economics of decision making. You will be paid in private and in cash at the end of the experiment. The amount you earn will depend on your decisions, so please follow the instructions carefully.

During the part 1 of this experiment you will have the chance to earn points, which will be converted into cash at the end of today's session, using the exchange rate of 1500 points = 1US dollar. Thus, the more points you earn, the more cash you will receive at the end of the session.

It is important that you do not talk to any of the other participants until the session is over.

Overview

Four groups, named Red, Blue, Rectangle and Triangle respectively, competing for a prize. Your roles, decisions and the corresponding payoffs are illustrated below.

Your roles

At the beginning of the experiment, you will be randomly assigned to 2 groups simultaneously. During the experiment your groups will be playing against other groups, and those groups you do not belong to will be the opponents of your groups. Note that, you will not learn the identity of your group colleagues or your opponents, neither during nor after today's session. Likewise, neither your group colleagues nor your opponents will learn about your identity.

Specifically, there are four possible situations as shown in Figure B.1:

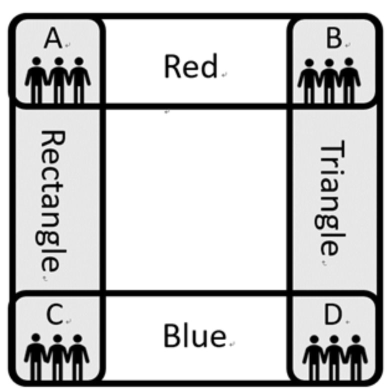


Figure B.1: Possible situations

(1) In situation A, you belong to group Red and Rectangle simultaneously;
(2) In situation B, you belong to group Red and Triangle simultaneously;
(3) In situation C, you belong to group Blue and Rectangle simultaneously;
(4) In situation D, you belong to group Blue and Triangle simultaneously;

The experiment will consist of 20 rounds, your roles will keep constant during the 20 rounds, so as other participants. As in Figure B.1, each group consists of six members, your decisions and your payoffs will now be explained.

Your decisions

At the beginning of each round you will receive 1000 points from us. You can then use these points to purchase "contest tokens" for both of your groups. The sheet labeled "Decision Costs" shows you the cost in points associated with the number of tokens you purchased. Look at the sheet and you will find that the more tokens you purchase, the more points you will spend. You can purchase up to 14 tokens in each round. Any points you do not invest into contest tokens will simply be added to your point balance and are yours to keep, you cannot use these points for further purchase. Likewise, your group colleagues and your opponents will have the chance to purchase contest tokens, in exactly the same way.

In each round, you will firstly decide how many tokens you would like to purchase in total; then you will decide how to allocate these tokens between the two groups you belong to. The sum of the tokens you give to your two groups must be equal to the tokens you purchase in total.

Your payoffs

As soon as everybody has chosen how many contest tokens to purchase, and how to allocate the contest tokens between her/his two groups, a computer program will determine ONE winning group among these 4 groups. The prize for the members of winning group is worth 6000 points (1000 for each group member) and your chance of winning the prize depends on how many contest tokens your groups have received and how many contest tokens your opponents have received. The program works as follows:

The chance for one group winning the prize will be the ratio of the number of contest tokens received by this group to the total number of tokens received by all four groups. Specifically, if group Red received X contest tokens, group Blue received Y contest tokens, group Rectangle received Z contest tokens and group Triangle received W contest tokens. Then the chance group Red wins will be X/(X+Y+Z+W) and so on. As long as you are the member of the winning group, you will win 1000 points in this round.

Thus, your chances of winning the prize increase with the number of contest tokens your groups received. Conversely, the more contest tokens your opponents received, the higher the chance that you lose. If one of the groups doesn't receive any contest tokens, this group cannot get the prize with certainty. If nobody purchases any contest tokens, no competition takes place and the prize is lost.

After the chance that each group winning the competition has been calculated according to the formula above. The computer will then make a random draw to determine the winning group, according to the calculated chances.

The points you earn in each round will be added together. At the end of the session you will be paid based on your total point earnings from all 20 rounds.

Information at the end of each round

At the end of each round, you will be informed the number of tokens each group gets, the competition results (which group wins), and your corresponding payoffs in this round.

Example

Let's look at an example. Suppose you belong to group Blue and group Rectangle in this experiment (as situation C in Figure B.1). In one round, you decide to purchase 10 tokens in total for both groups, and you decide to give 4 of them to group Blue, 6 of them to group Rectangle. Because you purchased 10 tokens in total, the costs are therefore 500 points.

Also suppose in this round, group Blue receives 20 tokens, group Red receives 15 tokens, group Rectangle receives 20 tokens and group Triangle receives 25 tokens. Thus, the chance for each group winning the competition will be:

The chance for group Blue wins $= \frac{20}{20+15+20+25} = 0.25$;
The chance for group Red wins $= \frac{15}{20+15+20+25} = 0.19$;
The chance for group Rectangle wins $= \frac{20}{20+15+20+25} = 0.25$;
The chance for group Triangle wins $= \frac{25}{20+15+20+25} = 0.31$.

If group Blue wins this competition: You belong to the winning group, you win the competition and therefore win the prize. Your payoffs in this round are 1000 (initial endowments) + 1000 (prize) – 500 (costs) = 1500 points;

If group Rectangle wins this competition: You belong to the winning group, you win the competition and therefore win the prize. Your payoffs in this round are 1000 (initial endowments) + 1000 (prize) – 500 (costs) = 1500 points;

If group Red wins this competition: You don't belong to the winning group, you lose the competition and therefore not win the prize. Your payoffs in this round are 1000 (initial endowments) – 500 (costs) = 500 points;

If group Triangle wins this competition: You don't belong to the winning group, you lose the competition and therefore not win the prize. Your payoffs in this round are 1000 (initial endowments) – 500 (costs) = 500 points.

This is the end of the instructions. You will be given a short quiz to ensure that you understand the instructions. Once you complete the quiz successfully, you'll proceed to the experiment.

Total number of tokens	Cost in points
0	0
1	5
2	20
3	45
4	80
5	125
6	180
7	245
8	320
9	405
10	500
11	605
12	720
13	845
14	980

Table B.1: Decision Cost

Appendix C. Intra-group cooperation

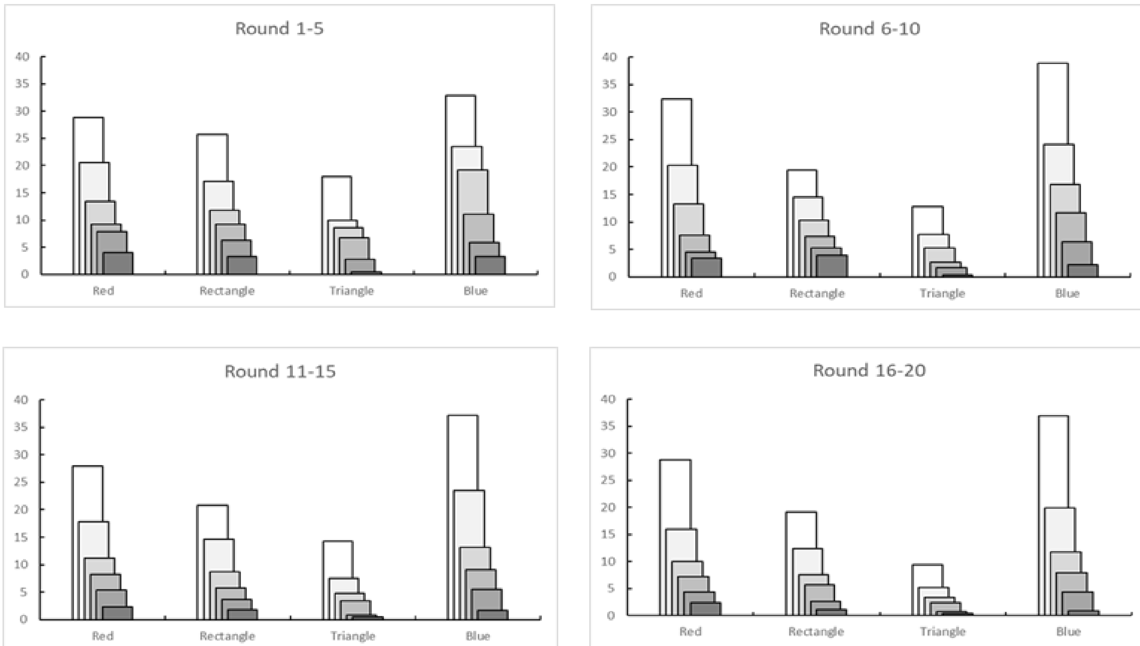
To compare the extent of intra-group cooperation between the NEG contest and the EG contest, we adopted the method in Abbink *et al.* (2010). For each group and each quarter of the experiment, we ranked the effort contributed by the individual members and then computed across all groups the average effort contributed by the highest, second highest ... and the lowest contributors, respectively. The results are shown in Figure C.1.

In both treatments, we find extreme differences in the contributions between the group members from the beginning. In the NEG contest, the highest contributor exerted more than sevenfold the effort of the lowest contributor, on average. In the EG contest, the highest contributor exerted more than fourfold the effort of the lowest contributor, on average. There was no evidence that group members' behavior converged; the gap on the effort contributed between the top contributor and bottom contributor remained large throughout the session (Jonckheere-Terpstra Test, $p = 0.18$ for NEG contest and $p = 0.83$ for EG contest, on the descending order alternative). This demonstrates that players failed to cooperate with their group members in both of the contests.

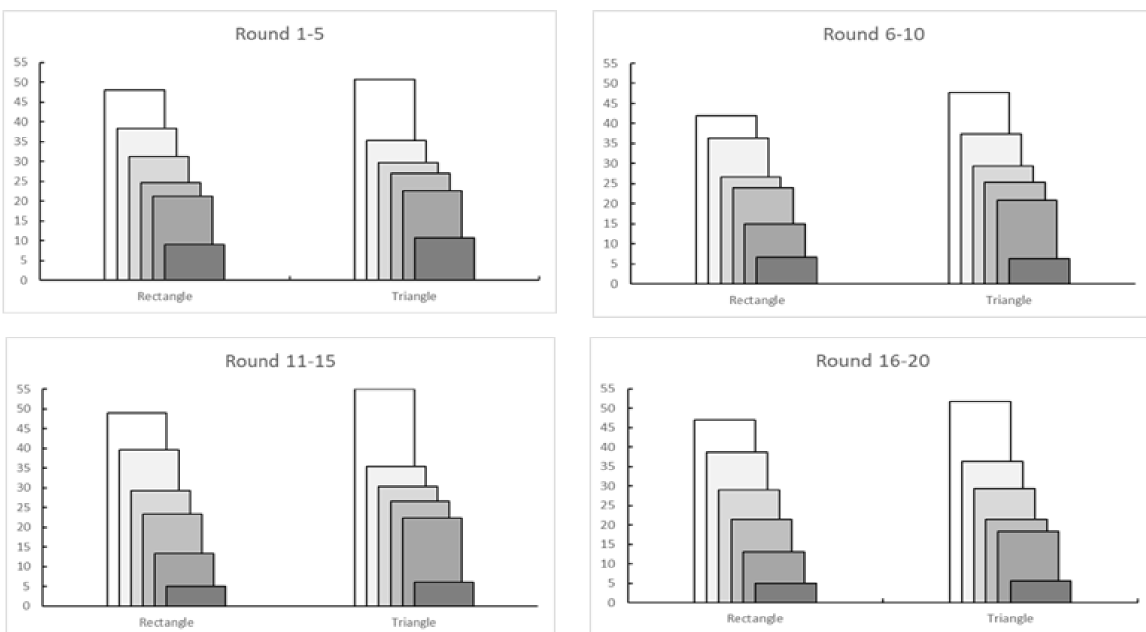
	NEG	EG
Not belong to any group	12 (12.5%)	5 (13.8%)
Belong to one group	32 (33.3%)	31 (86.2%)
Belong to two groups	52 (54.2%)	0 (0%)

Table C.1: Group attachment elicitation results. Note: The first figures represent the number of observations, and the figures in quotes represent the corresponding percentages.

Table C.1 demonstrates the group attachment elicitation results. We find that a non-negligible proportion of players did not feel that they belong to either of their groups in both treatments. That may be the reason on why players failed to cooperate well with their group members. Although the percentage of players who feel "they do not belong to any group" is similar between two treatments, there are significant differences on remaining parts. In the NEG contest, around 54% of players felt that they belong to both groups.



(a) NEG contests



(b) EG contests

Figure C.1: Intra-group cooperation in (a) NEG contests and (b) EG contests